IS IT GOOD TO BE GREEN?: AN ASSESSMENT OF COUNTY GREEN INFRASTRUCTURE PLANNING IN COLORADO, FLORIDA, AND MARYLAND

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ABSTRACT

IS IT GOOD TO BE GREEN?:
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Amy J. Lynch

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Over the past twenty years, landscape-scale green infrastructure planning has emerged as a way to support green spaces that provide ecosystem services and to revalue them in the planning and land development process. Despite the growth, there is little empirical research on the specific strategies that comprise local government green infrastructure planning and their success in supporting three important aspects of green space networks: size/shape, quality, and connectivity. This research fills that gap by examining how county planning agencies carry out green infrastructure planning and the effectiveness of county strategies in retaining, preserving, and connecting green space over time. The mixed-methods approach uses interviews and document review to create a framework for green infrastructure planning followed by remote sensing, GIS analysis, and a landscape ecology-oriented spatial analysis program (FRAGSTATS) to assess on-the-ground change in green space networks between 2000 and 2010. Results show that counties that incorporate many green infrastructure planning policies and strategies are more successful in retaining green space acreage, quality, and connections over time than those that use fewer. The facets of green infrastructure planning with the greatest potential impact on green space results are connectivity and growth management. The outcome suggests that counties interested in supporting green space networks should focus on policies specifically designed to support connectivity – such as purchasing land and development rights to create large contiguous blocks of protected forestland – and strategies oriented toward bounding growth, such as urban growth boundaries and restrictive rural zoning.

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CHAPTER 1: INTRODUCTION

What I have learned convinces me that there is one overriding consideration… It is, simply, that open space must be sought as a positive benefit. Open space is not the absence of something harmful; it is a public benefit in its own right, now, and should be primarily justified on this basis. – William Whyte (1959)

The United States is expected to add 130 million people by 2050 (U.S. Census 2008). Given predominant suburban and ex-urban settlement patterns, much of this growth will be accommodated though the development of natural and working landscapes. Natural lands, like forests, wetlands, and grasslands, and working lands, such as forestry and agricultural operations, provide a variety of goods and services. These *ecosystem services*, which include food production, flood mitigation, climate regulation, and air and water purification, benefit human populations and support life on Earth. The green spaces that provide these services comprise a community's *green infrastructure*, an important part of healthy, livable, and resilient communities.

The conversion and degradation of green infrastructure undermines the ability of green spaces to provide ecosystem services. As the United States Forest Service recently stated, "conversion of forest land to commercial and residential use is increasingly affecting the ability of ecosystems to provide basic services to humankind" (2009, 1). Furthermore much of the development impact is due to local planning and decision-making. Factors such as habitat fragmentation that degrade ecosystems – and consequently their ability to provide services – "occur at the local level and are generated by local land use decisions" (Brody 2003, 512). But the connection between local land use planning and green infrastructure goes both ways. If local land use planning and decision-making can cause the problem, they can also be the solution.

In response to the growing understanding of the manifold benefits of green spaces, local governments are increasingly adopting programs and policies intended to protect or enhance lands that provide ecosystem services. Collectively, these strategies are known as *green infrastructure planning*. This research assesses the process and outcomes of such planning as a strategy to maintain landscape-scale green space networks that support ecological functions and services.

Background

The objective of landscape-scale green infrastructure planning is to ensure adequate ecosystem services through delineating, preserving, and maintaining a functional green space network (Benedict and McMahon 2006; Kambites and Owen 2006). Overall, two facets of green infrastructure planning distinguish it from other environmental planning efforts. The first is its broad focus on natural systems, ecological functions, and associated ecosystem services (McDonald, Allen et al. 2005). The second is the elevation of the role of green space in the planning and development process (Randolph 2004). Of these two characteristics, the first - the simplest to understand and implement - dominates the field both in practice and in theory. The second is less well–documented and is the focus of this study.

Planning in the United States usually implies preparing for or accommodating development (Daniels and Daniels 2003). In contrast, green infrastructure planning encompasses actions that include both conservation *and* development. Its objective is to elevate green spaces to the same level as conventional "gray" infrastructure (e.g. sewers, water lines, roads, and schools) and protect ecological processes proactively, along with development, or even before development occurs. Actions that support green spaces occur across the rural-urban continuum. On a regional scale, green infrastructure planning protects forests and farmlands. In urbanized areas where development already exists, it solves problems caused by the removal or compaction of green space. This study judges the level of green infrastructure planning by identifying the variety of strategies that a local government uses to support positive green space characteristics and whether those strategies are remedial or proactive.

Three characteristics impact the ability of a green infrastructure network to support ecosystem services: size/shape, quality, and connectivity. While research on how counties can create such a network is common, most studies emphasize mapping and analysis, usually with the objective of identifying land preservation priorities. Such studies often mention implementation, but do not assess on-the-ground outcomes. So while the body of literature surrounding green infrastructure planning has grown significantly in the past ten years, the majority of published research is theoretical. Empirical research on the specific strategies that comprise green infrastructure planning, and their success in supporting large, high quality, and interconnected green space networks, is minimal.

In addition, the majority of green space planning research and practice focuses on green infrastructure quantity, and rarely addresses quality and connectivity. For example, land preservation practitioners often use green space quantity as a success measurement (somewhat pejoratively referred to as "bucks and acres calculus"). Such metrics make no mention of the quality or configuration of protected land. Despite the importance of quality and connectivity as characteristics of effective green infrastructure networks, research on how local governments can best support them in the planning and land development process is limited. Green infrastructure planning theory suggests that large-scale, proactive strategies are the most effective way to create the high-quality, interconnected networks of green space needed to support ecosystem services. But few studies examine long-term quality and connectivity outcomes and those cover only a small number of approaches, mostly land preservation and clustered development strategies. A host of local policies and tools (e.g. connected open space dedications and preservation of sensitive areas through development review) rarely appear in the literature, even though they have implications for ecological quality and connectivity at the landscape scale. Furthermore, larger scale strategies such as land preservation, urban growth boundaries, and restrictive zoning are more proactive than smaller scale strategies like clustered development, open space requirements, development review, and site planning - and have greater potential for supporting overall ecological quality and connectivity - yet their relative and overall impact remain understudied.

Despite the fact that green infrastructure planning is on the rise, - and increasingly important given the uncertainty surrounding climate change - overall assessments of the effectiveness of current approaches to supporting green space networks are scarce. More research is needed to 1) Understand the overall success of local government green infrastructure planning in retaining and enhancing green space acreage, quality, and connectivity over time, and 2) Identify and understand the effectiveness of the individual strategies that comprise local government green infrastructure planning and their potential for fostering ecological quality and green space connectivity.

Budget shortages, ecological uncertainties, and population growth suggest that the efficient use of conservation dollars and effective support of ecosystem services are as important as ever. So, as the number of communities adopting green infrastructure planning increases, understanding the types of policies and strategies that communities are using and whether they lead to positive environmental outcomes is critical. This study begins to fill the gap by examining green infrastructure planning strategies and results over time. It details the plans, policies, and outcomes of counties with different levels of green infrastructure planning to determine the on-the-ground impact of green infrastructure strategies and provide recommendations to local governments seeking to improve their green space planning and create healthy, livable, and resilient communities.

Research Questions

Two overarching questions guide this study:

1. How do county planning agencies carry out green infrastructure planning?

2. Are agencies that employ many green infrastructure planning strategies more effective at retaining green space, preserving ecologically significant lands, and creating green infrastructure networks than those that employ fewer strategies? If so, how, why, and to what extent?

The major hypothesis of this study is that county planning agencies that employ many of the policies and strategies associated with green infrastructure planning will be more effective at retaining, protecting, and connecting green infrastructure over time than county planning agencies that employ fewer. A strong relationship between a local government's level of green infrastructure planning and its green space success supports the hypothesis while a weak relationship suggests that green infrastructure planning has little impact.

Research Design and Conceptual Frameworks

This research assesses the differences in outcomes between county planning agencies that are highly involved in green infrastructure planning and those that are not. It does so through a comparative approach, a quasi-experimental multiple case study analysis. The study involves a pre-test (retrospective) and post-test (modern), and qualitative examination of three sets of three case studies, grouped by state and other attributes. The matched design creates theoretical replication (Yin 2009) that highlights the effects of high- versus low-level green infrastructure planning in the three states. A framework for green infrastructure planning provides additional clarity and explains green space outcomes.

The study includes two main components, each with a different conceptual framework: 1) creating and applying a green infrastructure planning framework, and 2) assessing the on-the-ground outcomes of green infrastructure planning in nine case counties: Baltimore, Anne Arundel, and Charles Counties in Maryland, Leon, Alachua, and Marion Counties in Florida, and Boulder, Arapahoe, and Adams Counties in Colorado. Broadly, the first component addresses research question one and the second answers research question two.

Creating the Green Infrastructure Planning Evaluation Framework

This study uses a 'principle-policy' framework to examine county green infrastructure planning programs. The framework is based upon a review of content analysis and plan evaluation literature. A principle-policy framework is an assessment structure comprised of the principles that define an overarching planning goal (e.g. smart growth, sustainable development, green infrastructure planning) and policies and strategies that – if integrated into planning practice – would support the principles. The more policies and techniques that a local plan includes, the greater its support for the overarching planning goal. The framework for green infrastructure planning that this study develops – called the Green Infrastructure Planning Evaluation Framework (the Framework) – enables a standardized analysis of the level and relative emphasis of green infrastructure planning in each of the case study counties. Similar frameworks exist for many different planning regimes and goals (e.g. smart growth, coastal resources management) – mainly to assess the degree to which comprehensive plans support them – but this is the first such framework for green infrastructure planning. The Green Infrastructure Planning Evaluation Framework includes 7 principles (shown below) and 88 policies and strategies.

1. Create linkages and foster connectivity
2. Value areas of ecological quality and local importance
3. Support a variety of landscapes and ecosystem services
4. Restore and mitigate damage to green infrastructure
5. Manage green infrastructure to support ecosystem services
6. Enact land use planning strategies to protect and retain all scales of green infrastructure
7. Protect and support green infrastructure through a collaborative and cooperative process

Assessing Green Space Outcomes

The approach of this study is unique in that it overcomes three challenges inherent in assessments of green infrastructure planning outcomes. First, ecological systems are complex and ecosystem services are notoriously difficult to measure. There are many variables in play and it is difficult to conclusively link environmental outcomes to planning actions. However, the environmental outcomes of green infrastructure planning are a result of the natural functions of green space, the extent and value of which can be measured far more easily. Thus, this study does not measure ecosystem services and environmental quality outcomes directly, but uses green infrastructure quality, coverage, and connectivity as indicators. These metrics simplify complex and dynamic natural systems to a series of discrete, non-field-based, point-in-time measurements. The strategy captures only a portion of the impact of green space planning activities, and does not fully account for local and seasonal variation, but provides a good foundation for measuring green infrastructure outcomes. Decades of ecological studies support the importance of quality, quantity, and connectivity as conservation network characteristics and the measures align with the values and goals of green infrastructure planning. In addition, the measures are more feasible for local governments than complex and resource-intensive field-based metrics.

Second, a temporal mismatch exists between planning actions and their effects. The vast majority of local governments have instituted green infrastructure plans and programs only in the last five years, meaning efforts are too recent to have been implemented completely, much less show a measurable impact. This study overcomes that limitation by examining county programs that may not be labeled 'green infrastructure planning', but employ the same policies, strategies and programs. Local governments have been planning in support of some forms of green infrastructure for over a century. The inclusion of strategies under other headings acknowledges that legacy. By including green infrastructure strategies that may not be labeled as such, this study is able to examine mature green infrastructure efforts - activities that began around 2000 - and related change in on-the-ground green space.

Third, green infrastructure planning suffers from a disconnection between the scale of the resource and the scale of agency. The most natural scale for the study of ecosystem services and conservation networks is the ecoregion. Ecoregional efforts align with natural systems and can better account for disturbance regimes and migration patterns (Beier and Noss 1998). But green infrastructure planning includes all strategies, policies, and analyses intended to protect or enhance lands that provide ecosystem services. These actions occur most logically at the local government level. Research shows that the factors that negatively impact ecosystem function, particularly urban development and habitat fragmentation, "occur at the local level and are generated by local land use decisions" (Brody 2003, 512).

Of the levels of government with significant planning powers, this study examines counties. Counties, rather than cities, are the appropriate unit of analysis because green infrastructure planning emphasizes natural areas, open spaces, and large-scale green space networks, and counties simply have more land of this type under their jurisdiction. Additionally, most green infrastructure plans are adopted at the county level, making it a natural unit upon which to focus, and ensuring an audience for the results. Municipal green infrastructure planning efforts are different in character, more often focused upon recreation and small, site-specific projects for urban stormwater management

Methods

This study uses Yin's (2009) interpretation of case study research as a research method rather than a data collection strategy and makes use of both qualitative and quantitative information and analyses. The design considers not only green infrastructure planning strategies and outcomes, but the context of the situation, and the structure of planning agencies and their partnerships and relationships. The research uses both qualitative and quantitative data to answer the research questions. While qualitative data, in the form of document review and interviews, is critical in assessing agency policies, organization, and relationships – and completing the Green Infrastructure Planning Evaluation Framework for each case county – the work also uses quantitative information such as land cover change statistics, ecological quality measures, and patch metrics to assess change over time.

The study addresses the research questions through five main steps:

1. Case selection, based a upon preliminary scan of counties in Colorado, Florida, and Maryland
2. Development of an in-depth Green Infrastructure Planning Evaluation Framework
3. Application of the Green Infrastructure Planning Evaluation Framework to nine selected case counties for the period of 2000 and 2010
4. Follow-up interviews with county planners and decision-makers to verify Green Infrastructure Planning Evaluation Framework results
5. Quantitative assessment of the change in the quality, quantity, and connectivity of green infrastructure between 2000 and 2010 in the nine case counties

Significance

This research is most significant for its grounded, practical assessment of landscape-scale green infrastructure planning. It contributes to scholarship on strategies for ensuring long-term ecological viability and resiliency and examines the utility of green infrastructure planning as a public–sector strategy. The study also creates the first framework for green infrastructure planning and identifies policies and program that impact the quality, quantity, and connectivity of local green space networks.

The research also provides recommendations for planning agencies and organizations adopting or adjusting green infrastructure planning strategies, and for those seeking to understand the potential of this increasingly visible facet of environmental planning. The study provides a basis for communities to select policies and programs that support important attributes of green space networks and to identify measures that best support green infrastructure planning objectives.

Overview of Dissertation

This chapter provided an introduction to the study's objectives and research approach. The following six chapters will describe in detail the study's methods, outcomes, and conclusions. Chapter 2 summarizes and assesses relevant planning and ecology literature and identifies major gaps that the research will address. Chapter 3 outlines the study's research questions, and the methods through which it will address them. Chapter 4, 5, and 6 present the results for counties in Maryland, Florida, and Colorado, respectively. Each of the state chapters provides background information on three counties and assesses their level of green infrastructure planning and green space outcomes. Finally, Chapter 7 compares results for the three states, answers the research questions, explains the implications of the research for the practice of green infrastructure planning, and identifies areas for further research.

CHAPTER 2: GREEN INFRASTRUCTURE PLANNING LITERATURE REVIEW AND HISTORY

Green infrastructure is increasingly accepted as an important part of healthy, livable, and resilient communities. Popularized in the United States by the President's Commission on Sustainable Development (PCSD) in 1999, the term has quickly become a part of our land use and environmental planning vocabulary. But despite the importance of green infrastructure, current suburban and ex-urban development patterns threaten to further fragment, consume, and degrade it. Ill-planned development and undervaluing of the lands supporting ecosystem services impacts food production, recreation, flood mitigation, aesthetics, climate regulation, and water purification, and wildlife habitat, among others, negatively affecting the nation's environment and economy. Only some of these tasks can be technologically replicated, and even then such solutions are rarely as economical or functional as nature (White, Morzillo and Alig 2008, Berke 2008).

The principles behind planning for green infrastructure are not new, but the most recent repackaging of over a century of efforts to protect green spaces for their natural functions and cultural and recreational benefits. During that time, planners have gained significant knowledge on the qualities of green space networks that best support environmental services. Conservation biology and landscape ecology literature suggest that networks intended to support biodiversity – which has been recognized as a proxy for ecological services (Termorshulzen, Opdam et al. 2006) – should consist of large hubs of green space with significant core areas and corridors connecting to nearby natural resource patches. Most green infrastructure planning literature draws upon this work to recommend that local planners employ a hub and link framework. The literature is largely in agreement on the form that green space should take and the characteristics that environmental and conservation planners should foster in on-the-ground green infrastructure: large parcels, regularly shaped, interconnected, and with high ecological quality. However, research is spare on how precisely planners at the local government level are to accomplish the task and even thinner on the results of efforts to do so. This review examines landscape ecology, conservation biology, and planning literature to answer three practical green infrastructure planning questions: 1) What are the characteristics of an effective green infrastructure network?, 2) Through what tools can planners help to foster those characteristics?, and 3) Does empirical research indicate that those and overall strategies are effective?

Understanding Green Infrastructure

Green infrastructure is most commonly defined as "an interconnected network of green space that conserves natural ecosystem values and functions and provides associated benefits to human populations" (Randolph 2004, 98). Adapted from work by Benedict and McMahon (2002), pioneers of the green infrastructure movement, this view supports the eco-centricity of green infrastructure, and its role in sustaining the ecological processes that contribute to human health and quality of life (McDonald, et al. 2005). Green infrastructure is pervasive and worldwide, a vast network of natural areas providing ecosystem services that support life on Earth (Benedict and McMahon 2006, Randolph 2004). It is the land that supports natural services, regardless of form, scale, ownership, disturbance, or level of protection.

Any green space or open space that provides ecosystem services is part of a community's green infrastructure. Scientists have identified up to 32 different types of ecosystem services, which the United Nations Millennium Ecosystem Assessment (2005) divides into four broad categories: provisioning, regulating, cultural, and supporting (Costanza, et al. 1997; De Groot, Wilson and Boumans 2002; De Groot 2005). Provisioning functions provide goods such as food, fiber, and energy. Regulating functions are our main life support functions and affect climate, waste treatment, and water quality and quantity. Cultural functions are more purely anthropocentric, referring to opportunities for recreation, education, and spiritual or aesthetic enjoyment. Supporting services underpin the others and include such fundamental processes as photosynthesis and nutrient cycling (Millennium Ecosystem Assessment 2005). Because different types of green spaces provide different portfolios of services, communities need a variety of green infrastructure, including more managed types, such as farmland and silvicultural lands. While many ecologists would consider agricultural lands to be a threat rather than a boon to the natural environment, they provide services such as food production and groundwater recharge which are important open space functions and critical factors in planning for healthy and resilient regions. In addition, working landscapes are broadly recognized as fostering regional connectivity in areas that have been fragmented by development (Sundseth and Sylwester 2009). Moreover, farmers and ranchers own most of the privately-held land in the United States, about 900 million acres.

The literature related to green infrastructure notes similarities with open space, green space, and natural areas, often suggesting the terms open space and green infrastructure to be equivalent (Hellmund and Smith 2006, Erickson 2006). In fact, this work often uses green infrastructure, green space, and open space interchangeably. But, while many of the planning procedures and benefits are the same, there are important differences among the three. Green infrastructure is a broader term than the others and less indicative of scale and degree of disturbance or alteration. Users of the term generally fall into two main camps, one which envisions green infrastructure as a site-scale stormwater management strategy and a second which views it as landscape-scale conservation for broader ecosystem services. The latter category could more descriptively be called 'natural infrastructure' and the former 'green infrastructure,' as the second emphasizes existing land-based systems while the first is usually constructed or engineered (e.g. swales and street trees) and aligns green infrastructure with other engineered 'greens' such as 'green' buildings and 'green' roofs. Engineered and site-scale green infrastructure is most often remedial, used to retrofit a developed area with green spaces, rather than proactive, identifying high quality conservation areas prior to development. The ecosystem services of more natural green infrastructure are broader, and much of the literature on green infrastructure planning references landscape scale efforts. In addition, proactive planning for land conservation and development to support large-scale green infrastructure networks minimizes the need to add remedial green spaces at a later date, and so is a more fundamental approach to retaining ecosystem services.

Green Infrastructure Planning Principles

Green infrastructure planning suffers from a disconnection between the scale of the resource and the scale of agency. The most natural scale for the study of ecosystem services and conservation networks is the ecoregion. Ecoregional efforts align with natural systems and can better account for disturbance regimes and migration patterns (Beier and Noss 1998). But while such efforts can inform and supplement government actions, there are few regional governance structures strong enough to support implementation (Huber, Greco et al. 2010). At the regional scale, most implementation mechanisms are non-regulatory (e.g. land acquisition, conservation easements, partnerships). State efforts are also popular and have many of the large-scale benefits of ecoregional projects (McDonald, Allen et al. 2005). But state analyses are course-grained from the perspective of local governments, and provide little local detail on the quality and diversity of ecosystems (Huber, Greco et al. 2010). They can also be subject to the same implementation issues as regional efforts. State regulations can have an impact – particularly where they require local governments to include certain characteristics or principles in comprehensive plans – but direct regulation of green spaces or sensitive environmental areas cannot address regional variation or differences in local priorities.

Green infrastructure planning includes all strategies, policies, and analyses intended to protect or enhance lands that provide ecosystem services. These actions occur most logically at the local government level. Research shows that the factors that negatively impact ecosystem function, particularly urban development and habitat fragmentation, "occur at the local level and are generated by local land use decisions" (Brody 2003, 512). So local government – county or municipal – is the level of agency for impacting green space conversion and degradation. In addition, because most land use decisions and regulations in the United States are local, counties and municipalities have a greater number of regulatory and incentive-based tools for protecting and enhancing green infrastructure, in addition to local environmental and cultural knowledge. One of the most straightforward ways for public or private organizations to protect green infrastructure is to acquire it, through a local land conservation program or to add to a state or national park system. But green spaces on unprotected private lands also provide important services. For example, 95% of endangered and threatened species – both flora and fauna – have some portion of their habitat on private land and 19% remain *only* on private lands (Wilcove, Bean et al. 1996). So, at the local level, green infrastructure planning encompasses not only permanent preservation – through public acquisition in-fee or purchase of development rights – but a host of other planning, zoning, and funding strategies intended to restrict development of high quality and sensitive areas, retain connections between green spaces, and plan development in a way that minimizes the degradation and fragmentation of natural areas.

Notably, not all conservation actions are equivalent. Studies contend that losses of ecosystem function are due as much to haphazard conservation as haphazard development (McDonald, Allen et al. 2005, 7). So successful green infrastructure planning is comprised of local land use decisions that support purposeful development *and* conservation (Benedict and McMahon 2006). More specifically, development that respects ecological quality and function, and conservation that leverages the greatest amount of ecological function for the investment, considers the boundaries and needs of the broader system, and allows landowners an economic use of their property.

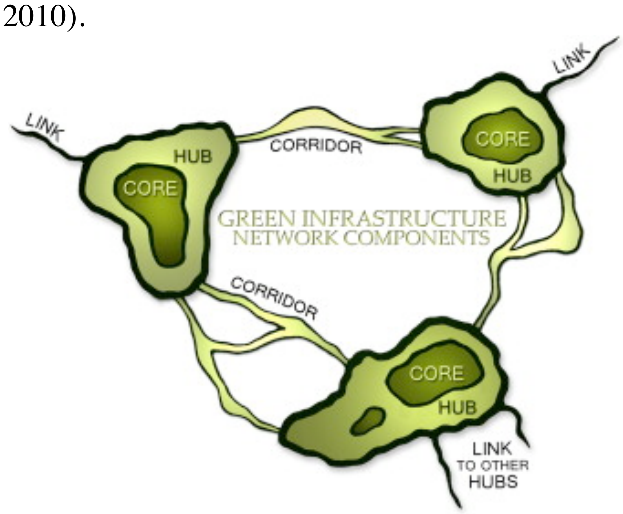
Ecological Foundations

The benefits of a green infrastructure network are naturally derived, so their provision depends upon the network's ecological characteristics. Communities use a combination of preservation, planning, and regulatory protection to balance the residential, commercial, industrial, and ecological needs of residents. Because green infrastructure covers only a portion of the landscape, communities must think carefully about the attributes of the network they are creating and implications for ecosystem services. In doing so, communities have decades of ecological research at their disposal.

The fields of landscape ecology and conservation biology indicate that there are three main characteristics that impact the ecological success of conservation areas: quality, size/shape, and connectivity. Since the benefits of green infrastructure are derived from natural systems, environmental quality and ecological processes are paramount. Large, undisturbed natural areas provide services more effectively and efficiently than smaller degraded areas, mainly because they contain a greater amount of core area - interior area that is not impacted by surrounding land uses – and cover a larger percentage of the natural landscape. Landscape ecology research shows that large patches of a land cover type – for example forest – have more interior species (which are usually the most sensitive), larger interior species populations, lower probabilities of species extinctions, greater overall diversity of habitats and species, greater coverage of species ranges, more natural disturbance regimes, and more comprehensive cover of important natural features than small patches (Harris 1984; Shafer 1990; Opdam 1991; Forman 1995). Smaller patches of green space may have a greater diversity of edge species – species that thrive upon disturbance – but these species tend to be abundant in the landscape overall. The shape and proximity of natural areas is also important. Irregular or geometric (e.g. square) features have a higher proportion of edge area than rounder shapes. The increased edge area means increased interaction with surrounding land uses, and increased edge species diversity. In addition, green spaces that are close together provide for more movement of species between patches and more continuous protection of features (ibid). In their landscape ecology synthesis for land use planning, Dramstad, Olson, and Forman identify the 'ecologically optimum patch shape' to be an amoeboid structure with a large rounded core, a few irregular bumps and dips along the boundary to enhance edge species diversity, and connective corridors leading to adjoining patches (Dramstad, Olson et al. 1996).

In landscapes that are fragmented by development, corridors between green spaces allow for movement of species and environmental flows (ibid). There has been considerable debate over the years on whether corridors provide support for species diversity and populations (Simberloff 1992; Beier and Noss 1998), but enough studies support their ecological benefits that the concept remains relevant (Tewksbury, Levey et al. 2002; Damschen, Haddad et al. 2006). Green infrastructure networks are usually conceived as a system of hubs and links, a configuration adapted from landscape ecology and applied by Maryland in their 2001 green infrastructure assessment and by Florida in 2000 and 2008 (Weber, Sloan et al. 2006; Florida Natural Areas Inventory 2009). The hub/link arrangement is useful because it supports the 'ecologically optimum patch shape' model and can be applied at multiple scales and designed to include any type of green infrastructure from large wild areas to neighborhood trail networks. It can also help to bring nature into the city where even small elements support numerous ecological benefits such as biodiversity and urban heat island mitigation. "Hubs" anchor the network, and support a variety of species, natural processes, and the most sensitive environments (Figure 2-1). They are often previously protected areas such as national reserves or state parks, but can include many other types: working lands, naturalized city parks, and even restored or reclaimed mines or large brownfields (Benedict and McMahon 2006). Links, sometimes called corridors, are usually linear, and connect the hubs to maintain ecological connections and mitigate the effects of landscape fragmentation (Weber, Sloan et al. 2006). Trail networks, riparian corridors, and greenways are common links.

Figure 2-1. Conceptual diagram of typical 'hub and link' conservation land framework with large hubs, high quality core areas, and connective corridors (from Weber and Allen 2010).



Recognition of the importance of size, quality, and connectivity is not a recent occurrence. Early conservation and green space planning efforts, described in the previous section, employed these same qualities to support ecological function. Olmsted's Emerald Necklace fostered restored quality and connectivity, McHarg's suitability analysis – often called the ecological method – was a means for identifying important high quality natural areas for protection, and the RPAA worked to cluster development to ensure that large areas of green space were retained in more rural areas.

Historical Foundations

Green infrastructure planning is not a new idea; it has a rich conceptual heritage, incorporating aspects of the parks and sanitation movements, as well as greenways, trails, and other attempts to balance development with conservation. Designs by Frederick Law Olmsted are among the earliest examples of green space planning that emphasizes a variety of natural services and functions. Olmsted's late 19th century work on components of Boston's Emerald Necklace addressed not only aesthetics and health, but water quality, drainage, flood prevention and mitigation and, indirectly, wildlife (Figure 2-2) (Hellmund and Smith 2006). He held that natural systems and processes were often better choices than engineered systems and argued, for example, that "a 'natural' water body, rather than a masonry flood storage basin, would be more effective and attractive" in minimizing flooding and maximizing water quality (Spirn 1984). Olmsted's later projects such as the Back Bay, the Fens, and The Riverway (all in Boston – components of the Emerald Necklace), relegated conventional park considerations (e.g. property values, recreation) to secondary considerations and set a precedent for designing parks to provide a broader variety of ecosystem services (ibid).

Figure 2-2. Boston's Emerald Necklace, as designed by Frederick Law Olmsted. While designed a century ago, its configuration exhibits several of the attributes espoused by modern landscape architects. (Image from futureboston.wordpress.com)

In emphasizing the landscape scale and ecological sensitivity, green infrastructure planning also harkens back to Ebenezer Howard's Garden City concepts and RPAA efforts of 1920s and 30s. Benton McKaye, Clarence Stein, Lewis Mumford, and others in the Regional Planning Association of America (RPAA) worked to promote regional networks of garden cities, modeled upon Ebenezer Howard's earlier designs. The RPAA envisioned environmentally and culturally sensitive development clustered in new towns thus minimizing landscape destruction and retaining large quantities of green space. The work was an early stride toward the conservation/development balance upon which green infrastructure is focused.

But while work by Olmsted, Howard, and the RPAA comprise the roots of modern green infrastructure planning, Ian McHarg's more recent contributions are even more critical (Kambites and Owen 2006; Weber, Sloan et al. 2006). In *Design with Nature* (1969), McHarg advocated for an environmentally sensitive approach to development and stressed the importance of strategic land use planning based upon the ecological attributes of an area (Hellmund and Smith 2006). McHarg introduced "physiological determinism," the idea that decisions about development should be based upon the importance and sensitivity of natural processes (McHarg 1969). He also introduced land suitability analysis and, with map overlays, gave land use and environmental planners a way to incorporate large amounts of spatial data. Once exceedingly laborious, with the advent of GIS, McHarg's land suitability analysis has become a staple of land use planning and is particularly important in planning green infrastructure networks which require extensive mapping and data management (Weber, Sloan et al. 2006).

Green infrastructure planning takes McHarg's land suitability analysis a step further. He sought to discern, based upon landscape characteristics, which areas were valuable in their natural state and should not be developed. In planning green infrastructure networks, communities also seek to understand which areas have a natural state, or function, so valuable that they should not only be bypassed by development, but protected (ibid). Although the principles are similar, McHarg's analyses were largely defensive, focused upon protecting sensitive areas from development. Green infrastructure planning includes both defensive and more proactive moves. The latter are more conservation driven, intended to protect and enhance natural and working landscapes independent of whether development seems imminent.

The earliest published reference to green infrastructure is by Charles Little in his well-known book Greenways For America (1990). Little deduced that, although rare at that time, the next step in greenway development would be "greenway infrastructure," an integrated network of interlocking greenways based upon the "regional landforms within a particular geographic area" (Little 1990). Although these networks are only part of modern green infrastructure, the principles are similar, and his idea of a landscape-specific network of multifunctional open space that supports the area underpins the modern movement. In addition to similarities with McHarg's physiological determinism, Little's idea harkens back to Benton MacKaye's "open ways," linear natural areas intended to form a "belt around and through the locality" (Hellmund and Smith 2006). In MacKaye's vision, open ways were to be wooded and to follow natural landforms such as mountains and rivers, surrounding and containing development.

"Green Infrastructure Planning" in the Literature

Landscape-scale green infrastructure planning strives to ensure adequate ecosystem services through delineating, preserving, and maintaining a functional green infrastructure network (Benedict and McMahon 2006; Kambites and Owen 2006). Green infrastructure planning does take place at smaller scales, but is remedial, and oriented toward bringing green spaces into already developed areas or mitigating the loss of green infrastructure in the subdivision and land development process. Landscape-scale green infrastructure planning is oriented toward impacting the broader conservation-development balance to create – and more importantly retain – the integrity of a conservation network. In one of the more developed areas of green infrastructure research, many academics and practitioners have suggested broad considerations or steps in accomplishing this task. The Conservation Fund (TCF) is a leader in green infrastructure planning and has assisted a number of counties and municipalities in creating green infrastructure plans. McDonald and her colleagues at TCF suggest frameworks for assessing green infrastructure plans and outline three attributes of green infrastructure planning: 1) landscape-scale; 2) driven by public process; and 3) resulting in a strategy intended to protect an ecological network and (McDonald, Allen et al. 2005).

Overall, literature supports two facets of green infrastructure planning which distinguish it from other environmental planning efforts. One is the broad focus upon ecological function and associated ecosystem services (ibid) and the second is the elevation of green infrastructure in the planning and development process (Randolph 2004). Of these two characteristics, the first is the simplest to understand and implement and the focus of a vast majority of literature. But the deviation from other conservation methods in this area is slight. Watershed management, ecosystem management programs, integrated environmental planning, and strategic conservation for example, all tend toward landscape scale and focus upon ecological systems (two of McDonald's principles).

Much of the research on green infrastructure planning focuses upon mapping. Notable work includes that of Anthony Walmsley in New Jersey (2005) and of Weber, Sloan, and Wolf with Maryland's Chesapeake Bay Program (2005) who discuss the Green Infrastructure Assessment methodology. Both studies describe, in detail, the principles and methods by which their respective states mapped out future green infrastructure networks but largely avoid issues of implementation. However, as Kambites and Owen note, mapping is a "relatively straightforward technical activity" and separate from the far more political and challenging decision-making processes that are involved with broader green infrastructure planning (2006). Although mapping, usually a GIS activity, is valuable and imperative in the planning process, unless it is situated within an effective and proactive planning framework, it accomplishes little. Notably, this discussion is most applicable to large-scale green infrastructure networks; smaller scale interventions (e.g green roofs, swales, etc) also support ecosystem services, but are intended to mitigate the impacts of green infrastructure loss and naturally have a different, more reactive, planning process.

Given that mapping is a technical activity, this review emphasizes the second component of green infrastructure planning - the elevation of green infrastructure in the planning process - and leaves the mapping to others. The more important distinction between, 'open space' and 'green infrastructure' planning, this second characteristic requires a shift of planning values. Planning usually implies planning for development (Daniels and Daniels 2003); planners routinely evaluate the suitability of land for development, conduct environmental assessments of development and plan the direction of future development. But green infrastructure planning is planning for both conservation *and* development. In elevating green spaces to the same level as conventional infrastructure, green infrastructure planning means protecting ecological processes proactively, along with, or even before, development. Notably, this process is only possible at scales that include undeveloped forests and farmlands. In urban areas, where development has already occurred - and planners add green infrastructure to solve the problems caused by the removal of green space - the strategy is impossible. So a local government's level of green infrastructure planning is best identified by the variety of land use planning strategies the agency uses to support green spaces and their size/shape, quality, and connectivity in the development process, and – more broadly - whether the overall strategy is remedial or proactive.

Green Infrastructure Planning Strategies and Success

Landscape ecology and conservation biology research hold that the size/shape, quality, and connectivity of green infrastructure networks are important factors in supporting ecosystem services. But, for the attributes to impact community health, livability, and resilience, they must be supported by the land use planning and decision-making process. There are several strategies for accomplishing this task, some more effective and proactive than others. Among the better-studied local government strategies are land preservation, growth management, and clustered subdivision design. Of the three, land preservation is most proactive – and clearly aligned with green infrastructure planning principles – but growth management strategies such as restrictive zoning and urban growth boundaries also protect important systems prior to development and complement land preservation. Clustered development is different in character and could be best described as a mitigation strategy. It is intended to minimize the loss of green space in areas under suburban or ex-urban residential development. However, the majority of research on these strategies emphasizes green space quantity, most likely because it is the easiest to measure and to convey to decision-makers. In most cases, more green space *is* better, but conservation funds are limited and, as previously discussed, ill-planned conservation can do as much damage to ecosystem function as poorly planned development. There are far fewer studies of the success of local governments in supporting the quality and connectivity of green space networks.

The objective of green infrastructure planning is to support and enhance lands that provide ecosystem services through conservation and development strategies that protect and connect high quality green spaces. One way to consider this task is through the lens of ecological determinism – a McHargian strategy where land use is determined by the natural characteristics of the land (Maruani and Amit-Cohen 2007). A 2007 review of open space planning models concluded that ecological determinism is among the most useful for conservation. It is the only popular model that is focused upon conservation, yet flexible enough to be applied at almost any scale, from site to landscape (ibid). Since green infrastructure planning takes place at a variety of scales, this flexibility is critical. At the county or landscape scale it means prioritizing conservation lands based upon environmental characteristics, at the local government scale it is using protective zoning or regulations to ensure that high quality lands are not fragmented or degraded, at the community-scale it is subdivision design that clusters development to protect green space, and at the parcel-scale it means site-planning that minimizes impact on sensitive areas and restores or mitigates impacts where necessary. Notably, not every action along the continuum is equivalent. Large-scale actions tend to be more proactive, and yield more connectivity and core area than smaller scale activities. Community and parcel-scale actions – such as clustered development – are more oriented toward mitigating the impacts of development and piecing together smaller sections of preserved land which, necessarily, results in more irregularly shaped conservation areas with less core area. The presence of residential development and discontinuity of conservation area created through strategies that mix development with conservation can also impact ecological quality. The remainder of this review discusses strategies that support quality and connectivity and the degree to which research provides insight on the outcomes of specific strategies intended to support high quality interconnected green infrastructure.

Local Land Preservation
Land preservation is a popular strategy for local governments. There are three main mechanisms: purchase of land in-fee, purchase of development rights to the land (PDR), and transfers of development rights (TDR). All three are voluntary. In the former, land is transferred to ownership of the county or municipality while, in PDR and TDR, the land stays in the hands of the original private landowner, but with a conservation easement that restricts development. Land trusts and other non-profit organizations are also active in land preservation and frequent partners in local efforts (Daniels and Lapping 2005). Land preservation is usually proactive, but can be reactive when land is preserved in response to development threats. The strategy is among the best for supporting long-term green infrastructure quality and connectivity. Since communities acquire parcels individually using limited conservation funds, they are motivated to prioritize properties with the greatest environmental return, usually those with high ecological quality or in close proximity to other preserved lands. Some communities also identify critical green space connections and prioritize properties within those areas for preservation. However, these benefits assume a proactive preservation approach. When land preservation is more opportunistic, occurs in response to imminent development, or without consideration of surrounding ecological systems, quality and connectivity outcomes are less robust. In addition, it is usually cost prohibitive for most communities to build a critical mass of protected green infrastructure using land preservation alone, even through conservation easements. Other supplementary actions, such as growth management, are needed to protect lands that cannot (or should not) be purchased. Finally, since land preservation increases a community's responsibility for protected lands – either through direct ownership or enforcement of a conservation easement – it raises land management costs.

There is no empirical research on the connectivity or ecological outcomes of land preserved through TDR, but significant research informs purchase in-fee and PDR programs at the local government level. The majority emphasizes prioritization schemes – a symptom of the general tendency of green infrastructure planning literature to focus on mapping. Because of variations in local conditions, resources, and priorities, it is difficult to compare empirical land preservation results across programs, much less regions, so the literature that makes comparisons within programs to identify relative success is most useful. Two such studies, outlined here, suggest that local government preservation programs are generally supportive of connectivity but may be less successful in fostering ecological quality, particularly biodiversity.

In recent years, PDR programs have been a target of scrutiny, particularly for the lack of data on the cost-benefit balance and spatial distribution of outcomes (Merenlender, Huntsinger et al. 2004; Wallace, Theobald et al. 2007). The research is filled with studies, particularly in the field of conservation biology, describing how land preservation organizations can target easements to lands that maximize ecological value per dollar spent (Ando, Camm et al. 1998; Abbitt, Scott et al. 2000; Newburn, Berck et al. 2006). Based upon applied statistical models, recent research shows that the most efficient prioritization strategies consider three factors: cost, environmental benefits, and the likelihood of future land conversion (Newburn, Berck et al. 2006; Prato 2006). The latter is particularly important since land does not need to be preserved to provide ecosystem services. Privately owned green spaces provide significant benefit with little intervention and may even yield better ecological outcomes - for example, if preserved lands are degraded through intensive public use.

Recent work by Huber and colleagues suggests a spatial land preservation prioritization strategy. The study uses ecological criteria to model a landscape-scale conservation network for California's Central Valley and, using the same criteria, one for each county within that region. The authors found that only 54% of local corridors overlapped with regional corridors and that a mere 44% of regional corridors overlapped with modeled county networks. The result indicates that working at either scale alone neglects the other in some way and that prioritizing potential conservation lands within the overlap area of the two scales could ensure that benefits accrue at both levels (Huber, Greco et al. 2010).

A few studies have used empirical research to understand the aspects of green space that lead to ecosystem service success. Schiller and Horn examined the wildlife conservation characteristics of six representative local greenways in the southeastern United States and concluded that "if a greenway is wide, forested, and, more importantly, has forest connectivity to other areas, it should contain [the two indicator species] fox and deer regardless of its proximity to urban areas" (Schiller and Horn 1997, 113). While only 18 of the 38 study greenway segments had either fox or deer (12 with fox, 6 with fox and deer, and none with deer alone), none of the five managed like a city park had either species and 4 out of 5 of the more remote greenways had both. Results also highlighted that the wildlife conservation value of greenways in urbanized areas is heavily impacted by surrounding land uses and their resource characteristics. Greenways with greater amounts of adjacent habitat and connected forested areas were also more likely to have the indicator species. All 14 greenway segments with adjacent forested area – whether large or small - had fox, and 4 out of 5 with large adjacent forest areas had deer (Schiller and Horn 1997).

A more rural examination of local government land preservation efforts - in Larimer County, Colorado – suggests that city and county open space programs are more effective at fostering connectivity than biodiversity or agricultural values. Half of lands preserved through city and county open space programs in Larimer were contiguous with other private preserved parcels, 43% were adjacent to publicly-owned protected lands, and 30% served as connectors between multiple parcels. But while a third of lands preserved through government programs included prime irrigated agricultural lands and another

10% prime (non-irrigated) agricultural lands, only 17% had very high or outstanding biodiversity, and 13% had ‘moderate or high’ biodiversity. But, authors also found that a greater percentage of lands preserved by city and county programs included high levels of biodiversity than those preserved by non-governmental organizations such as land trusts. Only 2% of land preserved through NGO programs included prime agricultural lands, 8% had very high or outstanding biodiversity, and 16% included areas with more moderate levels of biodiversity (Wallace, Theobald et al. 2007). Benefits of land preservation by these organizations seems largely aesthetic or recreational.

Growth Management
Communities use growth management strategies to shape development patterns over time, usually with the objective of retaining a desirable conservation/development balance. Tools such as urban growth boundaries and restrictive rural zoning protect green infrastructure by keeping development compact and thus minimizing sprawl into rural resource lands. Research exploring the effects of such tools is robust, and will not be discussed here, but generally supports the success of the strategies in reducing sprawl and minimizing the acreage of land developed per new resident added to a community. A low rate of land conversion indicates that a community is using undeveloped lands efficiently. But efficiency is a quantity measure; impacts on green space quality and configuration, particularly the latter, vary by the type of growth management tool. Two of the most common are urban growth boundaries and restrictive zoning.

Urban growth boundaries (UGBs) are a popular strategy for communities seeking to guide growth to existing communities and protect rural resources beyond. UGBs. UGBs limit urban services expansion beyond a certain point, help to reduce sprawl, and in doing so help a community to retain its natural resources. A strong UGB is also supportive of connectivity. Less development in rural areas means less fragmentation of green spaces. However, the tool is a blunt one, from an environmental quality perspective. Unlike land preservation, which is usually proactive, and targets protection to the most important lands, UGBs are defensive, preventing development more broadly, with little impact on whether lands that *are* developed are ecologically marginal. Yet, the delineation of a growth boundary *can* be used to allow growth only in desirable directions, for example into areas with lower ecological quality or fragmented farmland. UGBs are also impermanent, and are intended to expand every 20 or so years as the population grows.

Most growth management research advocates that communities support UGBs with land preservation and rural or natural resources zoning. The two strategies re-enforce the growth boundary and allow a greater consideration for quality. Land preservation can shore up areas of the boundary, creating a permanent edge – or green belt – and providing green spaces that are directly accessible to populated areas. And since land preservation can prioritize areas with high ecological quality, when used in close proximity to a UGB, it can keep resource-rich areas from being developed as the boundary expands over time. Natural resources zoning works more broadly than land preservation, but is also less permanent. There are several types of zoning that communities use to reduce densities in rural or resource areas: agricultural zoning, forestry zoning, and conservation zoning (Daniels 1999). The hallmark of such strategies is very low-density zoning (i.e. less than

1 dwelling unit per 10 acres). Research supports that the low densities reduce the inventive to sell land to developers and consequently minimize fragmentation of the target areas farmland, forestland, open space, and sensitive natural resources - by development (Coughlin 1991). Unlike a UGB alone, restrictive zoning can impact the quality of a green infrastructure network because it can be tailored to the rural resource it protects. It can provide more restrictions where resources are particularly important or high quality – wetlands, prime farmlands, riparian areas, species habitat – and less in more marginal areas. However, there is little research on the impact of restrictive zoning on ecological quality and connectivity, specifically. The greatest challenge with restrictive zoning is feasibility. If enforced, very low-density zoning is de facto land preservation. It greatly reduces a landowner's potential economic use of the property, but without the compensation provided by a PDR. While some communities have undertaken large-scale downzonings, in many areas, such a move is politically, if not legally, impossible.

Clustered Development Strategies

Clustered development is a smaller scale strategy than land preservation and growth management. It is rooted in the same principles of ecological determinism, but applies them on a site-scale. The approach is designed to mitigate the impacts of development, and to retain larger, higher quality green spaces than would be protected under conventional suburban development patterns. But it *is* development. In theory, clustered development strategies protect resource land by grouping development on a marginal portion of a site rather than spreading disturbance evenly across it and onto ecologically valuable lands. But clustered development can also further fragment resource lands by facilitating the spread of development further into rural areas, especially through providing bonus densities for developers that cluster housing. The positive aspect of clustered development is that it impacts only the configuration of development (i.e. does not reduce the allowed density), which makes it feasible in areas where regulatory actions like downzoning are politically contentious. Typically, clustered developments, often called conservation subdivisions, consist of two sections, development and preservation. Conservation success is measured by the percentage of the site that is within the preservation area and therefore considered 'protected.' Several studies go further to consider biodiversity outcomes. Most conclude that the ecological benefits of conventional conservation subdivisions are limited but that the tool is not irredeemable and could be improved. However, the 'new and improved' models set a high conservation bar that is not met in a way that is economical. They also depend heavily upon management, which requires long-term support.

The previously discussed Larimer County, Colorado study found clustered development to be less effective than land conservation in supporting conservation outcomes. While biodiversity levels were comparable to county and municipal open space preservation programs at the moderate level (13%), only 8% of the preserved areas of cluster development included very high or outstanding biodiversity, compared to 17% for local open space programs in the same county (Wallace, Theobald et al. 2007).

Lenth et al. compared the wildlife value of six clustered housing developments, six dispersed housing developments, and six undeveloped sites managed by parks departments in Boulder Colorado. They found that the flora and fauna of clustered housing developments is more similar to that of dispersed housing than that of undeveloped areas (i.e. gap species and invasives). The authors suggest that two factors lower the conservation value of clustered developments: scale and plant community composition. The protected areas of conservation developments are necessarily smaller than undeveloped sites of a similar size. In the study, the protected areas of clustered developments averaged less than 80 hectares while undeveloped sites had 480 hectares. The latter was also dominated by native plant species while clustered and dispersed development were characterized by non-native vegetation. Clustered and dispersed developments also had high incidences of disturbance-oriented species and low incidences of species that are sensitive to disturbance. In several cases, the authors also found the configuration of conservation subdivisions to be problematic. Green spaces were designed in ways that maximized edge effects and minimized support for natural communities of concern (Lenth, Knight et al. 2006).

Two further studies seem to corroborate that conservation subdivisions have a negative impact on natural resources and attempt to understand whether the strategy could be improved by using more conservation-oriented variations. Milder and colleagues reviewed ten conservation and limited development projects (CLDPs), a type of clustered development strategy initiated by land trusts and/or developers to balance profit and conservation outcomes. Compared to typical conservation subdivisions, CLDPs usually have fewer developed parcels – often less than the allowed maximum density – and are highly oriented toward conservation. The examined CLDPs had offsite connectivity and riparian protection similar to traditional conservation subdivisions, but led to more positive ecosystem impacts, fewer negative ecosystem impacts, and greater overall impact scores. They also yielded less land disturbance, edge-effected area, and impervious surface. While the study examined ten CLDPs and only three conservation subdivisions, the conclusion seems to agree with of other studies that suggest we can do better than conservation subdivisions, which seem to be just a different form of sprawl. Since conservation-focus is the main difference between CLDPs and conservation subdivisions, it is unsurprising that management was the major divergence. Conservation subdivisions did reduce the negative impacts of development – fragmentation, edge effects, etc – to an extent, but did not increase positive activities, such as land management and restoration (Milder, Lassoie et al. 2008).

A second study compared how clustered development (1 acre lots with a protected reserve) and traditional rural development (5 to 10 acres lots with non-native vegetation) compare with ‘ecologically beneficial subdivisions,’ 20 to 40 acre lots characterized by restored or maintained native vegetation and a single small acre disturbance area. Examining the characteristics of streams in catchments with similar land cover characteristics to the three conditions, the authors concluded that the ecological model produces better water quality outcomes and is preferred by the public as more attractive (Nassauer, Allan et al. 2004). The success of the ecological model in this study is encouraging since it approximates the open space or agricultural zoning that is increasingly popular among counties that would like to minimize development in rural areas. For example, in 2004 Baltimore County, Maryland downzoned much of the rural area outside their urban growth boundary from 1 dwelling unit per 5 acres to 1 per 25 or 1 per 50 (Baltimore County 2005). The big difference between the two models is the type of vegetation that is likely on such large parcels. In most cases, areas zoned for 25 or 50-acre lots are agricultural and managed specifically *for* the growth of non-native vegetation.

While there is general acknowledgement of the potential of connecting the preserved portions of conservation subdivisions to greater natural resource networks (Arendt 1996; Lenth, Knight et al. 2006), very few studies have examined local governments' success in doing so. Ecological results for conservation subdivisions are a mixed bag, so the synergistic environmental benefits that could be derived from making such connections would be a boon to the utility of the tool (Lenth, Knight et al. 2006). Limited research on cluster development connectivity suggests that linkages are fewer than with land preservation. One challenge is that the preserved open space is usually managed by a Homeowners' Association (HOA), which may have little interest or experience in managing open space. The Larimer County, Colorado study discussed in the previous section found that 40% of lands preserved as part of a clustered development strategy were contiguous to other preserved private lands, 17% were adjacent to publicly-owned protected areas, and 28% connected multiple protected parcels (Wallace, Theobald et al. 2007).

Conclusion

Green infrastructure planning includes strategies and polices intended to support ecosystem services, particularly in the local planning and land development process. Research shows that ecologically successful green infrastructure networks should be large, high quality, and contiguous. There is significant research on how counties can create such a network, but most focuses upon mapping rather than implementation and on acreage of green space rather than quality and connectivity. Local governments use a number of strategies such as land preservation, urban growth boundaries, restrictive zoning, clustered development, open space requirements, and the development review and site planning process to retain connections and protect and enhance high quality green spaces. The larger scale strategies – land preservation, urban growth boundaries, and restrictive zoning – are more proactive than site scale strategies – clustered development, open space requirements, development review and site planning – and have greater potential for supporting overall ecological quality and connectivity. But there is little empirical information on the success of the tools.

Existing research is most instructive regarding land preservation and clustered development. While empirical research is scant and difficult to compare, it corroborates that land preservation yields greater connectivity between green spaces than clustered development (Wallace, Theobald et al. 2007). The main reason is likely that clustered development is a form of sprawl. The developed portion fragments the green space in which it is located. While there may be potential for clustered development strategies to support connectivity, it has not been realized. Empirical studies of greenways have also confirmed the importance of habitat connectivity in supporting wildlife and the synergies to be realized by connecting green spaces (Schiller and Horn 1997). Results of ecological quality literature are more complicated, but clearly suggest that land preservation is a more effective strategy for protecting biodiversity than clustered development (Wallace, Theobald et al. 2007). Since clustered development is still disturbance, the result is not surprising. Findings that the impacts of clustered development more closely resemble conventional dispersed development than undeveloped land corroborate the conclusion (Lenth, Knight et al. 2006). It also appears that - likely due to the robust literature on mapping - preserved land has higher connectivity values than biodiversity values. Since the values of preserved land is a function of the prioritization criteria of the organization undertaking land preservation and the location of interested landowners, the result is not generalizable. But communities should be careful to balance the connectivity and ecological quality values of potential open space.

One role that planners play is that of allocator. They apportion lands to residential, commercial, industrial, institutional and green space uses. But, much like other types of infrastructure, green space is part of a network, and the services it provides depend upon quality and connectivity, as well as size. Despite the importance of the quality and connectivity of green infrastructure, there is little research on how local governments can best support it. Green infrastructure planning suggests that large-scale, proactive strategies are the best way to create the high-quality, interconnected networks of green space needed to support ecosystem services. And indeed, most literature supports land preservation and doubts clustered development strategies. But there are a host of other policies and tools that could have implications for ecological quality and connectivity at the landscape or site scale. For example, some communities require connectivity of open space requirements through subdivision regulations, have strict development review and environmental permitting requirements, or focus land preservation on certain sensitive zones (e.g. Maryland's Coastal Rural Legacy Area). The potential of these strategies to support quality and connectivity remains understudied.

In addition, while some strategies are more effective in fostering connectivity and ecological quality than others, it is most important that they work together to support high quality, interconnected green infrastructure networks that provide ecosystem services. As previously discussed, broader studies of green infrastructure planning emphasize mapping and analyses oriented toward identifying preservation priorities. They usually mention implementation, but are not outcome-oriented. So, despite the fact that green infrastructure planning is on the rise, - and increasingly important, given the uncertainty surrounding climate change - there are no overall assessments of whether it is effective in supporting green space networks over time. Consequently, to sustain the green infrastructure needed for livable and resilient communities, more research is needed, particularly in two areas: 1) Understanding the overall success of local government green infrastructure planning in retaining and enhancing green space acreage, quality, and connectivity over time, and 2) Understanding the effectiveness of the individual strategies that comprise local government green infrastructure planning and their relative success in fostering ecological quality and green space connectivity.

CHAPTER 3: HYPOTHESES, APPROACH and METHODS

Hypotheses and Research Questions

Research indicates that green infrastructure planning is taking place, and is distinct from other environmental planning efforts. But the area is relatively young and remains empirically unexplored. Despite the fact that 65% of surveyed organizations indicate they have adopted green infrastructure planning strategies (Lynch, unpublished), the specific actions and outcomes remain unclear. This study fills that gap by examining green infrastructure planning strategies and results over time. It details the plans, policies, and outcomes of counties with different levels of green infrastructure planning to determine the on-the-ground impact of green infrastructure strategies. Thus, the study is based upon two main research questions:

- How do county planning agencies carry out green infrastructure planning?

- Are agencies that employ many green infrastructure planning strategies more effective at retaining green space, preserving ecologically significant lands, and creating green infrastructure networks than those that employ fewer strategies? If so, how, why, and to what extent?

The overarching hypotheses are:

H_1: County planning agencies that employ many of the policies and strategies associated with green infrastructure planning will be more effective at retaining, protecting, and connecting green infrastructure over time than county planning agencies that employ fewer.

H_0: There will be no difference in on-the-ground green space outcomes between county planning agencies that apply many green infrastructure planning policies and strategies and those that employ few.

There are two components to each hypothesis: 1) policies and strategies associated with green infrastructure planning and 2) on-the-ground green space outcomes. A strong relationship between the two will disprove the null hypothesis and support the alternative hypothesis that green infrastructure planning leads to better green space outcomes. For the purposes of this study, a 'strong relationship' means an overall trend that counties employing a 'high' level of green infrastructure planning outperform counties employing a 'low' level of green infrastructure planning in the three areas of analysis: retaining green infrastructure over time, protecting high quality areas, connecting green infrastructure into functional network).

Approach to Hypothesis Testing

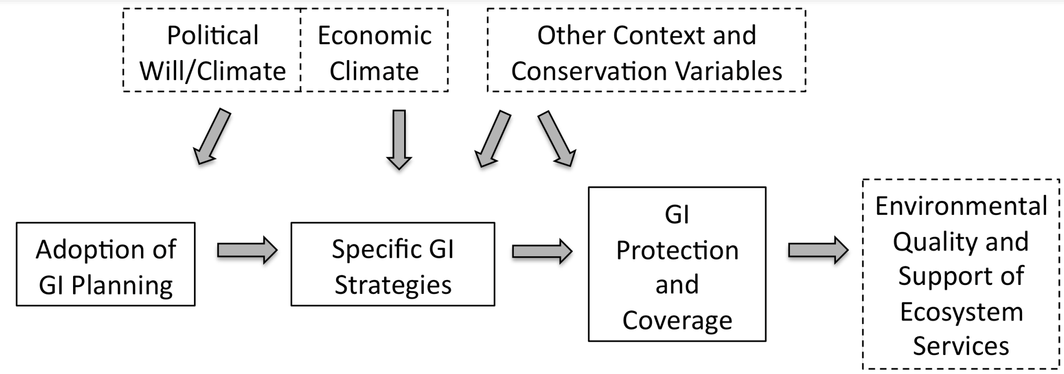
The main objective of this research is to assess the differences in outcomes between county planning agencies that are highly involved in green infrastructure planning and those that are not. The structure of this inquiry necessitates a comparative approach. As contextual variables and data limitations preclude a strictly experimental design or statistically significant modeling and analysis, this research uses a quasi-experimental multiple case study approach. The study involves a green infrastructure pre-test (retrospective) and post-test, and qualitative examination of three sets of three case studies, grouped by state and other attributes. The objective of the matched design, and the inclusion of three pairs, is theoretical replication (Yin 2009). The results of the nine case studies will vary, but for largely predictable reasons, and will identify the effects of green infrastructure planning.

Conceptual Framework

This study is based upon the understanding that the environmental outcomes of green infrastructure planning result from the impacts of policies, plans, and programs on the quality and extent of green infrastructure networks. Green infrastructure planning strategies protect rare and important lands and minimize loss of green infrastructure to development. These lands – natural areas, working landscapes, parklands, and greenways – provide the ecosystem services necessary to support human populations, create a healthy, livable, and resilient environment, and promote economic opportunity and social well-being.

There are three main challenges in assessing the environmental outcomes of green infrastructure planning. First, ecosystem services are notoriously difficult to measure. Second, there is a temporal mismatch between planning actions and their effects. Third, there are so many other variables in play that environmental quality may not be conclusively linked to planning actions. However, the environmental outcomes of green infrastructure planning are a result of the functions of green infrastructure, the extent and value of which can be measured far more easily. Thus, this study does not measure ecosystem services and environmental quality outcomes directly, but uses green infrastructure quality and coverage as an indicator. As shown in the conceptual framework below (See Figure 1), adoption of green infrastructure planning leads to implementation of specific green infrastructure planning strategies. The strategies then impact green infrastructure protection and coverage which affect environmental quality and ecosystem services.

3-1. Conceptual Framework



Arrow signifies impact, not causation.
GI: Green Infrastructure
Dashed Line: Context variable, not measured directly.
Solid Line: Variable of interest.

The main variables of interest in this study are: 1) green infrastructure planning strategies, and 2) the resulting on-the-ground protection and coverage of green infrastructure. In examining specific green infrastructure strategies, the study also addresses several of the motivations behind county adoption of green infrastructure planning. In short, these three steps are the 'why,' the 'how,' and the 'outcome' of green infrastructure planning. The effects of contextual variables such as political and economic climate, and inherent baseline quality and extent of green infrastructure are also factors, and accounted for mainly through case selection.

A second challenge is that the vast majority of local governments have instituted green infrastructure plans and programs only in the last five years, meaning efforts are too recent to have been implemented completely, much less had a measurable impact. This study overcomes that limitation by examining county programs that may not be labeled 'green infrastructure planning', but employ the same policies, strategies and programs. Local governments have been planning in support of some forms of green infrastructure for over a century. The inclusion of strategies under other headings acknowledges that legacy. By including green infrastructure strategies that may not be labeled as such, this study is able to examine mature green infrastructure efforts - activities that began in 2000 - and related change in on-the-ground green infrastructure.

Unit of Analysis: The County

The final challenge in assessing the impact of green infrastructure planning is scale-selection. Green infrastructure planning exists at a point of tension among the site, neighborhood, area, and landscape scales. As previously mentioned, there are two defining features of green infrastructure planning, 1) the focus upon functional ecological systems and the ecosystem services they provide, and 2) the elevated role of green space in the planning process. In the second case, the municipal and county scales are appropriate because planning and land use decisions are largely the domain of local government. Local governments are the principal creators and implementers of green infrastructure planning efforts and a natural choice for examining the strategy. But, while the level of action is appropriate, municipal and county boundaries are not based upon ecological systems. The first defining feature indicates that green infrastructure planning emphasizes functional natural systems, which have a larger scale. It is only through consideration of the landscape, or ecological, scale that green infrastructure planning can succeed in protecting and enhancing ecosystem services. If the objective is a functional ecological system, it is necessary to work on the scale of that system, for example a watershed. This study accounts for the difference in level of action and scale of influence by examining how local governments consider the larger eco-region and take steps to coordinate efforts with surrounding jurisdictions and larger scale state and non-governmental efforts.

Of the levels of government with significant planning powers, this study examines counties. Counties, rather than cities, are the appropriate unit of analysis because green infrastructure planning emphasizes natural areas, open spaces, and large-scale green space networks, and counties simply have more land of this type under their jurisdiction. Additionally, most green infrastructure plans are adopted at the county level, making it a natural unit upon which to focus, and ensuring an audience for the results. Municipal green infrastructure planning efforts are different in character, more often focused upon urban stormwater management. However, as connectivity is a key component of green infrastructure planning, connections between city and county green infrastructure planning are considered in the case study portion of the analysis.

Methods

A major objective of this research is to assess the differences in outcomes between county planning agencies that are highly involved in green infrastructure planning and those that are not. The structure of this inquiry necessitates a comparative approach. The study involves a green infrastructure pre-test (retrospective) and post-test (modern), and qualitative examination of three sets of three case studies, grouped by state and other attributes.

There are five main parts of the study:

I. Case selection, based a upon preliminary scan of counties in Colorado, Florida, and Maryland
II. Development of an in-depth green infrastructure planning evaluation framework
III. Application of the green infrastructure planning evaluation framework to selected case counties
IV. Follow-up Interviews with county planners and decision-makers
V. Quantitative assessment of green infrastructure networks

This section details methods and methodology for all five sections, briefly identifies and describes the nine selected cases, and introduces a green infrastructure planning evaluation framework and interview protocol used in later chapters.

I. Case Selection, Based upon a Preliminary Scan of Counties in Colorado, Florida, and Maryland

Due to the quasi-experimental design of this research, results hinge upon the comparability of nine case studies. Case selection is particularly imperative since comparing cases with similar contexts, but differing levels of green infrastructure planning (High, Moderate, Non), best identifies the effects of the GI strategy.

Cases were selected through a three-step process:

1) Identification of counties in Colorado, Florida, and Maryland that gained population between 2000 and 2010 and had a 2000 population of between 100,000 and 1,000,000.

2) Review of county policies and documents to identify the level of green infrastructure planning employed by candidate counties and categorize counties as 'high-level' 'moderate-level' or 'non-' green infrastructure planning.

3) Use of information from steps one and two, as well as additional data on the maturity of green space planning efforts and state/federal land ownership, to select one county at each level of green infrastructure planning in Colorado, Florida, and Maryland.

Population and Growth Characteristics

Populous and growing counties are more able, and inclined, to conduct large-scale, comprehensive planning efforts. This first step toward case selection narrows the field from all counties in Colorado, Florida, and Maryland to a subset with ten-year population increases and 2000 populations between 100,000 and 1 million. Limits are set in recognition of the resource-intensive nature of green infrastructure planning and need for comparability. They restrict cases to counties with similar planning capabilities and, more practically, those that are likely to have information and documentation readily available. The cutoff date for population estimates is 2000 and growth estimates is 2000 – 2010 as the research emphasizes planning efforts from that time and interval.

In 2000, Maryland and Colorado each had 10 counties with populations between 100,000 and 1 million while Florida had 33. Since 2000, all of the 53 counties except for Pinellas County, Florida gained population (U.S. Census).

Review of Policies to Identify Level of Green Infrastructure Planning

A major strategy of this study is to compare counties with different levels of green infrastructure planning. The second step in case-selection therefore was to identify those levels through a scan of green infrastructure-supporting practices in the 52 remaining candidate counties. Counties that employ few GIP strategies, or operate within a completely different conservation framework, were identified as non-green infrastructure planning while those moderately and highly involved in green infrastructure planning were identified as such. At that point, the characterization was based upon the extent of county-level green infrastructure planning in each state, individually. For example, a 'High' in Florida could be a 'Moderate' in Maryland.

This study employs a broad interpretation of green infrastructure planning (GIP). Plans, policies, and programs oriented toward any type of green infrastructure – parks, trails, natural areas, farms, forestlands, wetlands, stream buffers, etc - are part of a GIP strategy. The flexibility is necessary for two reasons. First, green infrastructure planning is only the latest in a line of characterizations of green space, open space, and conservation planning. County governments have long instituted programs and policies supporting green spaces and ecosystem services, without using the term 'green infrastructure planning.' Some may choose not to use the term, preferring to stick with traditional green space and conservation planning terminology. Second, this research emphasizes plans and programs that began around the turn of the century, when the term 'green infrastructure planning' was not widely used. While this study is oriented toward discovering the role of GIP, it does not hinge upon the use of that term specifically.

Key data sources in this initial scan were comprehensive plans, zoning ordinances, subdivision regulations, capital improvement programs, greenspace/open space plans and programs, county websites and meeting documents, and secondary literature by NGOs and state government. As the objective is to judge the impact of green infrastructure planning over time, the study focused on plans and policies instituted around 2000. Additionally, while the emphasis is county planning agencies, overlap with work by open space departments, parks & recreation departments, environment departments, and even public works, warrants a broad view of 'planning'. In the scan, policies or programs under any county department were considered toward the green infrastructure planning level of that county.

Following background research on the 52 counties identified in step one, a single evaluator rated each on its consideration of each of 12 categories that relate to the major principles that define green infrastructure planning (Figure 3-2). Counties were rated on a 1 to 4 scale, where:

1: None or no mention.
2: Some role or consideration, but few requirements, mandates, or mechanisms for support
3: Significant role or consideration, but few requirements, mandates, or mechanisms for support.
4: Significant role or consideration, with clear requirements, mandates, and mechanisms for support.

Figure 3-2. Green infrastructure (GI) principles and categories used to assess county-level green infrastructure planning.

GI Principle 1: Ecosystem Services. Focus on preserving, supporting, and enhancing ecosystem services.

Categories
a) Provisions for Connectivity (of green infrastructure)
b) Provisions for Management (of green infrastructure)
c) Provisions for Ecological Quality and/or Value
d) Provisions for a Variety of Services
e) Provisions for Restoration/Mitigation
f) Provisions for Cross-jurisdictional Cooperation in Planning

GI Principle 2: Infrastructure. Understanding of green infrastructure as a critical infrastructure network, similar in importance to conventional infrastructure (roads, schools, sewer and water facilities, etc.), and valued accordingly in the planning and decision-making process.

Categories
a) Public Participation in Planning (of green infrastructure)
b) Sustainability of Funding
c) Role of green infrastructure in CIP
d) Role of green infrastructure in Zoning Ordinance
e) Role of green infrastructure in Subdivision Regulations
f) Role of green infrastructure in Comprehensive/Master Plan

The 12 ratings were added to yield a GIP score for each county. The GIP scores were compared to other counties within their state and assessed to be High, Moderate, or Non. Generally, counties with scores in the 20s were designated Non-GIP, those in the low- or mid-30s as Moderate GIP, and those in the upper-30s or 40s as High GIP.

Case Selection

In the final step of case selection, data from the previous assessment was used to identify one county with each level of GIP in each state. In Maryland and Colorado selection was straightforward; there were only ten counties from which to choose, and most were in the Baltimore or Denver metro area. In both states, the highest and lowest scoring counties were clear, and good candidates for the study. Both states had several promising candidate counties at the moderate-level, but they were easily pared down by consulting expert-practitioners in the two states.

Case selection of Floridian counties presented more of a challenge, as the state has more counties from which to choose and a coastal/inland dichotomy. Since counties along the coast have a strong incentive to preserve and retain green infrastructure, and regulations that require that they plan to do so, a mixed coastal/inland selection could interfere with the results. Additionally, green infrastructure planning is relatively homogenous in

Florida, with the vast majority of counties in the state receiving scores in the low- to mid-30s.

Case-Selection Results
<u>Colorado</u>
The three selected counties, Boulder, Arapahoe, and Adams are adjacent Front Range counties, and although their growth rates and populations differ slightly, their population densities are similar. The greatest challenge in selecting among Colorado counties is their size disparity with some boasting upwards of 4,000mi^2 or more. Boulder, Arapahoe and Adams are comparable, and similar to other counties in this study, with 724 mi^2, 803 mi^2, and 1,191 mi^2 respectively (See Table 3-1).

Table 3-1. Attributes of selected counties in Colorado.

	Boulder	**Arapahoe**	**Adams**
2010 Population	294,000	585,000	441,000
Growth since 2000	8.4	17.2	21.4
Ecosystem Services: Provisions for…			
Connectivity of GI	3	3	2
Management of GI	4	3	1
Ecological Quality/Value	2	3	2
Variety of Services	3	3	3
Restoration/Mitigation	2	2	1
Cross-jurisdictional Cooperation in Planning	4	3	3
Infrastructure:			
Public Participation in Planning of GI	3	3	2
Sustainability of Funding	4	4	4
Role of GI in CIP	3	2	2
Role of GI in Zoning Ordinance	2	2	2
Role of GI in Subdivision Regulations	2	2	2
Role of GI in Comprehensive/Master Plan	3	3	3
Total Score	**35**	**33**	**27**
Level of GI Planning	**HIGH**	**MOD**	**NON**

<u>Florida</u>
All three of the selected counties, Leon, Alachua, and Marion, are inland. Major cities are highly influential; Leon County plans along with the capital city of Tallahassee (pop. 180,000), which is the main urban area within the county. Alachua County contains Gainesville (pop. 124,000) and Marion surrounds Ocala (pop. 54,000). Marion, with

1,579 mi^2 within its jurisdiction, is larger than Leon (667 mi^2) and Alachua (874 mi^2), but 672mi^2 of that area is Ocala National Forest. The county planning area is closer to 900 mi^2 (See Table 3-2).

Table 3-2. Attributes of selected counties in Florida.

	Leon	**Alachua**	**Marion**
2010 Population	275,000	247,000	331,000
Growth since 2000	15	13.5	28
Ecosystem Services: Provisions for…			
Connectivity of GI	4	3	3
Management of GI	3	3	3
Ecological Quality/Value	4	4	2
Variety of Services	4	3	3
Restoration/Mitigation	3	3	2
Cross-jurisdictional Cooperation in Planning	3	3	3
Infrastructure:			
Public Participation in Planning of GI	3	3	2
Sustainability of Funding	3	4	2
Role of GI in CIP	3	3	2
Role of GI in Zoning Ordinance	4	3	3
Role of GI in Subdivision Regulations	3	3	3
Role of GI in Comprehensive/Master Plan	4	2	2
Total Score	**41**	**37**	**30**
Level of GI Planning	**HIGH**	**MOD**	**NON**

Maryland

Because of the small number of counties in Maryland, and wide variation in population and growth rates, selecting comparable counties was a challenge. Baltimore, Anne Arundel, and Charles represent the clearest three-county set. The three form an urban-rural transect, with Baltimore County the most urban, Anne Arundel more suburban, and Charles on the rural-suburban fringe (See Table 3-4).

Table 3-3. Attributes of selected counties in Maryland.

	Baltimore	**Anne Arundel**	**Charles**
2010 Population	805,000	538,000	147,000
Growth since 2000	6.7	9.8	18.0
Ecosystem Services: Provisions for…			
Connectivity of GI	3	3	1
Management of GI	2	2	2
Ecological Quality/Value	3	4	2
Variety of Services	3	2	2
Restoration/Mitigation	1	2	2
Cross-jurisdictional Cooperation in Planning	2	2	2
Infrastructure:			
Public Participation in Planning of GI	2	2	2
Sustainability of Funding	3	2	2
Role of GI in CIP	3	2	2
Role of GI in Zoning Ordinance	4	3	2
Role of GI in Subdivision Regulations	4	3	2
Role of GI in Comprehensive/Master Plan	4	4	2
Total Score	**34**	**31**	**23**
Level of GI Planning	**HIGH**	**MOD**	**NON**

II. Development of an In-Depth Green Infrastructure Planning Evaluation Framework

A general scan is useful for case selection, but a more rigorous evaluation is needed to fully address the research questions. This study develops an assessment template, called the Green Infrastructure Planning Evaluation Framework (the Framework), through a two-step process: 1) review of evaluation literature to inform Framework structure, and 2) review of modern green infrastructure plans to provide the Framework structure with information and policy content.

Creating the Framework Structure

The backbone of long-range planning in most counties is the comprehensive plan, which is supported and implemented by zoning ordinances, subdivision and land development regulations, the capital improvement program, and other plans, programs and policies. For green infrastructure planning, common supplemental and complementary plans and programs include greenway plans, open space plans, land preservation programs, and forest and sensitive area regulations. An evaluation framework must show how well plans and policies described in these documents support the main principles of green infrastructure planning.

Most frameworks for understanding and assessing local planning efforts are rooted in plan evaluation literature. Plan evaluation schemes developed since the mid-1990s use content analysis and normative understandings of the planning process to assess the quality of comprehensive plans (Berke and French 1994; Baer 1998; Berke and Manta Conroy 2000; Brody 2003; Norton 2007; Berke and Godschalk 2009). The majority of studies use some form of the comprehensive plan evaluation framework detailed in Berke and Godschalk's meta-analysis (2008), which divides plan attributes into internal characteristics (goals, fact base, policies/actions, and implementation & monitoring) and external characteristics (inter-organizational coordination and public participation). But a second key distinction is between a plan's content (i.e. policy emphasis) and its quality, (i.e. the manner in which those policies are conveyed) (Norton 2007). The separation is particularly important for this study where the objective is not to assess the quality of individual plans, but to document the degree to which policies emphasize green infrastructure planning principles.

Several studies examine the degree to which the defining characteristics of certain programs or initiatives are integrated into planning documents and programs. The work derives from plan evaluation literature and tends to focus on local plans, with some coverage of zoning ordinances. Berke and Manta Conroy (2000) examine the degree to which sustainable development principles are integrated into comprehensive plans. They identify six major sustainable development principles, ranging from 'harmony with nature' to 'responsible regionalism' and a list of development management techniques which – if implemented – would promote each principle. Development management technique categories include Land Use Regulation (e.g. density, subdivision), Property Acquisition (e.g. TDR, PDR), Capital Facilities (e.g. concurrency, growth/service boundaries), and Financial Incentives (e.g. impact fees, bonus zoning), among others. Edwards and Haines (2007) use a similar method to assess the extent to which comprehensive plans promote Smart Growth. They identify six Smart Growth goals and a set of accompanying policies for each. For example, included under the goal 'Preserve Open Space, Farmland, and Critical Environmental Areas' are policies such as 'require open space dedication,' 'conservation subdivision design/cluster development,' and 'direct development to already disturbed areas.' Both studies examine local plans for the degree to which they include the techniques/policies identified as implementing the principles in question, a strategy referred to here as the 'principle-policy framework.'

Most assessment structures emphasize plans, but test for a variety of policies and techniques which are outlined more clearly in other documents (i.e. zoning ordinances, subdivision regulations, and capital improvements programs). Additionally, while labeled 'comprehensive,' the plans cannot include everything. Limiting review to plans restricts analysis to the policy statements and explanations contained in one document, which may be aspirational, oriented toward appeasing state planning bodies, or simply have little impact on local action. Reviewing zoning ordinances, subdivision and land development regulations, capital improvement programs, land preservation and management programs, and other local strategies gives a fuller picture of the various policies that counties support green infrastructure principles. It also contributes to a more robustly populated principle-policy assessment framework.

One of the main research questions in this study is '*how* do county planning agencies carry out green infrastructure planning?' To answer the question, it is important to know the policies that, if implemented, would support green infrastructure planning principles. Additionally, evaluation literature supports a principle-policy framework that assesses the degree to which a plan supports a specific planning principle by the number of related policies it includes. So evaluation of green infrastructure planning in case counties should include a list of specific policies, tools, and strategies that support each green infrastructure planning principle.

Expanding the ecosystem services principle of green infrastructure planning (used in the preliminary scan, See Table 3-1) into planning objectives provides the following framework structure:

1. Create linkages and foster connectivity
2. Value areas of ecological quality and local importance
3. Support a variety of landscapes and ecosystem services
4. Restore and mitigate damage to green infrastructure
5. Manage green infrastructure to support ecosystem services
6. Enact land use planning strategies to protect and retain all scales of green infrastructure
7. Protect and support green infrastructure through a collaborative and cooperative process

Making the Framework Robust: Implementation of GI Planning Principles
The concluding step in completing a principle-policy Framework for green infrastructure planning is to populate the Framework structure with policies that show implementation of the green infrastructure planning principles. Many local and regional governments have created green infrastructure plans in recent years. A review of a selection of those plans underscores the information, strategies, and policies generally associated with green infrastructure planning. Green infrastructure plans reviewed as part of this process include:

Metro Kansas City (2002)
Prince George's County, Maryland (2005)
Saratoga County, Florida (2006)
Cecil County, Maryland (2006)
Presque Isle County, Michigan (2007)
Angelina County, Texas (2008)
Nashville, Tennessee (2011)
Town of Cheverly, Maryland (2011)
Northwest Florida (2011)

Douglas County, Colorado (2012 – April Draft)

Notably, the list includes plans from all three case states, which ensures that the green infrastructure policies against which counties are evaluated are applicable to their region and governance structure. Green infrastructure plans for case counties were not included, even when they were created outside of the study period. The information, strategies, and policies were identified for each plan, with more taken from highly specific plans (ex. Prince George's County, MD and Saratoga County, Fl) and fewer from general or limited plans (ex. Northwest Florida and Angelina County, TX). Most strategies and policies were mentioned in more than one plan. Those that were overly complex or area-specific were removed from consideration. The final Framework includes between 9 and 17 strategies/policies for each of the seven green infrastructure planning principles, for a total of 88 policies and strategies (see Appendix 3-A).

III. Application of green infrastructure planning evaluation framework to selected case counties

To apply the Framework, a single evaluator reviewed the plans, programs, zoning ordinance, capital improvement programs (2004-2010), and subdivision and land development regulations for each of the nine green infrastructure planning programs. After review, remaining gaps or lack of consensus between planning documents were developed into questions for the interview phase of the study. Several counties began programs or developed policies included on the Framework during the period of study. If the actions were taken after 2004 (halfway through the study period), they were not included.

The review identified the extent to which each county implemented the 88 green infrastructure planning components identified in the Framework between 2000 and 2012. Given that counties may gather information and implement strategies and policies completely, partially, or not at all, results were and coded 0, if absent; 1, if present but not required/complete; or 2, if present and required/complete. The scale is the current standard and is used in the majority of plan assessment studies, including those employing principle-policy frameworks (Berke and French 1994; Brody 2003; Edwards and Haines 2007; Evans-Cowley 2009; Evans-Cowley 2011; Tang 2011).

The number of policies and strategies is not the same for each principle in the Framework. Principle 1, for example, 'create linkages and foster connectivity' has 11 while principle 2, 'value areas of ecological quality and local importance' includes 17. To avoid weighting one principle more highly than another, raw scores under each principle were normalized to 20. In principle 1, each of the 12 policies provide a maximum of 1.8 points while in principle 2 each of the 16 policies provide a maximum of 1.18 points to preserve the 20 point limit. The maximum score possible for any county's green infrastructure planning program is 140, twenty points for each of the seven principles.

The results are presented and analyzed in chapters 4, 5, and 6.

IV. Follow-up interviews with county planners and decision-makers

The previous sections address *how* county planning agencies carry out green infrastructure planning and some of the partnerships and information involved, but understanding the relative importance of county policies and strategies necessitates a more nuanced understanding. The approach is also important for verifying the accuracy of Framework results. To further understand key green infrastructure planning strategies, a single interviewer spoke with at least one planner in each county, in addition to state and nonprofit representatives where necessary or recommended. Interviews were unstructured and tailored to the specific state or county, but focused variously on the importance of specific green infrastructure planning strategies, planning document data sources and accuracy, relationships with local/state/federal entities, and Framework verification. While several were in-person, the majority of interviews were conducted over the phone or through email.

Results are presented and analyzed in chapters 4, 5, and 6.

V. Quantitative assessment of change in green infrastructure networks

The primary objective of green infrastructure planning is to support the green spaces that provide critical ecosystem services. The clearest measure of county green infrastructure planning success then, is a county's ability to a) retain, b) connect, and c) protect green infrastructure over time. This study examines 'a' and 'b' through GIS analysis and 'c' through GIS analysis and supplemental information provided by the counties and states themselves.

Retaining Green Infrastructure Over Time

The first step in assessing green infrastructure planning success is to understand on-the-ground gain or loss of green infrastructure over the 2000 to 2010 study period. This study uses remote sensing and GIS analysis of Global Land Survey Data through the following steps:

1. Downloading GLS 2000 and GLS 2010 Data
2. Classifying Land Use/Land Cover using three vegetation indices: NDVI, NDBI, and WET
3. Assessing Gain/Loss of Natural and Agricultural Land between 2000 and 2010

The USGIS Global Land Survey (GLS) 2000 and 2010 datasets are comprised of orthorectified leaf-on 30m Landsat TM and ETM+ satellite images taken within a year of the 2000 and 2010 study dates. The USGS processed all eighteen Landsat scenes used in this research to Standard Terrain Correction, the highest level widely available. The correction uses ground control points for radiometric and geometric accuracy and a DEM (Digital Elevation Model) for topographic accuracy (USGS 2012).

GLS scenes use the Landsat Path/Row system. For this research, the following scenes were downloaded and clipped to county boundaries. Where two scenes are listed, they were combined in a two-image mosaic to cover the county, with the scene that best matched the other two counties in the state as the dominant image.

County, State	Path/Row	2000 Image Date	2010 Image Date
Anne Arundel, Maryland	15/33	5 Oct 2001	29 Jun 2009
Baltimore, Maryland	15/33	5 Oct 2001	29 Jun 2009
Charles, Maryland	15/33	5 Oct 2001	29 Jun 2009
Alachua, Florida	17/39	16 Oct 2000	4 Oct 2010
Leon, Florida	18/39	6 Nov 1999	9 Jan 2009
Marion, Florida	17/40, 16/40	1 Dec 1999, 23 Oct 1999	8 Apr 2009, 15 Feb 2010
Adams, Colorado	33/32	20 Sep 2002	15 Jul 2010
Arapahoe, Colorado	33/32	20 Sep 2002	15 Jul 2010
Boulder, Colorado	33/32, 34/32	20 Sep 2002, 24 Sep 2001	15 Jul 2010, 21 Aug 2009

After data acquisition, three different vegetation indices were used to classify the images into a simple four-category land use/landcover map. Green vegetation, soil, water, and impervious surface absorb and reflect light differently, and within different spectral bands. Landsat images include 8 bands. When they are combined mathematically, in different combinations, they create values that indicate on-the-ground conditions and are useful for land use classification. This study uses three known indexes, the Normalized Difference Vegetation Index (NDVI), Normalized Built-Up Index (NDBI) (Waqar, Mirza et al. 2012), and a third unnamed combination of Bands 5 and 7, referred to here as WET (Ozesmi and Bauer 2002).

The Normalized Difference Vegetation Index (NDVI) is a popular vegetation index for long-term vegetation change studies. It is simple, largely insensitive to atmospheric and topographic effects and differences in solar illumination (Kumar 2007), and provides good estimates of green vegetation status (McCloy 2006). The chlorophyll in live green plants absorbs visible (red) light (0.4μm to 0.7μm) and reflects near-infrared light (from 0.7 to 1.1 μm). Since these are two of the eight bands included in a Landsat image, a simple ratio of the two provides an index of green vegetation. The index runs from 1 to -1 with healthy green vegetation at one end and bare ground and water at the other (ibid).

$$NDVI = \frac{(NIR - \mathrm{Re}\,d)}{(NIR + \mathrm{Re}\,d)} = \frac{(Band4 - Band3)}{(Band4 + Band3)}$$

Generally, cells with an NDVI greater than one have some vegetation while cells with an NDVI less than one are fallow, bare, paved, or water. On the vegetated side of NDVI, higher values are forested while lower values are scrubby vegetation or low agriculture. Classifying land cover using NDVI requires an understanding of the index ranges for each category of interest (forest, agriculture, developed, and water). This study obtained the ranges by comparing the NDVI map to a reference aerial image from the same time. Taking the NDVI values of 30 to 50 cells known to be forest and wetlands, agriculture, developed (including bare ground), and water, respectively, creates a starting range of for each. Ranges were refined further to create a picture that matched a reference image from the same date as closely as possible.

Use of NDVI presents two challenges. First, on the high end of the NDVI spectrum, values for certain types of agriculture are the same as for forested land. Second, on the lower end of the NDVI spectrum, values for fallow agricultural fields are similar to those for developed areas such as bare ground and yards. The similarity causes fallow fields to present as subdivisions and green fields to present as forests. Separating the land uses requires more spectral information than is included in the NDVI. While NDVI is the most popular, there are a variety of vegetation indices that employ different spectral bands and combine them in different ratios. These include the Soil Adjusted Vegetation Index, Green Vegetation Index, Enhanced Vegetation Index, Normalized Difference Infrared Index, Bare Soil Index, New Built-Up Index, Normalized Built-Up Area Index, Soil Index, and two unnamed spectral combinations aimed at separating water and wetlands from urban area, among others.

To find the best for separating forest from farmland and bare fields from developed areas, this study employed a simple exploratory approach. Each index was applied to Charles County, Maryland, and examined for a) success in separation between forest and green farmland, and b) success in separation between fallow fields and developed areas. Only three of the indices created more distinct separation than NDVI: New Built-Up Index (NBI), Normalized Built-Up Index (NDBI), and WET (a ratio of bands 5 and 7). All three provided distinction between forest and green farmland, with WET, due to addition of band 7 and orientation toward separating wetlands from urban lands, providing the clearest distinction. NDBI was selected as providing the clearest separation of fallow farmlands.

$$NBI = \frac{(TM3 * TM5)}{TM4} \; ; \; NDBI = \frac{(Band5 - Band4)}{(Band5 + Band4)} \; ; \; WET = \frac{(Band5 * Band7)}{(Band5 + Band7)}$$

The main vegetation index layers included in this analysis are: following table describes the creation of each of the four land use layers used in this analysis.

Land Use/Land Cover Category	**Source Vegetation Index**
Water	WET (water spectral range)
Forest	WET (forest spectral range)
Grassland (Colorado Only)	NDBI (grassland spectral range
Bare Ground/Cleared Cropland	NDBI (fallow spectral range)
Developed Land and Cleared Cropland	NDVI (developed/fallow spectral range)

Additional editing and map algebra was required to clean up layers, confirm accuracy, and minimize seasonal differences between 2000 and 2010 classified images prior to change analysis.

The resulting four data layers: Water, Forest, Developed, and Agriculture were reclassified as follows then added to create a single land use change dataset. Note that water was reclassified to zero to remove it from the analysis.

Land Use/Land Cover Category	**Reclassified Value**
2000 Forest	100,000
2010 Forest	10,000
2000 Agriculture	1,000
2010 Agriculture	100
2000 Development	10
2010 Development	1
2000 Water	0
2010 Water	0

The change matrix yields nine values:

Status of 30m by 30m Cell	**Change Matrix Value**
Water	0
Stays Development	11
Changes from Agriculture to Development	1001
Stays Agriculture	1100
Changes from Development to Forest/Grassland*	10010
Changes from Agriculture to Forest/Grassland	11000
Changes from Forest/Grassland to Development	100001
Changes from Forest/Grassland to Agriculture	100100
Stays Forest/Grassland	110000

* Rare

Results are presented and analyzed in chapters 4, 5, and 6.

Connectivity of Green Infrastructure
Fragmentation is one of the greatest threats to the health and integrity of green infrastructure. As forested areas are fragmented by development they suffer from increasing edge effects, become more vulnerable to disease and invasive species, and are less effective in providing ecosystem services such as wildlife habitat and water

purification. Agricultural areas are similarly vulnerable. The economic success, and therefore perpetuation, of farming in a community is dependent upon agricultural areas retaining a critical mass. There must be enough farming activity to support a local farm economy including available land and agricultural businesses (Daniels and Bowers 1997). Additionally, contact between forestry or agricultural lands and their new neighbors is not always pleasant. Residents may be concerned about the noise or smell associated with farm activities, the cutting of trees in their area, or potential for wild animals - or unknown hikers - in their backyard.

While the needs and services of forestland and farmland differ, both benefit from connectivity. A robust green infrastructure network is interconnected, particularly within individual land use types. This study examines the connectivity through the lens of landscape ecology. Landscape ecology envisions landscapes as series of hubs and linkages. Hubs are contiguous, high quality areas that are largely undeveloped and allow for undisturbed ecological processes. Links connect hubs through corridors of compatible land uses to create a function system of green space. Notably, agricultural lands have largely been rejected as green infrastructure network hubs, due to their incompatibility with many ecological functions and high degree of disturbance (Benedict and McMahon 2006). However, since critical mass is a main objective of farmland protection, and food production an important ecosystem service, the connectivity and contiguity of agricultural areas remains essential.

From an assessment perspective, landscapes are comprised of a series of patches, contiguous areas of the same land use/land cover type. This study includes three patch types, also called classes - developed, forest, and agriculture - that are spread throughout the landscape. Landscape ecologists have created a variety of metrics to measure the spatial arrangement of these landscapes elements. They can be divided, broadly, into two types, composition and configuration. Composition metrics examine the number and diversity of classes and patches. Configuration metrics assess the position and configuration of patches and classes within a landscape (Leitao, Miller et al. 2006).

There is a robust literature surrounding the selection of composition and configuration metrics, but the overwhelming consensus is that metrics must be carefully selected to align with the landscape processes being studied (Li and Wu 2004). For example, core-to-edge ratio is a commonly used landscape metric, but the edge depth used in the calculation must be calibrated to the species under examination. Since this study has no particular focal species, and associated edge depth/core distance metric, core to edge ratio calculations would be meaningless. However, there are several landscape metrics that provide more general composition and connectivity information and are supported broadly by landscape assessment literature (Riiters, O'Neill et al. 1995; Hargis, Bissonette et al. 1998; Li and Wu 2004; Leitao, Miller et al. 2006). The list of selected metrics (shown below) emphasizes measures which are known to be useful for planning applications (Leitao, Miller et al. 2006). As the emphasis of this study is the connectivity of individual land use classes, all metrics of interest are at the class level, which usually involves averaging values for all patches of a certain class:

Area-Edge Metrics
- Mean Radius of Gyration- Measures the mean patch extensiveness for each class

Shape Metrics
- Mean Shape – Measures the mean geometric complexity of patches in each class

Aggregation Metrics
- Clumpiness Index – Determines whether the ‘clumpiness’ of a class is greater than would occur under random conditions
- Mean Euclidian Nearest Neighbor – Average distance between a patch of a certain class and its nearest neighbor of the same class
- Proximity – Measure of patch isolation based upon the size and distance of like patches (defined search radius of 1000m)

Each of these metrics is calculated using FRAGSTATS, a spatial pattern analysis program. The program is oriented toward landscape ecology, but can be used to assess any spatial phenomenon. For input into FRAGSTATS, 2000 and 2010 land use classifications for each county were reformatted into simple three-category rasters (developed, forest, agriculture), with water included with the background class. Each of the six grids was added to the FRAGSTATS program and analyzed on the basis of the five metrics described above.

Results are presented and analyzed in chapters 4, 5, and 6.

Protection/Development of Green Infrastructure
One of the more important aspects of local green infrastructure planning - and land use and environmental planning more broadly - is the balance between land that is preserved and land that is developed. Some communities directly compare preserved acres with converted acres, with the understanding that the two should proceed at a rate that ensures new residents will have equal access to quality open space and natural areas. But the most popular land preservation metrics are, colloquially, ‘bucks and acres,’ or the funds spent on land preservation and the number of acres acquired for that expenditure. These measures do not speak to the quality, size, or, configuration of lands that are preserved or developed (Sawhill and Williamson 2001).

One objective of green infrastructure planning is to protect and retain the high quality resource lands that most effectively support ecosystem services. This study goes beyond expenditures and acres to understand the success of counties in meeting this key green infrastructure planning goal. A previous section described the procedure for identifying lands that were converted from ‘natural’ or 'agriculture' to ‘developed’ over the ten-year study period. In this section, a GIS-based analysis examines the mean ecological value of these converted lands and compares it to that of protected areas in the same county. If developed lands have a low average ecological value, as compared to the value of protected areas, a county has been effective at steering development away from critical ecosystem service areas and toward more marginal lands.

The metric ‘difference in quality between protected and developed land’ is unique to this study. While areas of a state may be similar, and many of the counties used in this analysis are located in the same region (i.e. the along the Front Range, coastal Maryland, inland Florida), no two counties have the same environment. Natural systems are complex and naturally variable. The difference in quality metric accounts for some of that variability by comparing ecological qualities *within* each county, rather than simply between counties. Counties with many sensitive and important ecosystems and low levels of development will have a high overall average ecological value, which inflates the value of both protected and developed lands above that of counties with less diverse and more fragmented landscapes. In such a case, comparing the ecological quality of protected and developed lands in one county to that of another county does not show relative environmental planning success, it reflects the background environmental quality within each jurisdiction. But examining the difference in quality between protected and developed lands within a county and then comparing the magnitude of the difference accounts for much of that variability.

The most effective way to understand the quality of protected or developed land is to evaluate and classify lands according to their relative ecological importance. In doing so, Ian McHarg’s “ecological determinism” (1969) and the Natural Resource Conservation Service’s “Land Evaluation and Site Assessment System” (1983) are useful models (Pease and Coughlin 2001). McHarg used overlays of natural resource attributes to understand the suitability of land for development, from a practical and environmental perspective. This work does the reverse. It uses natural resources information to understand the value of land for ecosystem services. In this, the process more closely resembles the Land Evaluation and Site Assessment System (LESA). LESA uses soil and other natural resource data to score sites on the basis of their agricultural value. Each parameter (e.g. soil potential, size, scenic quality) receives a score and a weight, after which sites are ranked by their relative agricultural importance. This research uses a similar process to rank 30m by 30m cells by their relative ecological importance.

Planning and natural resources departments in Maryland, Colorado, and Florida make available a variety of geographically-referenced natural resource information that can be combined into an ‘ecological value’ GIS layer. In Maryland, such an index already exists. The Maryland Department of Planning created a GIS layer, called ‘green infrastructure ecovalue,’ as part of the state’s 2001 Green Infrastructure Assessment. It is comprised of high-value and sensitive areas such as interior forest, wetlands and stream valleys, in addition to key green infrastructure hubs and links, combined and scaled from 0 to 100. The data is available through the agency’s website and provides information on the relative ecological importance of each 30m by 30m cell in the Maryland grid (See Table 3-4).

While Maryland has an existing ecological value (ecovalue) layer, Florida and Colorado do not. Creating ecovalue layers for Florida and Colorado that are identical to Maryland’s would be difficult, but also undesirable. Each state has different physiographic regions, ecosystems, species, programs, and interests. Consequently, each collects information on – and values – environmental systems differently. In creating ecovalue layers for Florida and Colorado, this study follows, but does not entirely replicate Maryland's strategy. The following section describes the components and procedure of Maryland's ecovalue layer and the process of creating similar datasets for Florida and Colorado.

Table 3-4. Parameters used in fine scale ecological ranking for Maryland (Maryland DNR 2001)

Parameters	Weight	Max Score
Rare Plant and Animal Element Occurrences	4	200
Delmarva Fox Squirrel Habitat	6	60
Proximity to Natural Heritage or other heritage areas	3-5	100
Land Cover	4	40
Proximity to Development	4	40
Distance to Nearest Road, Weighted by Road Type	2-4	40
Highly Erodible Soils	2	20
Proximity to Unmodified Wetlands	4	40
Interior Forest	4	40
Proximity to Streams	2-6	60
Proximity to Stream Nodes	1	10

From Table 8-4. Local ecological parameters and weighting (Maryland DNR 2003)

Maryland DNR combined the scores for each parameter and rescaled the result to 100. They also identified green infrastructure hubs and corridors, ranked them by their ecological integrity and importance for connectivity, and scaled that result to 100. The agency then combined the fine scale and hub/corridor datasets and rescaled to 100 a final time to yield the final Maryland ecovalue layer.

While Florida does not have precisely the same datasets as Maryland, the state has collected a variety of natural resource data through the Florida Natural Areas Inventory (FNAI), a non-profit organization administered by Florida State University (See Table 3-5). Portions of the data were updated regularly since the project began in the mid-2000s, but updates were not comprehensive and their impact on the data's appropriateness for this work is negligible. Additionally, any updates during the time period would serve to make the analysis more conservative, as newly developed areas receive ecological downgrades.

Table 3-5. Parameters used in fine scale ecological ranking for Florida (by Author)

Parameters	Weight	Max Score
Listed Species Locations & Species Richness (Original Data Source: Florida Natural Areas Inventory)	5	200
Underrepresented Natural Areas (ODS: Florida Natural Areas Inventory)	6	60
Aquifer Recharge Areas & Strategic Habitat Conservation Areas (ODS: Florida Natural Areas Inventory)	10	100
Proximity to Development (ODS: National Land Cover Database 2001)	4	40
Distance to Nearest road, Weighted by Road Type (ODS: ESRI Layer)	1	40
Proximity to Wetlands, Weighted by Type (ODS: National Wetland Inventory – based upon 1980s imagery)	4	40
Interior Forest (ODS: National Land Cover Database 2001)	4	40
Proximity to Streams (ODS: Florida Natural Areas Inventory)	2	60
Farmland Quality, Weighted by Type (ODS: NRCS Soil Survey Geographic Database)	4	40

Scores for each parameter were combined and rescaled to 100 to yield a fine scale ecological value dataset. Since there is no consistent green infrastructure hub/corridor or greenway data available for Florida, the ecovalue dataset includes only fine scale data.

Colorado has the least available data of the three counties examined in this analysis. While the same streams, roads, and national land cover database information is available, the national wetlands inventory does not yet cover Adams or Arapahoe counties and there is little natural resources data collected at the state level. Most natural resources data in Colorado is collected at the MPO level, which does not extend to rural areas of the county, or county level, which leads to inconsistencies between jurisdictions. Due to these limitations, the Colorado ecovalue layer depends heavily upon the national land cover database and key state programs identifying wildlife ranges and important natural heritage areas for potential conservation (See Table 3-6). Similar to Florida, the state-level ecological data is recent, rather than historic.

Table 3-6. Parameters used in ecological value ranking for Colorado (by Author)

Parameters	Weight	Max Score
Species Range, Combined for 21 Tracked Species (Original Data Source: Colorado Parks and Wildlife)	10	200
Potential Conservation Areas (ODS: Colorado Natural Heritage Program)	10	100
Proximity to Development (ODS: National Land Cover Database 2001)	4	40
Distance to Nearest road, Weighted by Road Type (ODS: ESRI Layer)	1	40
Proximity to Wetlands, Weighted by Type (ODS: National Land Cover Database 2001)	4	40
Interior Forest (ODS: National Land Cover Database 2001)	4	40
Proximity to Streams (ODS: ESRI Layer)	2	60
Farmland Quality, Weighted by Type (ODS: NRCS Soil Survey Geographic Database)	4	40

Scores for each parameter were combined and rescaled to 100 to yield a fine scale ecological value dataset. Since there is no green infrastructure hub/corridor or greenway data available for Adams or Arapahoe County, the Colorado ecovalue dataset includes only fine scale data.

In the previous section, land use classification and change analysis identified areas within each county that were converted from agriculture or forest to developed land between 2000 and 2010. Zonal statistics, through ArcGIS, enable calculation of the mean ecological value of each patch of development throughout the landscape. To minimize error, and focus on areas with the greatest impact, analysis was limited to newly developed areas greater than 2 acres. Because forestland and agricultural areas have inherently different magnitudes of ecological value, the two land covers were kept separate in the analysis, except in Colorado where the transition between agricultural and natural land is relatively fluid. The same zonal averaging technique was then completed for protected forested and agricultural areas greater than 2 acres within each county. The ecological value analysis of protected areas is intended principally as a point of comparison, so – in most cases - all protected areas with the focal land cover (i.e. forest, agriculture) were included, even those under state or federal ownership. Since state and federal lands tend have more mature ecological communities, and a higher ecological value, they were separated from county protected lands for the sake of comparability when one county in a state had far more or less state and federal land than others.

Results are presented and analyzed in chapters 4, 5, and 6.

Summary
The objective of this study is to identify the relationship between county green infrastructure policies and programs and on-the-ground green infrastructure network change. The major hypothesis is that counties that employ many green infrastructure policies and strategies will be more effective at retaining, protecting, and connecting green infrastructure over time than those that employ fewer. Hypothesis testing involves nine case counties, one identified as 'high-level', one identified as 'moderate-level', and one identified as 'low-level' in each of three states. The study first assesses the level of green infrastructure planning in each county by creating and applying a green infrastructure planning framework. It then compares the level of green infrastructure planning in each county to its level of success in retaining, protecting, and connecting green infrastructure over the 2000 to 2010 study period. The ability of a county to retain green infrastructure is assessed based upon land use/land cover classification of satellite imagery, which yields loss figures for forest and farmland over the study period. Assessment of success in protecting high quality lands is based upon the ecological quality of lands that were developed during the study period as compared to the ecological quality of county protected lands. Finally, the ability of a county to retain green infrastructure connections is assessed through patch metrics, which provide information on changes in the size, shape, and proximity of patches of farmland and forested land over the study period.

The next chapter is the first of three that discuss the results of the methods described above. It outlines the Framework results, on-the-ground green infrastructure outcomes, and relationship between the two for three counties in Maryland: Baltimore County (high-level), Anne Arundel County (moderate-level), and Charles County (low-level).

CHAPTER 4: GREEN INFRASTRUCTURE PLANNING IN ANNE ARUNDEL, BALTIMORE, AND CHARLES COUNTY, MARYLAND

INTRODUCTION

This chapter examines the green infrastructure planning programs and results of three counties in Maryland: Baltimore County (high-level), Anne Arundel County (moderate-level), and Charles County (low-level). The chapter begins with background on the programs and policies that comprise Maryland's green infrastructure planning framework. It then outlines each county's Green Infrastructure Planning Framework score, the plans, regulations, and policies that make up that score, and the results of each green infrastructure planning program. Key areas of assessment are:
1) Quantity: Loss of forested and agricultural land between 2000 and 2010,
2) Quality: Difference in ecological quality between protected and developed land, and
3) Connectivity: Change in connectivity and patch metrics from 2000 and 2010.

The analysis finishes with a comparative examination of the three counties and concludes that counties that employ more green infrastructure policies and strategies *are* more effective at retaining, protecting, and connecting green infrastructure than those that employ fewer policies and strategies. The result is particularly strong for the latter two assessment areas, quality and connectivity.

MAJOR STATE PROGRAMS

State policies and programs create a framework for local green infrastructure planning. In Maryland, there are four main categories of regulations and programs that impact local green space planning: land preservation, environmental protection, growth management, and green infrastructure planning.

Land Preservation

Maryland has been a national leader in land preservation since the 1960s. The state runs three programs that provide funding and support for preservation of forestland, farmland, and natural areas. The first, Maryland Environmental Trust (MET), is a state-wide land trust established in 1967. The quasi-public organization is run jointly by the Maryland Department of Natural Resources and a private Board of Trustees. MET accepts the donation of conservation easements from landowners who in turn receive a 13-year property tax abatement and federal income tax deductions, in addition to possible estate tax reductions. The organization also facilitates landowners' protection of natural, historic, and scenic land resources through partnerships with local land trusts. To date, MET has preserved nearly 130,000 acres (Maryland Department of Natural Resources 2013).

In 1969, Maryland launched a second initiative, Program Open Space (POS). POS has state-level and local components. At the local level, POS provides funds for local governments to acquire land for open space, natural areas, and local parks and playgrounds. Grants are awarded competitively to local governments, with funds from the State Real Estate transfer tax. In order to be eligible for POS funds, counties must have an approved Land Preservation, Parks, and Recreation Plan (LPPRP) (Conservation Fund 2003; Maryland Department of Natural Resources 2012). POS has helped local governments to preserve over 350,000 acres (Maryland Department of Natural Resources 2013).

The Maryland Department of Agriculture runs the state's third major preservation program through the Maryland Agricultural Land Preservation Foundation (MALPF), the nation's first state-level farmland preservation program, founded in 1977. MALPF supports food and fiber production within the state by purchasing easements on farmland. Working with local-level preservation programs and advisory boards, MALPF reviews easement applications and grants them competitively based upon local criteria and recommendations. Under the program, landowners must first establish an Agricultural Preservation District, a temporary agreement that prevents development for a term of five years. Only landowners in an Agriculture District can apply to sell an easement to the State under the MALPF program. (Maryland Department of Agriculture 2012) MALPF has preserved more than 280,000 acres (Maryland Agricultural Land Preservation Foundation 2013).

In the early 1990s, the state also began participating in the U.S. Forest Service's Forest Legacy Program. To participate in the program, a state must analyze the status and ecological merit of its forests and recommend high-value areas for approval by the Forest Service as Forest Legacy Areas. Approved Forest Legacy Areas are eligible for Federal land preservation funds, usually through state grants, but occasionally through direct investment. A modest 2,000 acres of high-value forested lands have been preserved in Maryland's seven approved Forest Legacy Areas, which include one in Anne Arundel County and one in Charles County (U.S. Forest Service 2012).

More recently, in 2002, the Maryland General Assembly passed a Joint Senate Resolution which set the goal of tripling the acreage of prime farmland preserved through state and local programs by 2022. The goal total is 1,030,000 acres. To meet it, the Governor directed state agencies to direct all state preservation investment to resource lands (Maryland Department of Natural Resources 2003).

Environmental Protection
In response to intense development pressure during the 1980s, Maryland adopted three statewide pieces of environmental legislation, the Chesapeake Bay Critical Area Law (1984), the Non-tidal Wetlands Law (1990), and the Forest Conservation Act (1991). They are largely implemented by local governments and continue to impact the quality and extent of green infrastructure throughout the state.

Nearly 94% of Maryland is in the Chesapeake Bay watershed, including all of Baltimore, Anne Arundel, and Charles Counties. In 1984, in partnership with Pennsylvania, Virginia, and Washington, DC, the Maryland Legislature passed the Chesapeake Bay Critical Area Act in hopes of reversing the decline of water quality in the Chesapeake Bay. The Act designated the Chesapeake Bay Critical Area (CBCA) as land within 1,000 feet of tidal waters or wetlands and all southeastern peninsulas. It requires protection of habitat areas, a 100 foot vegetated buffer around aquatic resources, shore erosion protection measures, and forest retention or replacement within the CBCA. The Act is implemented through local governments' zoning ordinances and development regulations with oversight from the Critical Area Commission (CAC) (Maryland Department of Natural Resources 2012). Land in the CBCA is divided among three land use categories, Intensely Developed Areas (IDA), Limited Development Area (LDA), and Resource Conservation Areas (RCA). Densities within IDAs and LDAs are determined by local governments, but development within RCAs is more tightly controlled. The CAC allows only minimal disturbance within RCAs and a density of one dwelling unit per 20 acres. LDAs and RCAs both have impervious surface restrictions and require that any removed forest be replaced. The Act also allows for some local flexibility through inclusion of a growth allocation that enables local governments to change the land use category of a portion of their CBCA from RCA to LCA or LCA to IDA. (Maryland Natural Resources Code 8-18).

Additionally, under the 2000 Chesapeake Bay Agreement, states within the Chesapeake Bay watershed agreed to permanently preserve 20% of resource land within the Bay watershed by 2010. For Maryland, that total - 1,241,605 acres - was easily met. But the goal, when combined with the previously mentioned prime farmland preservation target strongly oriented Maryland's 2000 to 2010 natural resource protection programs toward land preservation (Maryland Department of Natural Resources 2003).

As part of the Chesapeake Bay protection efforts, in 1989 the Maryland Legislature passed the Non-tidal Wetlands Protection Act, which set a goal of no net loss of non-tidal wetland resources. Under the law, any disturbance of non-tidal wetlands requires mitigation. Minor activities, and those disturbing small areas of isolated wetlands with no significant plant or animal communities, are exempt, but all other losses must be replaced. Replacement ratios (required replacement area per square foot of disturbed area) are dependent upon the quality and importance of the wetland community that was disturbed. On-site mitigation is preferred, but off-site or compensation-in-lieu is also allowed where mitigation is not feasible (Maryland Department of the Environment n.d.)

The Forest Conservation Act (1991), the first statewide forest protection legislation of its kind, was intended to minimize the loss of forests to development and to identify and protect priority forest areas. The Act sets standards that local governments must apply when reviewing applications for subdivision, grading, or sediment control permits for areas greater than 40,000 square feet (0.9 acres). The Act requires that developers submit two additional documents as part of development review, a Forest Stand Delineation and Forest Conservation Plan. The Forest Stand Delineation includes information such as existing tree species, location, and size, but also floodplains, critical habitat area, wetlands, and other data that will assist in development review and in determining the most appropriate sites for conservation. The information is used to create a Forest Conservation Plan; a plan for how disturbance to forests and sensitive areas will be minimized during and after development, and how any necessary mitigation will take place. Both documents are considered in the development review and site design process and must be completed by a certified forester or landscape architect (Maryland Natural Resources Code 5-16). Forest Conservation Regulations set retention and restoration priorities that have implications for green infrastructure quality and connectivity. The Regulations emphasize "contiguous forest that connects the largest undeveloped or most vegetated tracts of land within and adjacent to the site" and forest and shrubs in sensitive areas such as 100-year floodplains, riparian areas, and critical habitats (Maryland Natural Resources Code 5-1607).

Growth Management
In 1992, the Maryland legislature approved the State's first major growth management legislation, the Economic Growth, Resource Protection, and Planning Act. The Act identifies seven visions for future development in the state and mandated that local governments revise their comprehensive plans accordingly. Among the seven are #2, "Sensitive areas are protected," #3, "In rural Areas, growth is directed to existing population centers and resource areas are protected, and #4, "Stewardship of the Chesapeake Bay and the land is a universal ethic." Most critical in protecting green infrastructure, the Act identifies the four sensitive area types that must be protected: floodplains, endangered species habitat, streams/stream buffers, and steep slopes (Ingram, Carbonell et al. 2009).

In 1997, the General Assembly enacted the famous Smart Growth program. The program consisted of several bills, including two with significant impacts on the conservation-development balance, the Smart Growth Areas Act and the Rural Legacy Program. The Smart Growth Areas Act – the core of the smart growth program – focuses growth by requiring counties to identify growth areas, called Priority Funding Areas (PFAs), for state infrastructure investments. The objective of the Smart Growth Areas Act is to keep urban and suburban development compact, and minimize the sprawl of development and proliferation on-site septic systems that fragment and degrade resource land and contribute to pollution of the Chesapeake Bay. The Rural Legacy Program has similar aims and is in some ways the other side of the PFA coin. It supports cooperation by providing a framework for identifying key natural resources lands and provides funds for land preservation in those areas. Through the Rural Legacy Program, counties and land trusts identify and propose relatively undeveloped 'Rural Legacy Areas,' which then become eligible for special land preservation funds. An objective of the designated preservation areas is to concentrate preservation efforts and support connectivity through creating large contiguous tracts of protected resource land (Ingram, Carbonell et al. 2009). However, likely due to the geographic restrictions on the use of funds, only around 76,000 of the 866,000 acres designated as Rural Legacy lands have been preserved, making it the least active of Maryland's land preservation programs (Maryland Department of Natural Resources 2013).

Additionally, counties in Maryland must adopt comprehensive plans in order to use subdivision regulations. Maryland's state-level planning agency, the Department of Planning, reviews comprehensive plans on a six-year cycle for inclusion of ten elements, including land use, community facilities, sensitive areas, water resources, and priority preservation areas. While the state cannot force counties to improve plan elements by withholding funds or permits, they may take element strength into account in awarding loans or grants. Notably, the final two elements – water resources and priority preservation areas – took effect 2009 and so had relatively little impact on green infrastructure during the 2000 to 2010 study period (ibid).

Green Infrastructure Planning
In addition to incentives and assistance through the programs described above, counties embarking upon green infrastructure planning in Maryland have a base of information and working knowledge developed through the late-1990s Green Infrastructure Assessment and – now defunct – 2001 GreenPrint program.

The Maryland Department of Natural Resources (M-DNR) began Maryland's Green Infrastructure Assessment in the late 1990s to make conservation more strategic and target areas of high ecological quality for conservation and restoration (Weber, Sloan et al. 2006). Building upon landscape analysis methods pioneered by Ian McHarg in the late-1960s, M-DNR based its GIS analysis on five considerations:

1) A variety of natural resource values,
2) How a given place fits into a larger system,
3) The ecological importance of open space in rural and developed areas,
4) The importance of coordinating local, state, and interstate planning, and
5) The need for a regional or landscape-level view for wildlife conservation (Weber, Sloan et al. 2006)

M-DNR used landscape ecology principles and data on rare/sensitive species, interior forest, wetlands, waterways, existing conservation areas, and basic land use and land cover to identify a network of hubs and corridors critical to supporting ecosystem services in Maryland. The group also included a one-mile buffer of low-intensity land use around the designated network and ranked network components by relative risk of development and ecological importance. With the results of the analysis, M-DNR created a map of major green infrastructure hubs and corridors in all counties of Maryland (ibid).

Shortly after the Green Infrastructure Assessment, Maryland established the GreenPrint program (2001) to protect critical lands that it identified. Through 2006, GreenPrint provided preservation funding using Program Open Space procedures with 25% of funds supporting the MALPF program. During the five years of operation, the program funded protection of around 25,000 acres of important resource lands. Since the initial program ended, GreenPrint has become an information source and decision-making tool that provides parcel-level data on the relative ecological importance of each property in Maryland. The program also tracks the success of conservation efforts in protecting high ecological value lands and watersheds over time (Maryland Greenprint 2012).

MARYLAND COUNTIES: BALTIMORE, ANNE ARUNDEL, AND CHARLES

Case selection methods described in Chapter 3 identify the three Maryland counties that best fit within the period of the study (i.e. have aligning planning dates and horizons) and are most comparable in other ways: Baltimore County, a high-level green infrastructure planning county, Anne Arundel a moderate-level, and Charles, a low-level. The three are coastal counties of roughly the same size that grew in population during the 2000 to 2010 study period. However, due to limitations caused by the small number of counties in Maryland, they have two notable differences, population and growth rate. Baltimore County has the highest population (805,000) and grew by 6.7% during the study period, Anne Arundel has a moderate population (540,000) and grew by 9.8%, and Charles County, with the smallest population (146,000) grew by 21.6%. Accordingly, Charles County's planning capacity is not as high as that of the other two. However, this study examines only the 2000 to 2010 time period and accounts for the impact of growth and baseline capacity wherever possible. Capacity differences are also not as significant for Maryland Counties as they might be in other states. State-level requirements for comprehensive plan content and the strong emphasis on land preservation and environmental regulations mean that even 'small' county planning departments in Maryland have significant knowledge and skill. Funding differences also impact green infrastructure planning and will be outlined in later sections.

The following sections describe the strategies and programs that comprise each county's green infrastructure planning program, outline green infrastructure framework results, and describe land use change between 2000 and 2010.

HIGH GREEN INFRASTRUCTURE PLANNING: BALTIMORE COUNTY

Baltimore County is a leader in green infrastructure planning. The county was responsible for much of Maryland's early green infrastructure mapping under the 2001 Green Infrastructure Assessment and has a separate environmental protection and sustainability department. The county also employs a clear rural-urban distinction, strong rural zoning, and an innovative forest sustainability program.

Demographics, Economy, and Environment

In 2010, Baltimore County, Maryland had a population of 805,000, an increase of 6.7% over the 2000 population of 754,000 (US Census). The county surrounds – but does not contain – the city of Baltimore and includes 600 square miles of land and no incorporated municipalities. Development is strongly concentrated in the southern half of the county, within commuting-distance of Baltimore. Baltimore City public transit - including subway and light rail – extends slightly into Baltimore County in some areas, but coverage is not extensive. The majority of commuters (80%) drive alone, although the average commute time remains a moderate 28 minutes (US Census 2000, 2010). Education and medicine are the largest employment sectors in Baltimore County, with some public administration. The largest single employer is the Social Security Administration, which has its national headquarters in Woodlawn, an unincorporated community near the Baltimore City border. Due to its size and importance, locals often refer to the hub as Security, Maryland.

Economic indicators show Baltimore County to be slightly less prosperous than the state as a whole and impacted by the recent recession. Between 2000 and 2010, median household income fell by a small margin to $63,400, below the state median of $70,000. During the same time period, unemployment more than doubled, from 3.4% to 8.0%, above the state average of 7.5% (Bureau of Labor Statistics 2013). Between 2000 and 2010, housing units increased by 7%, a value in keeping with overall population growth, but 2010 home values remained below the state median ($321,400) at $273,600 (US Census 2000, 2010).

There are no major population centers in the northern half of Baltimore County. It remains largely rural, a mixture of rolling agricultural fields and deciduous forests. Agriculture is an important industry in Baltimore County. According to the 2007 Census of Agriculture, the market value of agricultural products sold in Baltimore County was $68.4 million, less than 4% of Maryland's $1.6 billion (United States Department of Agriculture 2009). The county also known for its natural resources, including 173 miles of coastline along Chesapeake Bay. Baltimore County manages nearly 7,000 acres of park space spread over 200 properties and three sizable reservoirs - Loch Raven, Prettyboy and Liberty, which are managed for drinking water and recreation (Baltimore County 2013).

Green Infrastructure Planning in Baltimore County

In Baltimore County, the Department of Environmental Protection and Sustainability (EPS) has the greatest responsibility for green infrastructure. With a staff of 111, EPS manages agricultural and land preservation programs, Chesapeake Bay Critical Areas, forest conservation programs, and is responsible for review of requests for building permits and subdivision and land development proposals with possible environmental implications. The Department of Planning and Community Conservation, numbering 34 individuals, handles traditional tasks such as comprehensive planning and zoning, but delegates natural resource aspects to EPS. The department in charge of park planning is called the Department of Recreation and Parks, and for good reason. Recreation, rather than natural resources, is the major emphasis of the department.

For the 2000 to 2010 time period, Baltimore County receives a score of 87, indicating that the county employed 62% of the strategies, policies, and programs included in the Green Infrastructure Planning Framework (See Table 4-1). Compared to the other two Maryland Counties, the score indicates a high-level of green infrastructure planning. The main contributors to the score were the high degree to which county plans, ordinances, and regulations valued areas of ecological quality and local importance, included land use planning strategies that protect and retain all scales of green infrastructure, and protected and supported green infrastructure through a collaborative and cooperative process. Also strong were the county's policies and programs that sought to create linkages and foster connectivity and those that managed green infrastructure to support ecosystem services. The county's weakness was in policies oriented toward restoration and mitigation of damage to green infrastructure. The following sections provide an overview of planning in Baltimore County and describe the policies and strategies through which Baltimore County furthered each principle of green infrastructure planning between the years of 2000 and 2010. For a complete Green Infrastructure Planning Framework for Baltimore County, see Appendix 4-A.

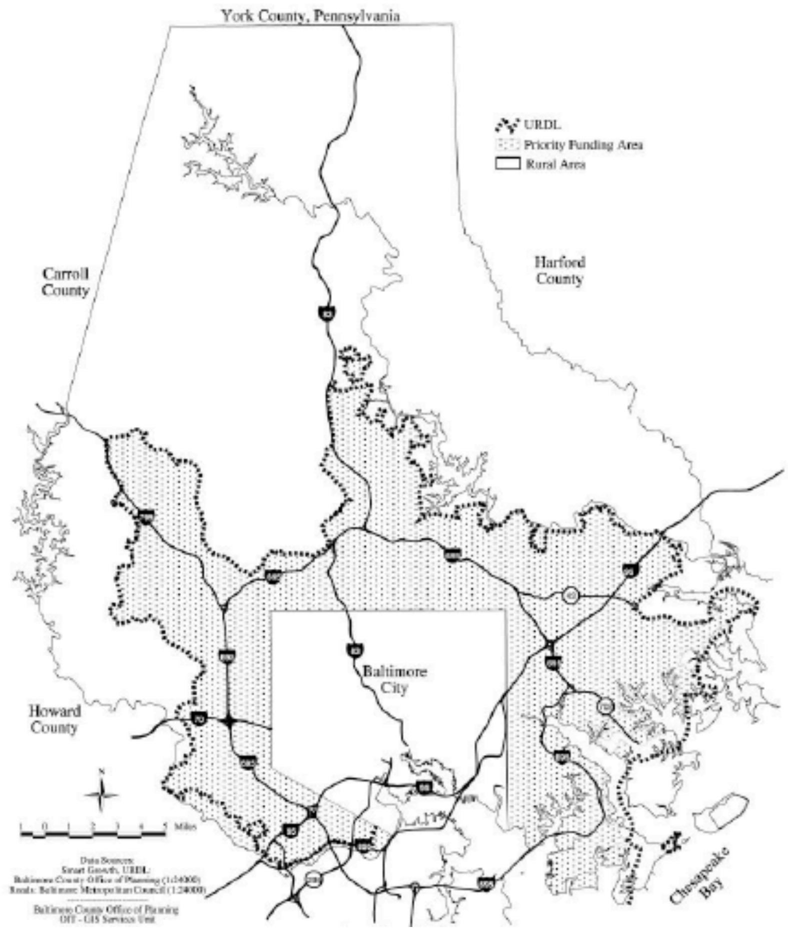
Table 4-1. Baltimore County Green Infrastructure Planning Framework Results Summary

Green Infrastructure Principle	**Framework Score (Out of 20)**
Create linkages and foster connectivity	**13**
Value areas of ecological quality and local importance	**15**
Support a variety of landscapes and ecosystem services	**10**
Restore and mitigate damage to green infrastructure	**7**
Manage green infrastructure to support ecosystem services	**12**
Enact land use planning strategies to protect and retain all scales of GI	**15**
Protect and support GI through a collaborative and cooperative process	**15**
TOTAL (Out of 140)	**87**
PERCENTAGE	**62%**

During the study period of 2000 to 2010, Baltimore County's land management approach was to contain growth within the Rural-Urban Demarcation Line (an urban growth boundary) and protect natural resources and conservation uses in the rural areas beyond. The strength of the urban-rural divide was a defining feature of Baltimore County's land use planning strategy. For example, the county's Master Plan during the study period ("Master Plan 2010") was divided into two halves, 'urban' and 'rural.'

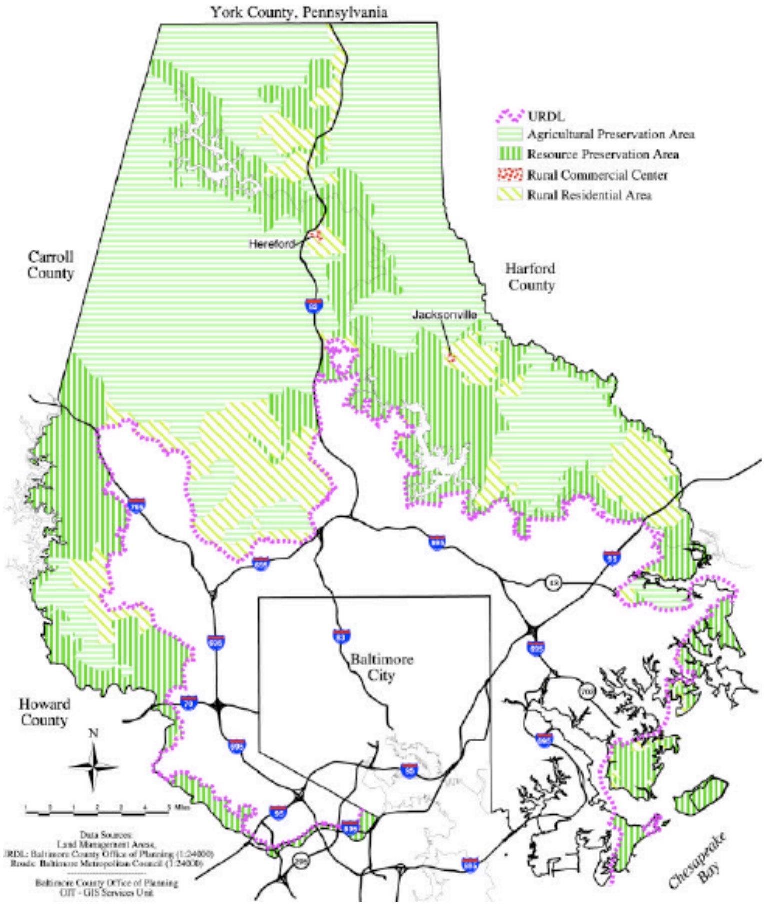
Baltimore County has separated urban and rural land management areas with an Urban-Rural Demarcation Line (URDL) since 1967 (Figure 4-1). The URDL meant that central sewer and water lines would not be extended into the countryside beyond the URDL boundary. This standard has been relaxed only once since 1967, when a sewer line was allowed to extend into the rural area to service a proposed golf course expansion. The growth of Baltimore County, and duration and stability of the URDL, strongly concentrated green infrastructure in the rural portion of the county. In addition, rural land was not served by public sewer or water and had significant development controls with strong conservation and agricultural emphases (Baltimore County 2000).

Figure 4-1. Growth boundary and Priority Funding Area in Baltimore County, MD in 2000 (from Master Plan 2010)



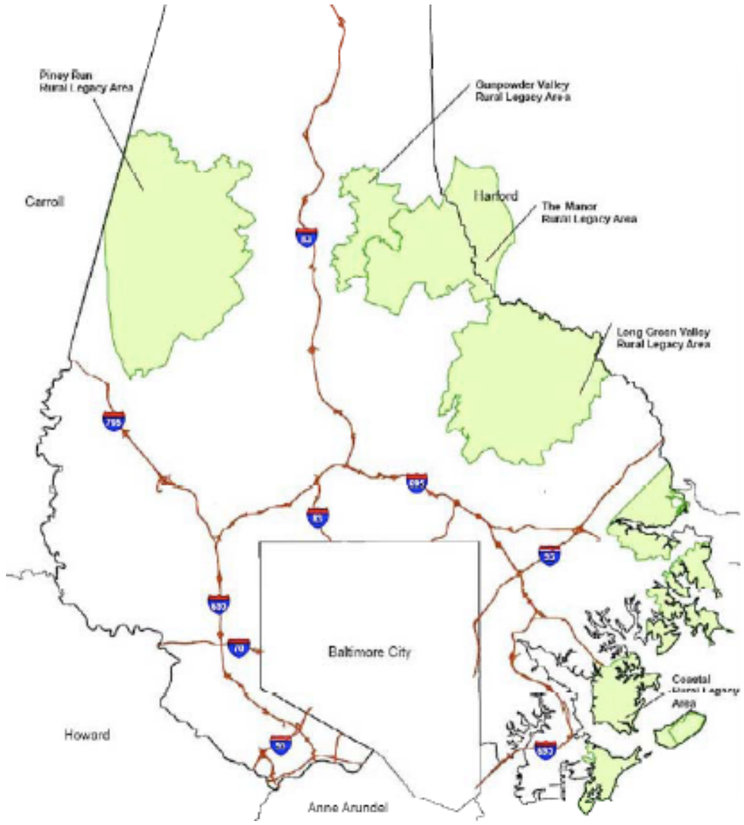
Under Master Plan 2010, which applied from 2000 to 2010, the majority of rural Baltimore County was Agricultural Preservation or Resource Preservation Area (Figure 4-2). Agriculture Preservation Areas were protected for agricultural use by a combination of restrictive zoning of one dwelling unit per 50 acres and regulations that protected prime and productive soils. The county also purchased conservation easements to keep land in Agricultural Preservation Areas in agricultural production and, with Master Plan 2010, set a goal of preserving 80,000 acres. By the end of the study period, Baltimore County had preserved more than 50,000 acres of farmland, making use of a variety of state and non-profit programs, in addition to the county's own Agricultural Land Preservation program.

Figure 4-2. Agricultural and Resource Preservation Areas in Baltimore County, MD in 2000 (from Master Plan 2010)



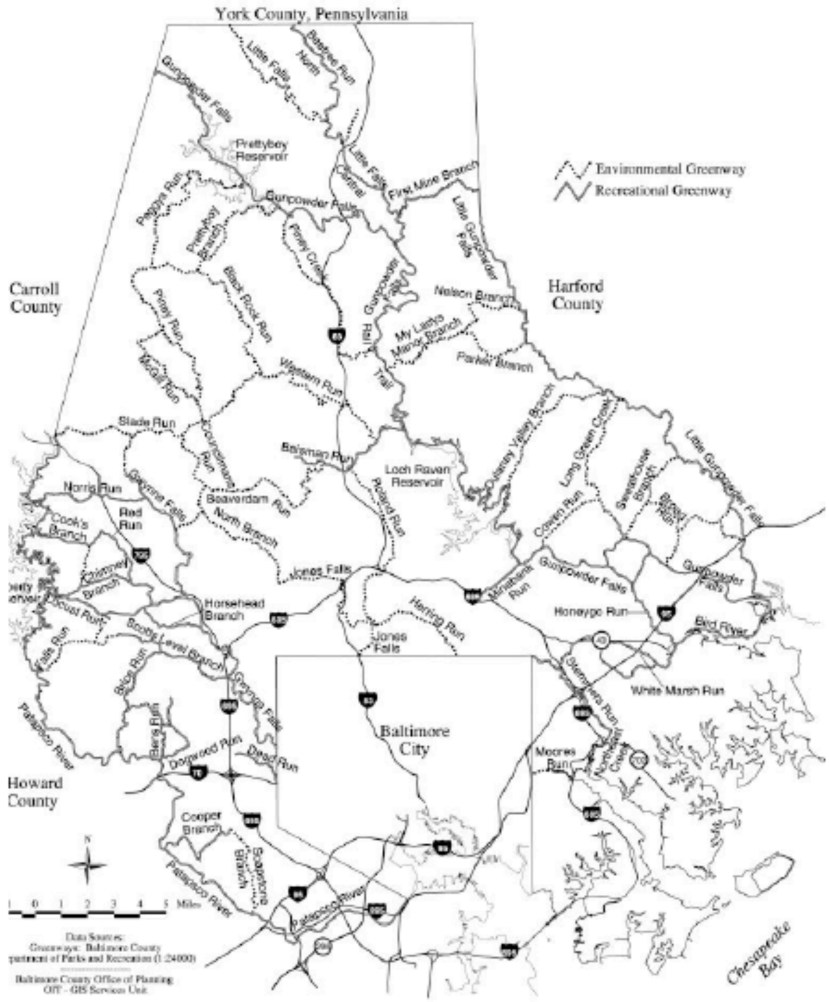
In 2000, Baltimore County had five active Rural Legacy Areas, including the Coastal Rural Legacy Area, which has a natural resource rather than agricultural emphasis (Figure 4-3). There were also at least seven active land trusts in the county (Baltimore County 2005). Resource Preservation Areas were more oriented toward historic, cultural, recreational, and environmental resources, in addition to limited residential development. In 2000, most Resource Preservation Areas were zoned for one dwelling unit per five acres (Baltimore County 2000).

Figure 4-3. Rural Legacy Areas in Baltimore County, MD in 2000 (from Land Preservation, Parks and Recreation Plan 2005)



The 1989 Master Plan identified an Open Space Network of "Stream Valley Greenways" (Figure 4-4). The greenways approximated stream corridors and covered the largest of the 100-year flood plain, wetland buffer, and forest buffer. The comprehensive network ran through both urban and rural portions of the county with "Recreational" Greenways in the urban section and "Environmental" Greenways in the rural. Regulations required that landowners dedicate Recreational or Environmental Greenways at the time surrounding or adjoining land was developed (Baltimore County 2000).

Figure 4-4. Recreational and Environmental Greenways in Baltimore County, MD in 2000 (from Master Plan 2010)



Create linkages and foster connectivity

While Baltimore County played a major role in Maryland's state-level green infrastructure assessment in the late 1990s and early 2000s, planning programs and documents were not heavily influenced by a network concept of green infrastructure planning. Master Plan 2010 included maps of recreational and environmental greenways, and the 2005 Land Preservation, Parks and Recreation Plan noted the importance of limiting forest fragmentation, and mentioned that greenways serve as wildlife corridors, but none of these connectivity-oriented ideas were major themes (Baltimore County 2000; Baltimore County 2005).

Networking of green space was not a central aspect of comprehensive planning documents between 2000 and 2010, but the county did promote the idea through several policies and programs, principally greenway protection, land preservation, and forest protection regulations. Baltimore County greenways followed stream valleys and consequently had a high degree of inherent connectivity. The county protected the greenways through development review, stream buffer protection, and Local Open Space requirements. Baltimore County also conveyed areas within mapped greenways – as Greenway Reservations or conservation easements - through the review and approval process for subdivision and land development proposals. Additionally, Local Open Space requirements included provisions that dedicated community open space should connect to greenways or through greenways to larger recreation areas wherever possible (ibid).

Land preservation practices in Baltimore County between 2000 and 2010 also fostered connectivity and contiguity. In general, there are two ways to foster connectivity through county preservation programs, 1) prioritizing properties in close proximity to existing protected or government-owned resource lands, or 2) preserving lands in predetermined and pre-delineated high quality or important areas. During the study period, Baltimore County employed both strategies. In selecting lands for preservation as part of the local program or through state mechanisms, the Department of Environmental Protection and Sustainability prioritized properties in close proximity to existing agricultural easements, greenways, and other conservation land. But the county also concentrated preservation by taking advantage of the state's Rural Legacy Program. For many years, Maryland state preservation policies, such as MALPF's bid system, resulted in scattered preservation. The Rural Legacy Program was one statewide way to correct the issue. The lack of connectivity was less severe in Baltimore County due to the aforementioned local prioritization of contiguity, but the Rural Legacy Program did play supportive role. Notably, a second reason the local connectivity strategy is probably the more important in Baltimore County is that Rural Legacy dollars are spread over five sizable Rural Legacy Areas.

Forest Protection Regulations also emphasized the importance of the connectivity of forested lands and included management plan and protection requirements that promoted connection to adjacent forested areas.

Value areas of ecological quality and local importance

Baltimore County's planning documents from the study period clearly identified several ecologically valuable features, including green infrastructure hubs. The county also mapped forestland, stream corridors, historic resources, and scenic views in comprehensive planning documents of the time (Baltimore County 2000; Baltimore County 2005).

Between 2000 and 2010, the county ensured the value and ecological significance of green infrastructure through forest conservation regulations, sensitive area regulations, zoning and agricultural districts, and land preservation requirements. As required under the Forest Conservation Act, Forest Conservation regulations mandated that forested developments retain a certain percentage of tree cover and that non-forested developments plant trees. Regulations also required Forest Conservation Easements that protect forested portions over the long term and prohibited the cutting of trees without permission from EPS. Forest quality was a major concern of EPS; the department prepared annual reports to the County Council that evaluated the implementation of Forest Conservation Regulations and described the acres of forest involved in development projects, the percentage of forest retained, and the mitigation required. Additionally, the development review and site planning process identified significant plant and animal habitat and protected in the development review and site planning process through stream regulations and priority forest retention areas (ibid).

Also, in keeping with Maryland state law, the county provided substantial protection for the Chesapeake Bay Critical area, imposing restrictions on impervious surface, forestation, and stormwater. As required by the state, the county reviewed land development proposals for compliance with the Chesapeake and Atlantic Coastal Bays Programs. County code required that subdivision or development proposals meet setback, impervious surface, and forest/tree clearing restrictions, include a vegetated buffer, and protect habitat areas. A unique use of the program, one of Baltimore County's Rural Legacy Areas, the Coastal Rural Legacy Area, is along the shoreline of the Chesapeake bay and focused upon protecting sensitive coastal environments by securing wetlands and large blocks of forest.

Stream buffer requirements in effect during the study period were comprehensive and went beyond state requirements to use restrictive covenants to protect vegetated buffers of up to 150 feet. Stream buffer regulations applied to all land development projects. The width of the buffer (25' to 150') depended upon stream use and order and relationship with any adjoining wetlands or floodplain reservations.

Land preservation procedures also protected important green infrastructure. To qualify for most land preservation programs, farms and woodlands had to meet size and soil quality specifications. For example, MALPF funds required a property to be 50 contiguous acres in size or adjacent to a preserved property, to contain at least 50% high quality soils or woodland, and to be outside ten-year water and sewer service expansion areas (Maryland Department of Agriculture 2011). The county also used Resource Conservation zoning and Agricultural Districts with subdivision restrictions to protect high quality and locally important farming and forest areas, Right-to-Farm laws for high value agricultural areas, and marketing campaigns for local farm products and services.

Support a variety of landscapes and ecosystem services

Between 2000 and 2010, the majority of green infrastructure efforts in Baltimore County are oriented toward forest sustainability and farmland preservation. While the county did not specifically identify underrepresented landscapes or prioritize them in preservation (e.g. through gap analysis), comprehensive planning documents from the time identify several key ecosystem services and riparian corridors and wetlands enjoy strong protection through stream buffer and tidal and non-tidal wetland regulations, respectively. The county also balanced recreation funding with conservation and restoration funding in the 2004 – 2010 Capital Improvements Programs and identified a system of scenic roads and views. Viewsheds were also a component of prioritizing land for preservation.

Restore and mitigate damage to green infrastructure
Baltimore County carried out green infrastructure restoration and mitigation mostly where required under state and national wetland legislation, state Forest Conservation rules, and the Chesapeake Bay Agreement. But the county did invest in voluntary reforestation initiatives for private landowners. The Rural Residential Stewardship Initiative (2005) encouraged residents of 'large-lot' subdivisions (3+ acres) to reforest parts of their property adjacent to existing forest or stream buffers. Staff met with subdivision homeowners to discuss forest types, outline necessary maintenance, and, upon agreement, provide free reforestation (Outen 2010).

The county also allocated capital funds for waterway restoration. Between 2004 and 2010, Baltimore County spent $68.5 million on watershed restoration efforts in 11 watersheds, an average of $8.5 million per year. Actions included stream restoration, reforestation, stormwater management, wetland restoration, shoreline enhancement, and other activities in support of water quality and waterway improvement (Baltimore County Annual Budget 2004 – 2010).

Manage green infrastructure to support ecosystem services
While the county had significant oversight of environmentally sensitive areas, particularly within the Chesapeake Bay Critical Area, its management focus was forests. As required by the State Forest Conservation Act, subdivision or development activities on greater than one acre of land had to have a forest stand delineation, forest easement, and forest conservation plan addressing how forested areas – protected by forest conservation easements – shall be managed over time. But the county also put significant resources into broader forest assessments, in an attempt to understand the stands' type, quality, and management needs. In 2000, the county completed a Forest Resource Management Plan to identify and prioritize core forest reserves and corridors. The information helped staff to make decisions that best supported the quality of the county's forest infrastructure. The county also helped to develop Maryland's Green Infrastructure methodology and subsequently served as a national pilot for the Linking Communities to the Montreal Process Criteria and Indicators project which led to a county-wide Forest Sustainability Program. The county's forest sustainability program included forest assessment and monitoring projects, urban tree planting and rural reforestation projects and a variety of reports and analysis such as the 2005 Forest Sustainability Strategy, forest sustainability forums, and the State of Our Forests 2007 report.

The county also encouraged farmers and individuals to be good environmental stewards. County regulations required that farms meeting size thresholds have Nutrient Management Plans and those participating in the land preservation program have a conservation plan that incorporated best management practices (Baltimore County 2005). Several programs also involved residents in stream restoration and reforestation activities (Outen 2010).

In 2000, Baltimore County also published a Landscape Manual (part of county Land Development Regulations) that outlined landscaping guidelines and standards for re-vegetation, residential buffers, historic structures, open space, and scenic routes and views. The manual identified local species and encourages landowners and developers to select them (Baltimore County 2000).

Enact land use planning strategies to protect and retain all scales of GI
At the county scale, Baltimore County's major planning strategies were the URDL, land management areas, and restrictive rural zoning. Over time, these actions strongly concentrated green infrastructure in the rural portion of the county. The Maryland Department of Agriculture describes the URDL as 'virtually fixed' and the majority of Rural Baltimore County is Agricultural Preservation Area or Resource Preservation Area (Maryland Department of Agriculture and MALPF 2007,12). During the study period, Agriculture Preservation Areas were protected for agricultural use by a combination of restrictive zoning and regulations that protect prime and productive soils. Resource Preservation Areas focused upon historic, cultural, recreational, and environmental resources. Most large-lot development occurred in Resource Preservation areas; in 2000, most were zoned for one dwelling unit per five acres (Baltimore County 2000). The 2000 Master Plan suggested downzoning to 1 to 25 (or 50) to enhance protection, which was completed in 2004 when 91% of the area outside the URDL was rezoned. The change strengthened zoning in Preservation Areas and reduced the number of major subdivisions (those with more than 3 lots) (Baltimore County 2005).

Zoning is Baltimore County's main tool for directing and controlling development in the rural part of the county. By 2004, the majority of the rural county was zoned for 2 dwelling units per 100 acres (or 1 dwelling unit per 50) with an additional 1 to 25 environmental zone (Maryland Department of Agriculture and MALPF 2007). Key zones in the rural area included Agricultural Protection (RC2) zones that protect agriculture with one lot allowed per 50 acres, Watershed Protection (RC4) zones that protect the three regional reservoirs by allowing only clustered development and agriculture at a density of one house per 5 acres, Rural Residential (RC5) zones that provide land for low-density residential development, RC6 areas that allow low-density residential, but require that a primary conservancy (sensitive natural features) and secondary conservancy (at least 50% of the total remaining area) be preserved in perpetuity, and Resource Preservation (RC7) zones that were also added in 2000 to protect cultural, historical, recreational, and environmental resources with restrictions against subdividing tracts less than 50 acres. As of 2004, the Resource Conservation zone with the greatest area was Agricultural Protection (36% of the county), with Rural Residential (10%) and Resource Preservation (8%) a distant second and third. The county also includes two Chesapeake Bay Critical Area zones, Critical Area (RC20) which covers the CBCA with an allowed density of 1 to 20 and Critical Area Agriculture (RC50) with an allowed density of 1 to 50.

At the project scale, subdivision and land development regulations provided much of the open space and recreation area in the urban section of Baltimore County. Small, undeveloped areas deeded to homeowners associations or land developers provided space for recreation, stormwater management, and other ecosystem services with no public maintenance requirements. In 2000, Baltimore County adopted a Local Open Space Manual that addressed the quality and – to a lesser extent - connectivity of local dedicated open spaces and provides requirements for greenways. The manual required developers to dedicate any stream corridor or floodplain land that was designated as greenway in the 1989 Master Plan at the time they propose a property for subdivision or development (Baltimore County 2000; Baltimore County 2000).

Protect and support GI through a collaborative and cooperative process
The Departments of Planning, Recreation & Parks, and Environmental Planning and Sustainability (EPS) collaborated on comprehensive planning documents. The county also had a separate Department of Permits, Approvals, and Inspections that managed the development plan review process with input from Planning, Recreation & Parks, Public Works, and EPS.

Baltimore County increased its collaboration with other counties over the study period. The Manor Rural Legacy Area crosses the boundary between Baltimore County and neighbor to the east Harford County. Baltimore County worked with Harford to manage the area along with the land trust that administered the Area. Baltimore County also coordinated with York County, PA to a lesser extent (Interview, Lippincott 2011). Main non-profit collaborators included the four non-profit organizations administering Rural Legacy Areas – The Gunpowder Valley Conservancy, The Valleys Planning Council, The Manor Conservancy, and The Long Green Valley Conservancy (the fifth is administered directly by Baltimore County) and Blue Water Baltimore, which organized local watershed councils and planning activities (Baltimore County 2005; Lippincott 2011, personal comm.).

Baltimore County also frequently worked with the State of Maryland to identify and manage green infrastructure. In addition to state-administered land preservation programs such as MET, MALPF, and POS, the county assisted the state in the original Green Infrastructure Assessment. To a lesser extent, the county also participated in the USDA Farm and Ranch Lands Protection Program, a national easement program.

Funding for Green Infrastructure
Baltimore County's Capital Improvements Programs (CIP) included three sections related to green infrastructure: Parks, Preservation & Greenways, Land Preservation, and Waterway Improvements. Between FY 2004 and FY 2010, Baltimore County spent an average of $10.4 million per year on acquisition of land and rights of way in the three categories (Table 4-2). Over the seven years, the County spent an annual average of $32 million on all types of green infrastructure protection and management.

Table 4-2. Funding for Green Infrastructure in Baltimore County, Maryland (Capital Improvements Program 2004-2010)

Baltimore County, MD	Seven -Yr Average	Seven-Yr Average (Percent of CIP)
Selected Parks, Preservation, and Greenways (Non-structural)	5,454,718	1.4
Land Preservation	6,244,644	1.6
Funds for Land and Right-of-way	10,473,962	2.5
Waterway Improvement (w/o dredging)	9,777,577	2.7
TOTAL GI	**31,950,902**	**8.2**
County GI Funds (Bonds and General)	5,023,401	1.5
Outside GI Funds	26,927,500	6.6
GI Funds from County (%)	**17**	

The Parks, Preservation and Greenways section included acquisition of open space, greenways, and park and recreation land in addition to development of trails and – in the case of one project – conversion of a property from an apartment complex to a park (CIP 2010). From FY 2004 to FY 2010, Baltimore County spent an average of $5.4 million per year on such projects, around 1.4% of the CIP annually.

The Land Preservation section included Agricultural Preservation and Rural Legacy expenditures. Agricultural Preservation included farmland and forestland preservation under all development right acquisition programs, including MALPF and Baltimore County's Agricultural Land Preservation Program. Rural Legacy was oriented toward protecting a variety of rural natural resources under the Maryland Rural Legacy Program. From FY 2004 to FY 2010, Baltimore County spent an average of $6.2 million on the two programs, around 1.6% of the CIP annually. Funds for projects in the two categories came from the state Rural Legacy and MALPF programs, in addition to County Open Space Bonds.

Waterway Improvements such as stream and wetland restoration, reforestation, stream bank stabilization, and buffer management also protected sensitive and productive environmental land. Baltimore County allotted restoration funds by watershed rather than individual project. Between FY 2004 and FY 2010 Baltimore County funded 11 watershed restoration programs in addition to general watershed and environmental management projects for an average of $9.8 million per year, around 2.7% of the CIP annually.

In 2008, Baltimore County passed a bond referendum for 255 million, 4% of which related to green infrastructure. Residents also passed parks, preservation, and greenways bonds in 2000 ($10M), 2002 ($5.5M), and 2004 ($4.8M) (Baltimore County 2005). While bonds funded a significant amount of green infrastructure preservation, restoration, and management, only 25% of funding for Parks, Preservation and Greenways, Land Preservation, and Waterway Improvement came from county general funds and bonds. The majority came from outside sources, mostly state and federal programs.

Greenways and trails development were funded by general obligation bonds, general funds, and outside funding such as Program Open Space the Maryland Department of Natural Resources. These programs, along with Local Open Space Waiver Fees, also funded parks and open space acquisition.

Land preservation programs were funded by general obligation bonds, general funds, funds from federal and state programs, and the Maryland agricultural transfer tax. The county also offered a 100% county property tax credit for land in agricultural districts. The credit did not apply to land under easement (Maryland Department of Agriculture and MALPF 2007).

Green Infrastructure Network Change in Baltimore County

Quantity

Based upon land cover classification of Global Land Survey images from 2001 and 2009, Baltimore County lost 9 percent of its unpreserved agricultural base and 3 percent of unprotected forested areas to development (Table 4-3). Developed area in the county increased by 8%.

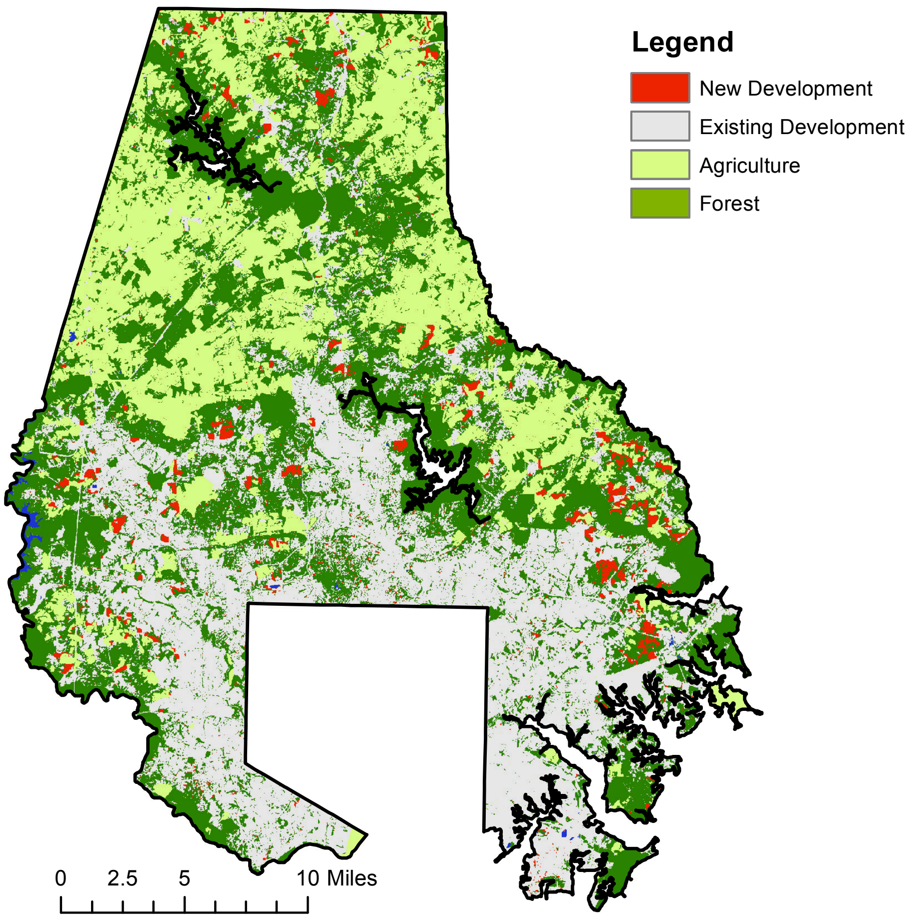
Table 4-3. Land Use Change in Baltimore County, 2001 to 2009 (by author).

Baltimore County Land Use Change

	2001 (acres)	2009 (acres)	Change (%)
Water	2,682	2,682	**0**
Agriculture	76,432	69,930	**-9**
Forest	96,666	93,744	**-3**
Developed Area	122,797	132,220	**8**

The majority of new development occurred in close proximity to the URDL, with a second concentration in the far north of the county (Figure 4-5). Areas in the middle of the county, where Rural Legacy and the majority of preservation areas are located, remained largely untouched by large developments.

Figure 4-5. Forestland, farmland, and developed area in Baltimore County in 2009. 'New Development' is development that occurred since 2001 (by author.)



By permanently preventing land conversion and supporting agricultural operations, land preservation has a substantial impact on land use change. In 2000, Baltimore County already had a substantial conservation network, nearly 28,000 acres, protected mostly in partnership with MALPF and MET. Between 2000 and 2010, the county worked with state partners to preserve an additional 22,300 acres (Table 4-4). The MALPF and Rural Legacy programs resulted in the greatest gain in easement coverage with 6,511 and 6,265 acres, respectively.

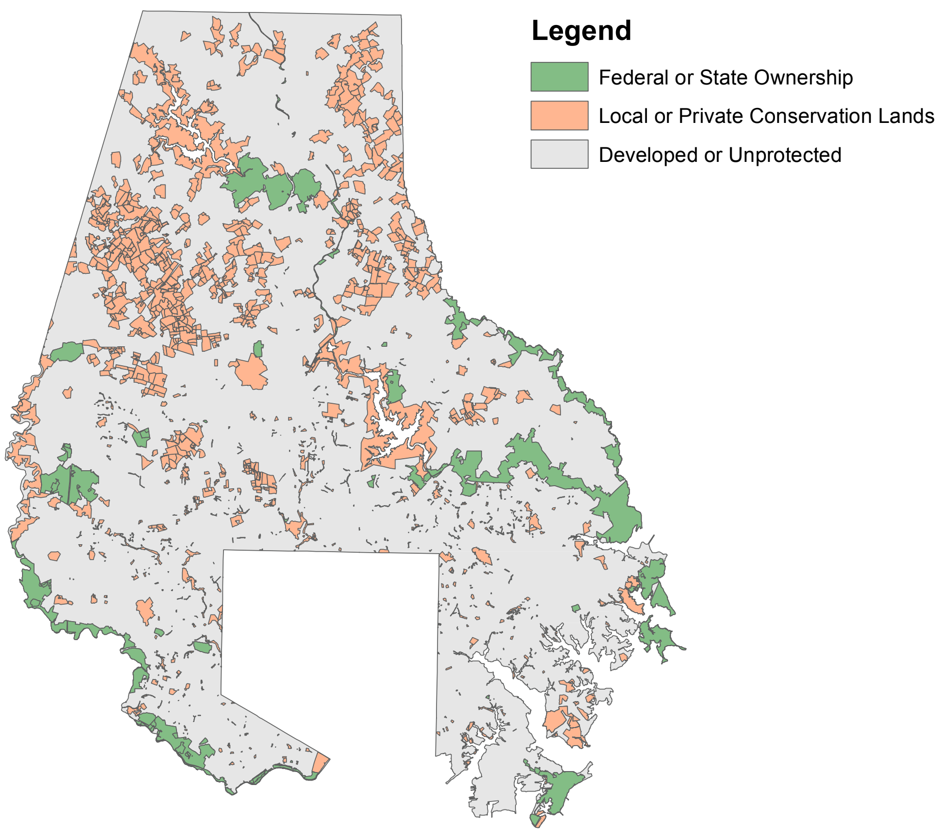
Table 4-4. Land Preservation in Baltimore County, Maryland.

	2000	2010	Added
County	1,058	4,600	3,542
MALPF	15,640	22,151	6,511
Rural Legacy	407	6,672	6,265
MET	10,496	16,479	5,983
TOTAL	27,601	49,902 *	**22,301**

*With land preserved by private land trusts, Baltimore County estimates the 2010 total to be greater than 55,200 acres.
Source: 2012 Baltimore County Master Plan, MALPF and MET Annual Reports

Protected lands in Baltimore County are well distributed (Figure 4-6). Local and private conservation lands form large clusters of protected farmland and buffer natural resources, usually waterways. State and Federal lands also protect water resources and are most often oriented along shorelines and riparian areas. Blocks of state land are larger than most local conservation areas, but the two are highly connected and oriented to provide synergistic protection of waterways.

Figure 4-6. Federal, state, local, and privately-owned protected areas in Baltimore County, Maryland in 2010 (by Author).

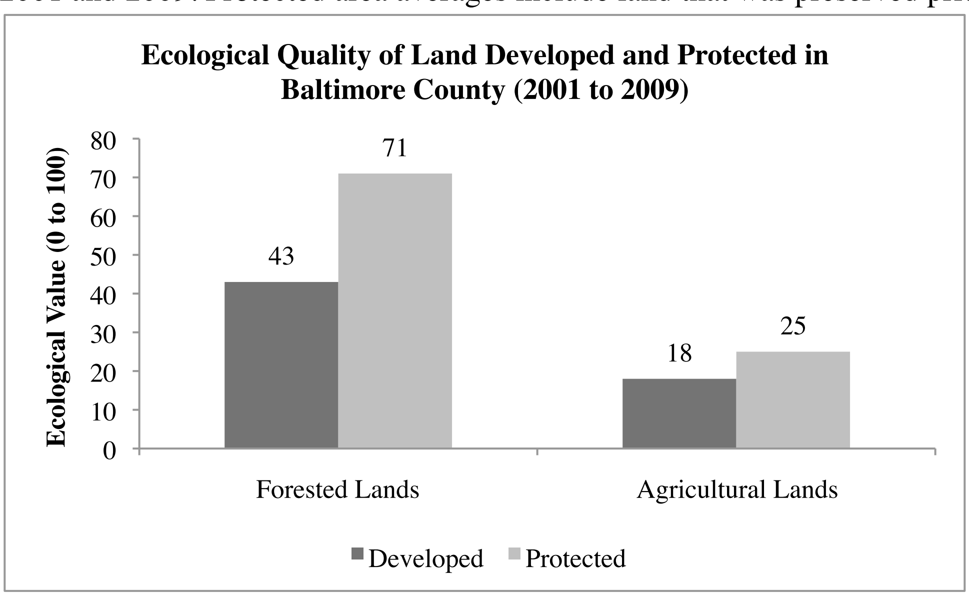


Quality
In 2001, as part of the State's Green Infrastructure Assessment, the Maryland Department of Planning created a GIS layer containing the relative ecological value of land throughout the state. The layer combines information on sensitive and important resources such as wetlands, critical habitat, interior forest, streams, and proximity to development and roadways to form a single layer that indicates the ecological importance of land in Maryland on a scale of 0 (no ecological value) to 100 (extremely high ecological value). As a point of comparison, the average ecological value for Baltimore County as a whole, in 2001, was 30.

An important objective of green infrastructure planning is to protect sensitive and high quality resources by a) preserving them or b) directing development to other areas. A county's success in these areas can be measured by the ecological value of protected and developed lands. Developed areas should have a relatively low ecological quality while protected land should have a high ecological value.

Forested lands provide a greater variety of ecosystem services than agricultural land and are generally accepted to have a higher ecological value. So it is important to examine the quality of forested and agricultural lands separately. In 2009, the area-weighted mean ecological value of local, state, and federally protected forested lands in Baltimore County was 71. The mean ecological value of land developed between 2001 and 2009 was significantly lower, at 43. (Figure 4-7). The trend is similar for agricultural land but is not as strong.

Figure 4-7. Mean ecological quality of land developed in Baltimore County between 2001 and 2009. Protected area averages include land that was preserved prior to 2001.



Connectivity
A second objective of green infrastructure planning is to retain lands that form a network of large, interconnected, green space. A county's success in this area is indicated by stability in the connectivity and patch attributes of green infrastructure over time. Increasing connectivity is not usually feasible, but local governments can retain existing connections by preserving critical linkages and planning development in a way that does not fragment the network.

Landscape ecology metrics provide information on the spatial configuration of landscapes. A patch is an area of continuous landscape, such as farmland or forested area. Metrics noted here discuss the average patch shape for each type of green infrastructure, as well as connectivity and proximity.

During the study period, Baltimore County's green infrastructure network was relatively stable. Forest patches became slightly smaller and more distant, but changes in all other measures of patch shape and connectivity were negligible (Table 4-5). Results for farmland are similar, but with an added change in patch shape. Farmland patches became slightly longer and less contiguous, which is most likely due to an increasing irregularity in patch shape as land was developed or as linear or irregularly-shaped planted portions of developed areas grew in.

Table 4-5. Patch Shape and Contiguity Metrics for Baltimore County Forest and Agricultural land in 2001 and 2009 (by author).

	Forested Land			Agricultural Land		
	2001	**2009**	**Change Notes**	**2001**	**2009**	**Change Notes**
Area-weighted Mean Patch Length/Contiguity (GYRATE_AM)	5818m	5831m	Minimal change	4269m	4394m	(Slight) Increase in patch length
Patch Shape Complexity (SHAPE_AM)	22	23	Minimal change	15	16	Minimal change
Patch Aggregation (CLUMPY)	0.83	0.83	Minimal change	0.92	0.92	Minimal change
Area-weighted Mean Distance to Nearest Like Patch (ENN_AM)	63m	63m	Minimal change	102m	110m	Minimal change
Area-weighted Mean Patch Size and Proximity Metric (PROX_AM)	6057	5954	Patches become (slightly) smaller and more distant	3026	1195	Patches become smaller and more distant

Overall
Between 2000 and 2010, the Baltimore County Department of Environmental Protection and Sustainability and Department of Planning conducted a high-level of green infrastructure planning. The county's activities covered 62 percent of the policies and

strategies included in the Green Infrastructure Planning Framework. The county's strong urban-rural divide supported by a fixed urban growth boundary and strict agricultural and resource protection zoning contributed to the high score. The county was also dedicated to forest sustainability and land preservation and had strong regulations that protected a system of recreational and environmental greenways including stream valleys and contiguous natural resource areas. Baltimore County also allocated capital funds for management and restoration and involved local landowners in programs that support green infrastructure quality.

During the study period, Baltimore County preserved nearly 22,000 acres of forestland, farmland, and natural area under the County's Agricultural Land Preservation Program, MALPF, Rural Legacy, and the Maryland Environmental Trust. Between 2004 and 2010, only 30% of county investment in land preservation came from general funds; the remaining was contributed by state and federal programs. The county also had five Rural Legacy areas, seven active land trusts, and a variety of partners.

While the county lost 9 percent of its unprotected farmland between 2001 and 2009, compact development and green infrastructure planning and protection efforts have been successful in retaining a high quality, interconnected, green infrastructure network. During the study decade, the county successfully guided development to existing developed areas and areas of low ecological quality. Forest and farmland that was developed during the decade is of much lower quality than forest and farmland that was protected. Additionally, between 2000 and 2010, green infrastructure patch shape and connectivity remained stable, with little decline in the proximity or contiguity of forested patches and only slightly more for agricultural patches.

MODERATE GREEN INFRASTRUCTURE PLANNING: ANNE ARUNDEL COUNTY

Anne Arundel County's green infrastructure planning strengths are strategic greenway planning and sustained land preservation funding (Maryland Department of Agriculture and Maryland Agricultural Land Preservation Foundation 2007). In 2002, the County delineated 71,700 acres of greenways, including hubs and corridors of high ecological quality and identified strategies for protecting them (Anne Arundel County 2002). Between 2000 and 2010, the county's broader strategy was to concentrate development in growth areas – away from agricultural and natural resource areas – and to use zoning and special districts to protect rural and environmentally sensitive areas. The county employed a local planning strategy where each of 16 small areas creates a Small Area Plan (SAP) for its community. SAPs combine to form the county's land use plan.

Demographics, Economy, and Environment

In 2010, Anne Arundel County, Maryland had a population of 538,000, an increase of 9.8% over the 2000 population of 490,000. The county contains 415 square miles of land, surrounding but not including two incorporated municipalities, Annapolis and Highland Beach. Annapolis, the state capital and a major job center, had a 2010 population of 38,400. Highland Beach, a Chesapeake Bay resort town, had only a nominal population –

96 according to the 2010 Census – but historic importance. It was incorporated in 1922 as a retreat for affluent African-Americans from DC and the first African-American municipality in Maryland. Anne Arundel County is part of the Baltimore-Washington Metropolitan Area, and located immediately south of Baltimore County. Population is loosely concentrated in the northern half of the county near the City of Baltimore and Baltimore-Washington International Airport (BWI). Annapolis is the southernmost major population and employment center, located on an eastern peninsula. While not incorporated, and thus under county jurisdiction, Glen Burnie (67,800), Odenton (37,000), Severna Park (37,600), and Crofton (27,000) are major population centers, all north of Annapolis.

Development is concentrated in the northern half of Anne Arundel county, within commuting-distance of Baltimore, Annapolis, and other northern job centers. Baltimore City light rail and commuter train service extends into northern Anne Arundel County, and bus service connects to Annapolis, but coverage is not extensive. Rail serves only the northeastern corner of the county, providing access between BWI, Baltimore, and Washington, DC. The majority of commuters (80%) drive alone (US Census 2000, 2010), although the average commute time remains a moderate 29 minutes (ibid). The largest single employer is Fort Meade, a US Army installation near BWI Airport. With 56,000 employees, it is also the largest employer in Maryland (US Army 2012). Education and medical facilities are also important employers, as are Northrop Grumman Corporation, a global security company, the State of Maryland (in Annapolis), and BWI Airport.

Economic indicators show Anne Arundel County to be slightly more prosperous than the state of Maryland as a whole. Between 2000 and 2010, median household income increased by 5% to $83,400, well above the state median of $70,000. During the same time period, unemployment doubled, from 2.4% to 6.8%, but remained below the 2010 state average of 7.5% (Bureau of Labor Statistics 2013). Despite the economic challenges of the time, between 2000 and 2010, the housing market remained strong. Housing units increased by 18%, and 2010 housing values remained above the state average ($321,400) at $360,500 (US Census 2000, 2010).

There are few major population centers in the southern half of Anne Arundel County, or on the eastern peninsulas, with the exception of Annapolis. The areas remain largely rural, a combination of agricultural and forested lands. Agriculture is locally important, but not a major industry. The county has less than half the farmland acreage of Baltimore County and produces a third of the revenue. According to the Census of Agriculture, the market value of Anne Arundel County agricultural products sold in 2007 was $19 million, about 1% of Maryland's $1.6 billion (United States Department of Agriculture 2009).

Anne Arundel is well-known for its natural resources, particularly its extensive and picturesque coastline. Over 500 miles of tidal shoreline, and 54 miles of scenic Chesapeake Bay frontage, support maritime industries and sports. Including Annapolis parklands, Anne Arundel County also has around 8,000 acres of park and recreation land, including 3,000 acres with waterfront access. The length and sinuosity of the shoreline also means that Anne Arundel County has more wetlands and estuaries than most counties (Anne Arundel County 2013).

Green Infrastructure Planning in Anne Arundel County

The Anne Arundel County Office of Planning and Zoning (OPZ), with a staff of 76, is responsible for the majority of the county's green infrastructure planning. The greenways program, for example, is housed in OPZ's Long Range Planning Division. But the Department of Recreation and Parks (DRP), which has three planners on staff, also plays a role. DRP manages the Anne Arundel Agricultural and Woodland Preservation Program and the local side of larger programs such as MALPF and Rural Legacy. DRP also coordinates with OPZ on the Land Preservation, Parks, and Recreation Plan. The Department of Public Works also participates, with the Watershed Ecosystem and Restoration Services Division that provides education and monitoring, and coordinates watershed management and restoration efforts. In the abovementioned departments, Anne Arundel County has approximately 65 staff members with planning-oriented job descriptions (2010 CIP), for 1.1 planners per 10,000 population.

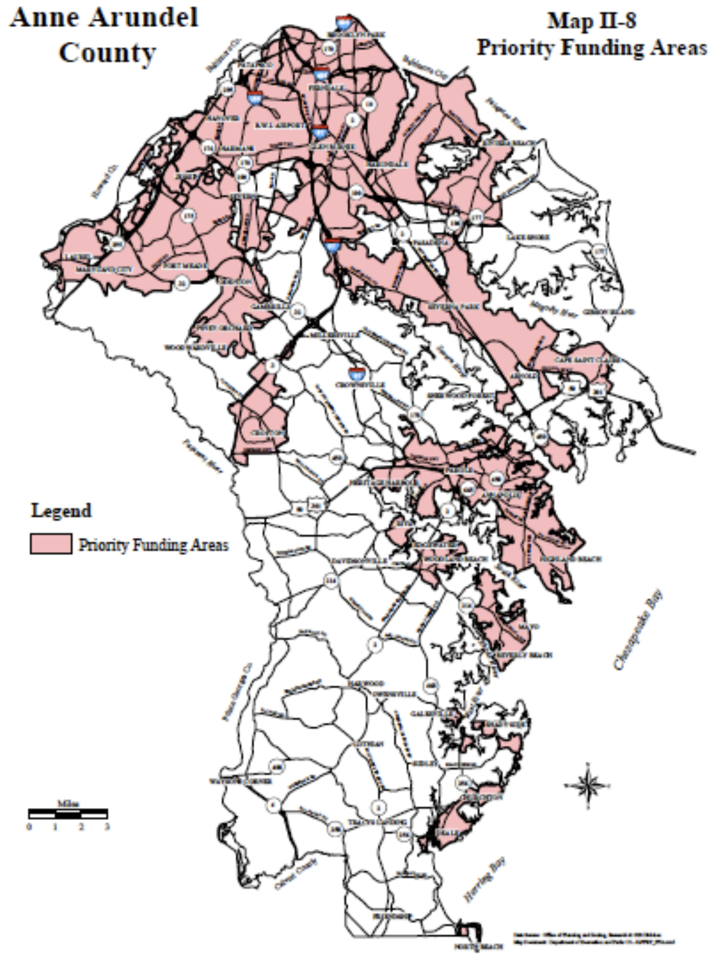
For the 2000 to 2010 time period, Anne Arundel County receives a score of 71, indicating that the county employed 51% of the strategies, policies, and programs included in the Green Infrastructure Planning Framework (Table 4-6). The score reveals a moderate-level of green infrastructure planning. The main contributors to the score were the high degree to which the county creates linkages and fosters connectivity and enacts land use planning strategies that protect and retain all scales of green infrastructure. The county's weaknesses were in its support for a variety of landscapes and ecosystem services, and programs that manage, restore, and mitigate damage to green infrastructure. The following sections provide an overview of planning in Anne Arundel County and describe the policies and strategies through which Anne Arundel County furthers each principle of green infrastructure planning. For a complete Green Infrastructure Planning Framework for Anne Arundel County, see Appendix 4-A.

Table 4-6. Anne Arundel County Green Infrastructure Planning Framework Results Summary

Green Infrastructure Principle	Framework Score (Out of 20)
Create linkages and foster connectivity	**15**
Value areas of ecological quality and local importance	**11**
Support a variety of landscapes and ecosystem services	**7**
Restore and mitigate damage to green infrastructure	**6**
Manage green infrastructure to support ecosystem services	**8**
Enact land use planning strategies to protect and retain all scales of GI	**13**
Protect and support GI through a collaborative and cooperative process	**12**
TOTAL (Out of 140)	72
PERCENTAGE	**51%**

During the study period, Anne Arundel's land management approach was to conserve rural areas and open space by directing at least 90% of development to designated growth areas – also Priority Funding Areas - with existing or planned infrastructure (Figure 4-8). The county's General Development Plans (GDPs) through the 1990s attempted to concentrate development in mixed use and town center areas and reduce rural densities. However, the 1997 GDP, the central comprehensive planning document during the study period, was general, intended to create a framework for sector-based planning under the county's Small Area Plan program.

Figure 4-8. Priority Funding Areas in Anne Arundel County, MD in 2005 (from LPPRP 2006)



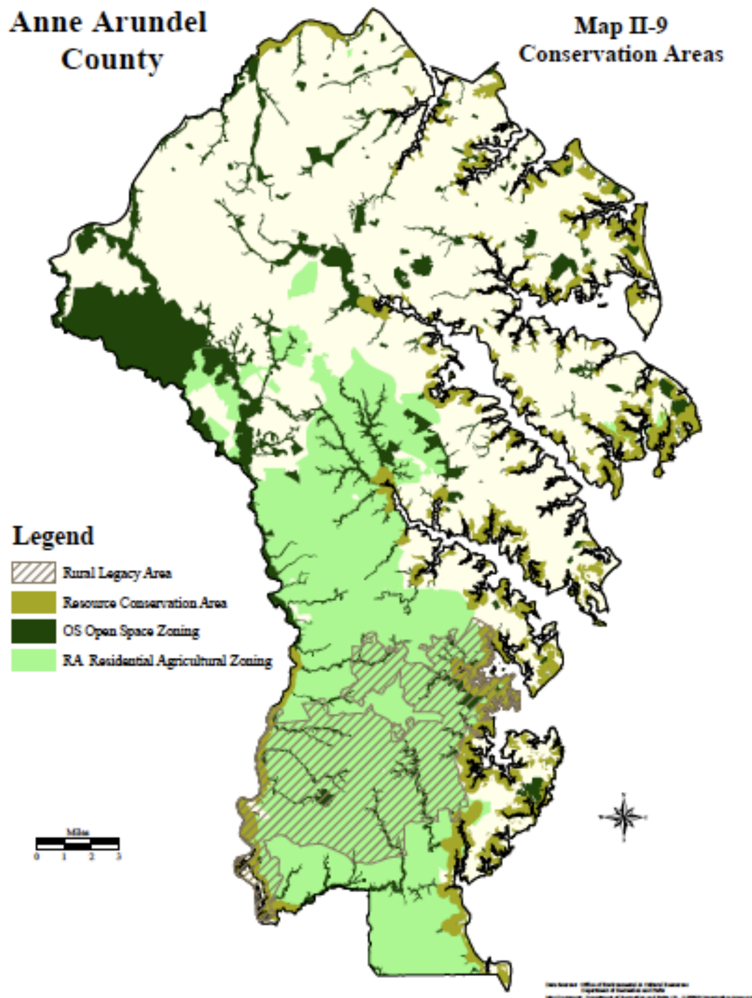
In 1998, the county began a comprehensive planning strategy based upon Small Area Plans (SAPs). The SAP process was designed to enhance quality of life and promote cooperation in the planning and development process (Anne Arundel County 1997, 7). Between 1998 and 2004, the county identified 16 small planning areas and assisted the communities in creating SAPs. Each SAP addressed land use, zoning, circulation, community design, and the environment and provided a land use plan and zoning map. OPZ combined the SAPs to create a countywide land use map with more detail and local clarity than the generalized 1997 GDP land use map. The strengths and emphases of SAPs varied by area. For example, much of the county's valuable agricultural land is located in one planning area, South County, so the South County SAP (2001) was more oriented toward protecting rural character and productive farming than more northern SAPs (ibid).

Anne Arundel County's main rural classifications were Rural and Natural Features, which comprised a significant portion of the county, particularly in the northeast and along the western border (with Prince George's County). Rural land was generally flat and agricultural while Natural Features followed stream corridors and existing protected areas such as floodplains, parks, and environmental preservation areas. Rural areas were intended to retain rural character and support farming and forestry, but allow residential development in clusters or villages (Anne Arundel County 2006, IV-4).

During the study period, Anne Arundel County had three designated conservation areas for land preservation comprising nearly 50% of the county: Rural Land Use Areas, open space zoning districts, and the Resource Conservation Area of the Chesapeake Bay Critical Area (Figure 4-9). Anne Arundel County had fewer acres of farmland than most counties in Maryland (it is 23rd out of 24 counties) - and much of that farmland was fragmented - but agriculture and forestry played significant roles in the county's long term planning. The county's land preservation goal during the study period was 20,000 acres by 2010 (Anne Arundel County 2006).

In 1990, the county created the Agricultural and Woodland Preservation Program, a local land preservation program. The county also worked with the State of Maryland to preserve land through the Maryland Agricultural Land Preservation Foundation (MALPF), and Rural Legacy Program. The county has participated in the MALPF program since 1980 and Rural Legacy Program since 1998 when it designated the Anne Arundel South Rural Legacy Area. South Rural Legacy Area covers 32,400 acres of productive farmland and scenic views in the South County planning area. The county also has a large Forest Legacy Area to the west of Annapolis, although permanent preservation in the Area as been minimal.

Figure 4-9. Conservation Areas in Anne Arundel County, MD in 2005 (from LPPRP 2006)



Anne Arundel County mapped an extensive system of greenways in its award winning *2002 Greenways Master Plan* (Figure 4-10). The Plan increased the resolution of the Anne Arundel County portion of the state-level Green Infrastructure assessment, based upon existing protected hubs of green space and five ecological and recreational values. The greenways were conceptual rather than official, and served as part of the county's broader land use framework (Anne Arundel County 2006).

Figure 4-10. Greenways in Anne Arundel County, MD in 2002 (from Anne Arundel Greenways Master Plan 2002)

Create linkages and foster connectivity
Networks, hubs and links, and green infrastructure connectivity were key principles in Anne Arundel County's comprehensive planning documents. The county promoted green infrastructure connectivity over time though the development review process, land preservation program requirements, and the Greenways Program. In reviewing subdivision and land development proposals during the study period, Anne Arundel County staff requested that dedicated open space and recreation space connect to that of adjacent parks, protected areas, and existing developments. Additionally, prioritization policies through the county's Agricultural and Woodland Preservation Program gave

more weight to properties that were in close proximity to other preserved, protected, and government-owned lands. The county also has a single Rural Legacy area, which further targeted preservation funds and encouraged clustering of preserved area within the boundary.

The program with the greatest potential for enhancing green infrastructure connectivity in Anne Arundel County during the study period was the Greenways Program, which proposed a system of ecologically significant hubs and connecting corridors. Program criteria included a provision requiring that hubs and corridors connect to the broader greenway network. Consequently, in delineating greenways, corridors that did not lead to hubs – and thus did not functionally increase connectivity - were excluded from the network. In assessing land for greenways, the County also identified approximately 100 priority 'critical connections' where important greenway segments or existing conservation land could connect in only one place. However, there was no inherent regulatory protection for greenway lands, so the maintenance of those connections depended upon land preservation actions alone. Corridors and connections were identified in 2002, but few were preserved. By 2010, the connections between conservation areas were lagging behind land conservation itself. The county's assessments of the program noted that the trend was characteristic of a general lack of implementation of the Greenways Master Plan (Anne Arundel County 2006; Anne Arundel County 2010).

Value areas of ecological quality and local importance
In comprehensive planning documents of the time, Anne Arundel County clearly identified and mapped key green infrastructure anchors and several ecological assets. The county protected land of high ecological quality through the Agriculture and Woodland Preservation and MALPF program, Agricultural Preservation Districts, habitat assessments, and Greenways mapping and protection. The Agricultural and Woodland Preservation Program had requirements similar to MALPF and considered the quality and size of farm and forestland parcels in preservation decisions, ensuring that only large, high quality lands were preserved. In 1999, the Program added an Installment Purchase Agreement to enhance the speed at which the county could purchase easements, but interest in the strategy faded (Anne Arundel County 2006). Also like MALPF, the Agricultural and Woodland Preservation Program encouraged landowners of high quality farm and forest areas of more than 50 and 10 acres, respectively, to form Agricultural Preservation Districts, which prevent development for five years and make landowners eligible for MALPF and County land preservation funding. The size requirements helped to ensure that the farmland or forested areas were large enough to remain ecologically and/or economically viable. The county also adopted a Right-to-Farm ordinance in 2004 to help protect forest and agricultural lands (Anne Arundel County 2006) and participated in *So. Maryland, So Good*, a Southern Maryland Agriculture Development Commission campaign to assist consumers in finding local products and farms (Maryland Department of Agriculture and Maryland Agricultural Land Preservation Foundation 2007).

Anne Arundel County also protected high quality and sensitive environmental areas through development review. Regulations applied at the time a development proposal is submitted for review included Chesapeake Bay Critical Area overlays, Bog Protection overlays, Forest Conservation regulations, and stream buffer requirements. The County also protected the habitat of threatened and endangered species in sensitive or significant development areas through habitat assessments. Developers submitting a subdivision plan in a County designated Critical Area or under the Forest Conservation rules were required to have a habitat assessment. But developments outside the Critical Area that were not subject to Forest Conservation regulations were not required to conduct an assessment, a notable weakness of the strategy (Anne Arundel County 2006).

The most significant action that Anne Arundel took to ensure the ecological quality and value of their green infrastructure over the study period was mapping significant hubs and corridors and combining them into a mapped greenway network and program. Anne Arundel County's Greenways Master Plan is one of the most faithful continuations of Maryland's statewide green infrastructure initiative. The county used an ecological approach to identifying greenways, including five main criteria: 1) habitat value, 2) size, 3) connections to other land with ecological value, 4) future potential for greenways, and 5) proximity to countywide and national trails (Anne Arundel County 2002) However, the Greenways Master Plan identifies but did not specifically protect greenways, it was merely a tool to guide land preservation, site design, and subdivision and land development review. Additionally, the county was not proactive in implementing the Plan, so action – particularly with connective corridors – lagged behind planning (Anne Arundel County 2010)

Support a variety of landscapes and ecosystem services
Anne Arundel County's green infrastructure planning emphasis between 2000 and 2010 varied by Small Area Plan and was largely oriented toward farmland. But several farmland-oriented areas did include multiple goals. For example, the county managed the South Rural Legacy Area to support a variety of landscapes and services, including farmland, historic and scenic roads, and other natural resources (Anne Arundel County 2006, IV-8). County comprehensive planning documents also identified a variety of landscapes and ecosystem services, and valued lands that supported several services through greenway planning efforts (Anne Arundel County 2002). OPZ also has a division devoted to cultural resources. The Cultural Resources Division (CRD) worked to protect historic sites and landscapes. CRD's website notes that, "Anne Arundel County is progressive in that it recognizes historic structures, roads and landscapes, and archaeological sites as resources that require protection, just like natural resources, such as farmland, wetlands, bogs, and shorelines" (Anne Arundel County 2012, 1). CRD provided education and outreach, and conducted research and assessments to ensure that cultural resources were adequately considered in planning and development decisions (ibid). However, the county provided little consideration for viewsheds or scenic roads, and did not quite balance recreation funding with conservation funding. Recreation received more support.

Restore and mitigate damage to green infrastructure
Between 2000 and 2010, Anne Arundel County carried out green infrastructure restoration and mitigation mostly where required under state and national wetland legislation, state Forest Conservation rules, and the Chesapeake Bay Agreement. Between 2004 and 2010, Anne Arundel county spent an average of $1.8 million per year (less than 1% of the annual CIP) on green infrastructure-oriented waterway and water quality improvement projects such as stream bank renovation and bog rehabilitation projects (reforestation) using funds from offset fees paid by developers. County CIPs indicate that county and state funds contributed to 16 such projects in seven years. The county also conducted reforestation projects funded by forest impact fees. One notable marsh grass re-vegetation program during the study period assisted organizations and individuals in assessing their properties for restoration and provided plants through Department of Recreation and Parks nurseries (Anne Arundel County 2006).

Manage green infrastructure to support ecosystem services
While the requirements were statewide, Anne Arundel County provided its greatest oversight in management of green infrastructure within Chesapeake Bay Critical Areas (i.e. tidal waterways and tributaries) and within land with recorded Forest Conservation Easements. Developments in both areas were required to have a vegetation (buffer) management plan. The plans describe how cutting of trees will occur and the procedure for reforestation or afforestation. Additionally, as required by the state for subdivision plans greater than 40,000 square feet, developers were required to submit a forest conservation plan including priority retention areas and protection/reforestation/afforestation plans.

Enact land use planning strategies to protect and retain all scales of GI
At the county-scale, zoning was a major tool for regulating development in Anne Arundel County. Since the county is historically suburban, much of it has been planned for rural and low-density residential development (one-half to five-acre lots) (Anne Arundel County 2009). As of the 1997 General Development Plan, 80% of the county was zoned residential, with the vast majority of that (83%) low density (i.e. fewer than two dwelling units per acre). The county did employ a number of zoning districts and overlays to help maintain agriculture and forestry in rural areas and to protect sensitive environmental resources during the study period, including Rural Agricultural (RA) zoning, Open Space districts, Bog Protection Areas, and the Resource Conservation Area (RCA) portion of the CBCA (Anne Arundel County 2006). But the persistence of low-density residential zoning in rural areas promoted the development and fragmentation of resource areas and undermined the protectiveness of restrictive zoning districts.

Between 2000 and 2010, the distinction between urban and rural in Anne Arundel County was moderate. Through 2005, most areas designated in the GDP or SAPs as ‘rural’ were zoned Rural Agricultural (RA) or Rural Low Density (RLD) (Anne Arundel County 2006). The RA zoning classification covered 30% of the county including forestlands, streams, floodplains, and much of the County’s prime farmland. In 2005, the county adopted more restrictive zoning for the district, allowing only major subdivision at a density of 1 dwelling unit per 20 acres (Anne Arundel County 2006, IV-13). But other rural areas, including RLD, retained weaker zoning and allowed development at a density of 1 dwelling unit per 3 to 5 acres.

Anne Arundel also used Open Space Districts and overlay zones to support green infrastructure. During the study period, about 14% of the county was zoned Open Space, a designation which supported farm and resource uses, but did not allow new residential development. Open Space districts included open space and natural areas such as wetlands, parkland, floodplains, and riparian areas. Overlay Zones covered bogs and Chesapeake Bay Critical Areas with special development restrictions. Bog Overlay Zones are unique to Anne Arundel County and protect sensitive wetland environments. In addition, a Critical Area Overlay covered the 18% of Anne Arundel County within the Chesapeake Bay Critical Area. Development proposals for land within the Critical Area were assigned to a dedicated 'critical area' review team (Anne Arundel County 2012). As required by the state, Anne Arundel County divided the CBCA into three protective categories – Resource Conservation Area, Limited Development Area, and Intensely Developed Area – each with a different degree of development restriction. The most restrictive zoning was 1 dwelling unit to 20 acres (RCA) and most permissive was marked for growth (IDA). Critical Area Overlay areas were also subject to impervious surface and forest conservation requirements (Anne Arundel County 2006).

At the project-level, development review was a major part of green infrastructure protection in Anne Arundel County. Subdivision and site design plans were subject to interagency review as part of the approval process. Designs were examined for their impact on natural features and relation to such features on adjacent properties. Anne Arundel County's Subdivision Regulations required that 30% of residential subdivisions be set aside as permanent open space, for both recreation and environmental attributes. Through development review and site planning, the county designed open space to maximize natural resource protection and, to the greatest extent possible, adjacency with other dedicated open space, parks, or conservation land. The review process also considered greenway impacts. County staff worked with developers to find environmentally sensitive site designs that minimized greenway impacts through clustering of development and preserving greenways within subdivision open space and recreation areas (Anne Arundel County 2006, V-18). Regulations also applied to floodplains and other natural features including non-tidal wetlands, streams, and stream buffers. Under most circumstances, regulations required developers of residential subdivisions to convey land within the 100-year floodplain to the County and prevented development within 25 feet of riparian areas or 100 feet of streams.

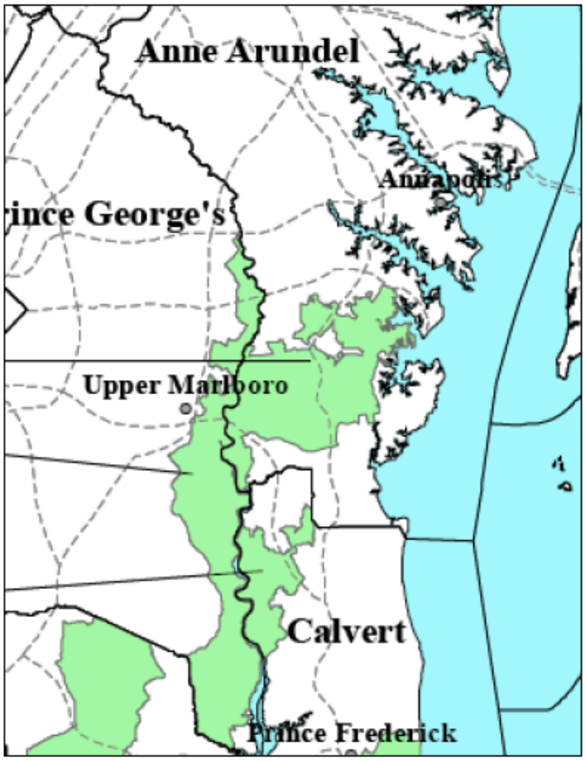
As required by the State of Maryland, the County's Forest Conservation Regulations (1991) mandated that subdivision plans greater than 40,000 square feet include a forest stand delineation and forest conservation plan detailing priority retention areas, protection/reforestation/afforestation plans, and a forest conservation easement. But where the regulations did not expressly apply, county staff were limited to encouraging developers to establish forest conservation easements (Anne Arundel County 2006).

Protect and support GI through a collaborative and cooperative process
The Small Area Planning process facilitated a significant amount of collaboration and community input in local land use planning, including green infrastructure planning (Anne Arundel County 2006). The strategy resulted in green space planning oriented toward local needs. But the degree to which SAPs coordinated with each other to plan for adjacent natural resources, downstream impacts, and cross-boundary green infrastructure remains unclear. Most of the collaborative planning occurred within planning areas, not between them. Anne Arundel County also involved local residents in marsh grass re-vegetation through cooperation with the Department of Recreation and Parks.

In addition to the state-level Maryland Environmental Trust, there were five local land trusts active in Anne Arundel County during the study period, including the only municipality-run land trust in the country, the Annapolis Conservancy Board. The local land trusts coordinated through the Coalition of Anne Arundel County Land Trusts and received financial assistance from the county's Conservation Trust Fund. The Maryland Historical Trust, which holds easements that preserve historically or architecturally important areas, was also active in the County. Anne Arundel County also worked with the Southern Maryland Agriculture Development Commission to promote Southern Maryland agricultural products (Maryland Department of Agriculture and Maryland Agricultural Land Preservation Foundation 2007) and coordinated with other counties in Maryland to jointly apply for and receive funds from the USDA Farm and Ranch Lands Protection Program, a national easement program (Anne Arundel County 2006).

Anne Arundel has only one Rural Legacy Area, and it was administered by the county alone rather than by a sponsoring non-profit organization. Coordination with Rural Legacy Areas in other counties is inconsistent. The South Rural Legacy Area corresponds with to the North Calvert Rural Legacy Area, an adjoining Rural Legacy Area across the border in Calvert County, but a sizable Rural Legacy Area on Prince George's County stops abruptly at the Anne Arundel County border, rather than continuing across the waterway (Figure 4-11) (Anne Arundel County 2006).

Figure 4-11. Rural Legacy Area south and east of Anne Arundel County, MD in 2002. Rural Legacy Areas shown in green (from LPPRP 2006).



Funding for Green Infrastructure
Anne Arundel County's 2004 to 2010 Capital Improvement Programs (CIP) included three main sections related to green infrastructure: Recreation & Parks, Land Preservation, and Waterway & Water Quality Improvement. The County spent an average of $7.2 million per year on green infrastructure acquisition, restoration, and management between FY 2004 and FY 2010, for around 2.4% of the annual CIP (Table 4-7). During that time, $3.8 million per year went to land acquisition in the three categories.

Table 4-7. Funding for Green Infrastructure in Anne Arundel County, Maryland (Capital Improvements Program 2004-2010)

Anne Arundel County, MD	**Seven -Yr Average**	**Seven-Yr Average (Percent of CIP)**
Selected Parks, Preservation, and Greenways (Non-structural)	4,362,000	1.3
Land Preservation	1,054,286	0.4
Reforestation	17,857	0.0
Funds for Land and Right-of-way	3,792,071	1.1
Waterway/Water Quality Improvement (w/o dredging)	1,799,000	0.7
TOTAL GI	**11,025,214**	**3.5**
County GI Funds (Bonds and General)	2,815,357	1.1
Outside GI Funds	8,209,857	2.4
GI Funds from County (%)	**40**	

Between 2004 and 2010, the Recreation & Parks category of the CIP included a variety of green infrastructure-related items, including 13 projects protecting land with significant forest, critical greenway or trail linkages, large open space and recreation areas, and waterway buffers and river/beach access. Between FY 2004 and FY 2010, the County spent an average of $4.3 million on these projects, around 1.3% of the annual CIP.

Land Preservation was also an important CIP component. Using a variety of funding sources, Anne Arundel County spent an average of $1 million per year between 2004 and 2010, around 0.4% of the CIP annually. The average is brought down by the dearth of funds for land preservation in 2005 and 2010. The totals included funds to assist land trusts in acquiring easements. The CIP also included nearly $18,000 per year in funds for reforestation within and outside of the Chesapeake Bay Critical Area, funded by tree protection fees paid by developers.

Finally, Waterway and Water Quality Improvement also had a significant role in the CIP, with 16 stream bank renovation, channel restoration, fish passages, and bog rehabilitation projects (dredging-related projects discounted) between FY 2004 and FY 2010. Over the seven years, the County spent an average of $1.8 million per year on the projects, around 0.7% of the annual CIP.

Land preservation and other green infrastructure projects during the study period were funded by a variety of means, including state programs, county bonds and general funds, and state agricultural transfer tax proceeds. Rural Legacy and Program Open Space funds were particularly important, as MALPF participation declined. In 2000, the County began using Installment Purchase Agreement Bonds, rather than general funds, to finance the Agricultural and Woodland Program. The change allowed the County to pay for easements in installments so that funds were more readily available and easement acquisition could proceed faster (Anne Arundel County 2006). Between 2004 and 2010, 64% of funds for Recreation & Parks, Land Preservation, and Waterway/Water Quality Improvement came from county bonds and general funds, with the rest provided by state and federal programs.

Reforestation programs were funded by fees collected through Chesapeake Bay Critical Area regulations and the Forest, Woodland, and Tree Protection Ordinance while stream restoration was funded partially through state grants, with some supplemental county investment.

The county also provided a 10-year real estate tax credit to landowners who participated in county or MALPF district or easement programs. Landowners were eligible to receive a 100 percent credit on land and up to $250,000 on structures (Maryland Department of Agriculture and Maryland Agricultural Land Preservation Foundation 2007). In 2005, the investment (in foregone revenue) was $433,000 (Anne Arundel County 2006, IV-12).

Green Infrastructure Network Change in Anne Arundel County

Quantity

Land classification of aerial images taken in 2001 and 2009 show that Anne Arundel lost 22% of its unprotected farmland (by acreage) to development over the study period (Table 4-8). The high number is confirmed by values from a National Agricultural Statistics Service study that found an overall change of 20% between 1997 and 2007 (National Agricultural Statistics Service 2008). Additionally, Anne Arundel had only 18,000 acres of unpreserved farmland in 2001, so every converted acre contributed strongly to the loss total. Over the same period, 3 percent of unpreserved forested land was converted to non-resource uses.

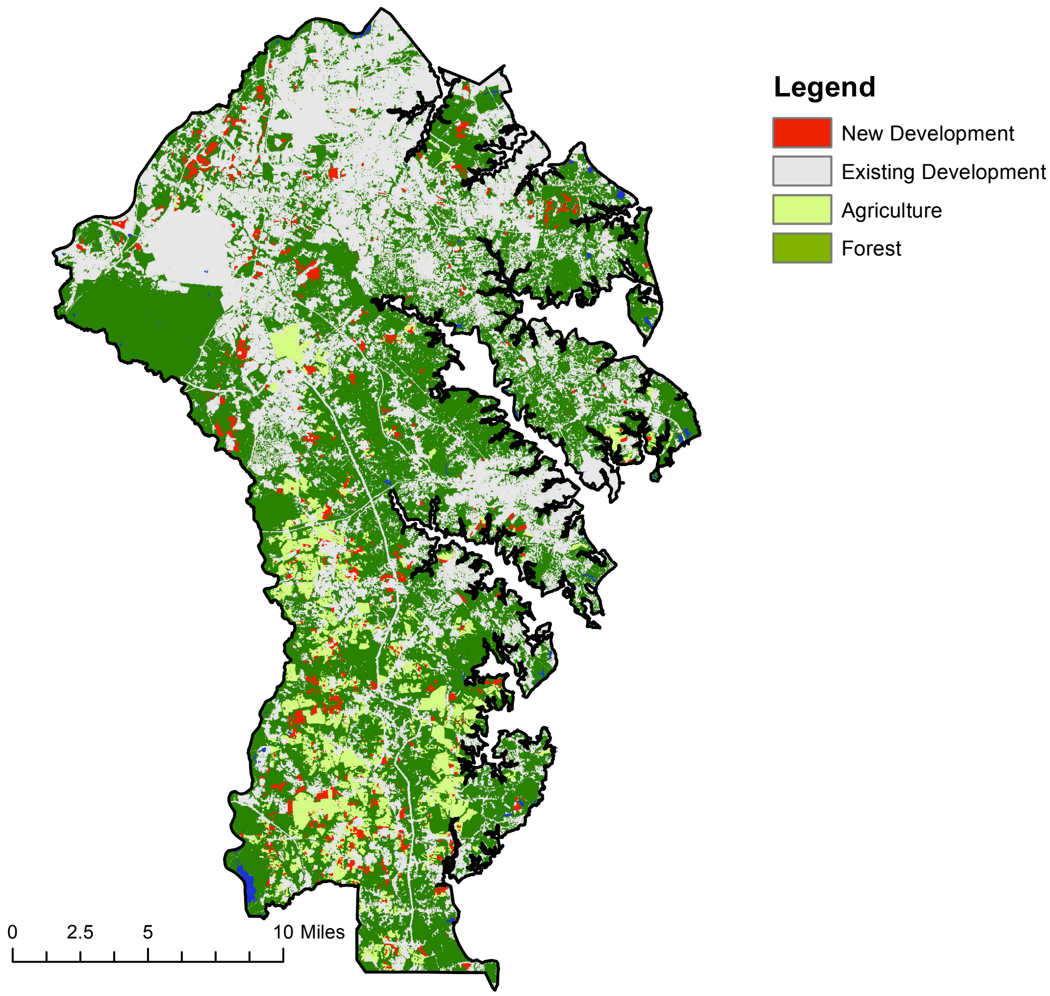
Table 4-8. Land Use Change in Anne Arundel County, 2001 to 2009 (by author).

Anne Arundel County Land Use Change

	2001 (acres)	2009 (acres)	Change (%)
Water	2,891	2,891	**0**
Agriculture	17,792	13,834	**-22**
Forest	108,884	105,700	**-3**
Developed Area	97,313	104,454	**7**

Newly developed areas are spread throughout the county, indicating significant sprawl, but roughly aggregate within the Development District in the north and agricultural area in the southwest (Figure 4-12). The county's Rural Legacy Area is in the southeastern corner, and received limited development during the time period. There was little new development in sensitive areas such as the eastern peninsulas.

Figure 4-12. Forestland, farmland, and developed area in Anne Arundel County in 2009. 'New Development' is development that occurred since 2001 (by author.)



In 2000, Anne Arundel County had nearly 6,800 acres of preserved land. Over the study period, the county doubled the value, protecting an additional 7,300 acres (Table 4-9). The county acquired the vast majority of new easements under the County Agricultural and Woodland Preservation Program, but also began leveraging Rural Legacy funds and working with MET. The partnership with MET was particularly fruitful, adding 2,600 acres to the county's network of protected area.

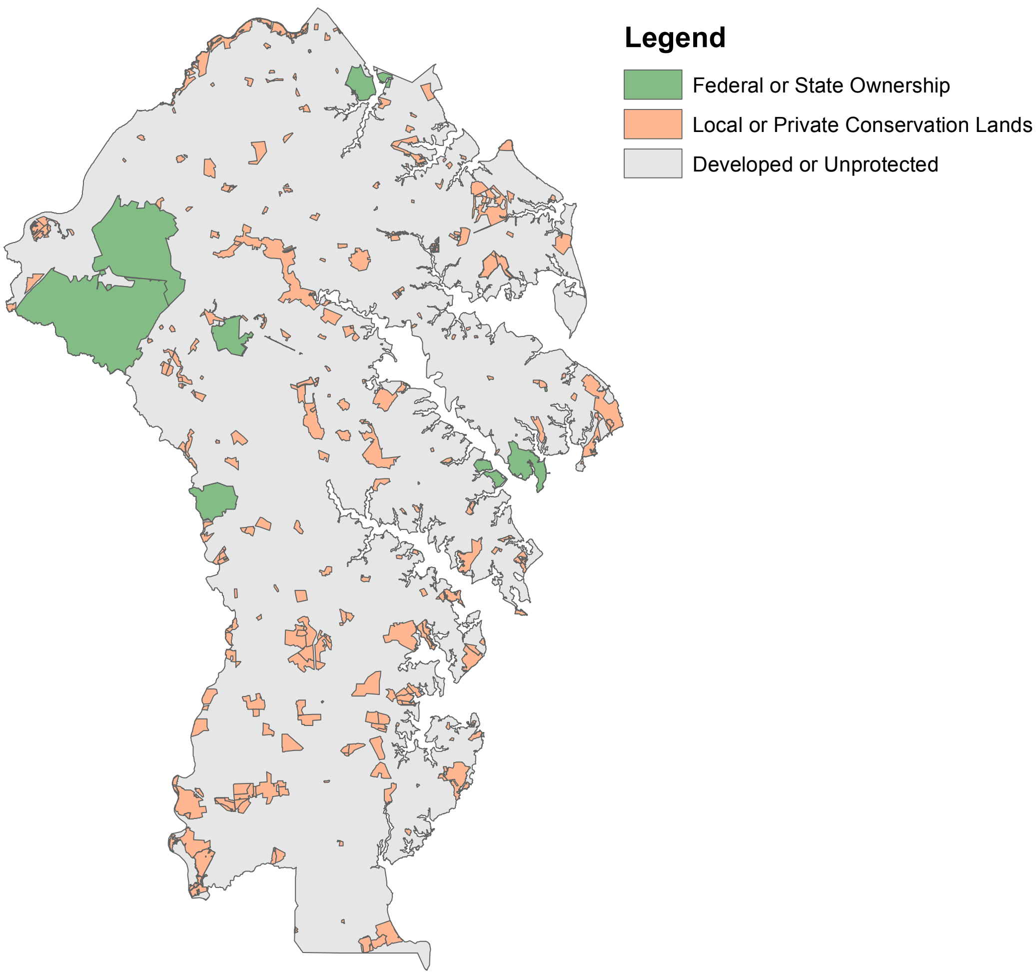
Table 4-9. Land Preservation in Anne Arundel County, Maryland.

	2000	**2010**	**Added**
County	3,023	5,912	2,889
MALPF	3,765	4,596	831
Rural Legacy	0	926	926
MET	0	2,661	2,661
TOTAL	6,788	14,095	**7,307**

Source: MALFP Annual Report 2001, Anne Arundel County 2012.

Most local and private conservation lands in Anne Arundel County are dispersed throughout the county with little clustering or connections to state and federal lands (Figure 4-13). The county has many large blocks of preserved land, but only a few are connected to other protected areas. Lands in the agricultural south are most clustered, with smaller properties forming several large blocks of protected area. State and federal conservation areas are more oriented toward protecting natural resources, and in many cases protect sensitive riparian or coastal areas.

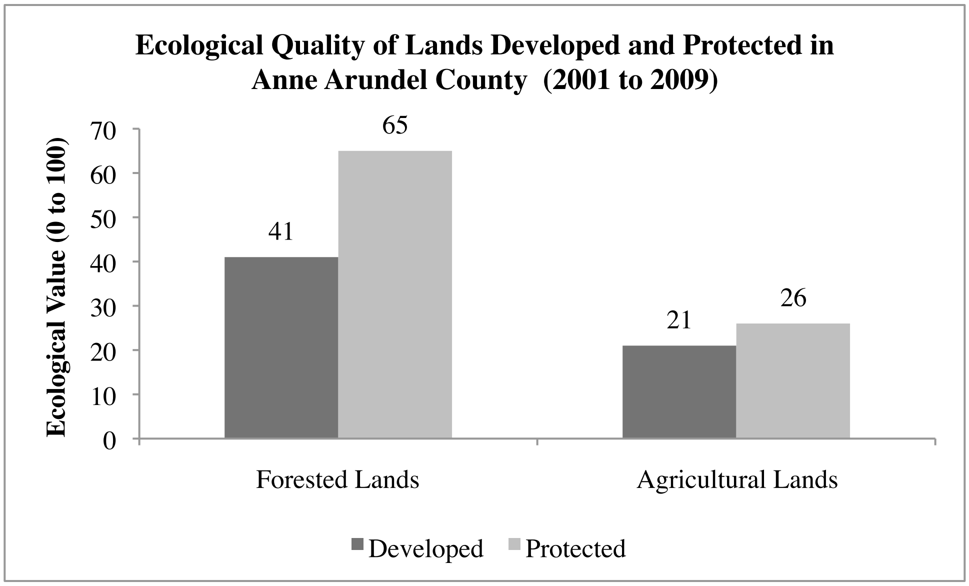
Figure 4-13. Federal, state, local, and privately-owned protected areas in Anne Arundel County, Maryland in 2010 (by Author).



Quality

Based upon Maryland's 2001 ecovalue assessment, the average ecological value of land in Anne Arundel County is 29. The area-weighted mean ecological value of protected forested lands of all types was 65. The value is high when compared to the average value of land developed during the study period, 41 (Figure 4-14). The contrast was not as strong for agricultural lands, where the value difference between developed and preserved lands was only 5.

Figure 4-14. Mean ecological quality of land developed in Anne Arundel County between 2001 and 2009. Protected area averages include land that was preserved prior to 2001.



Connectivity

Anne Arundel County was largely successful in preserving the connectivity of its forest network over the study period (Table 4-10). Forest patches became only slightly smaller and further apart. Agricultural lands proved more of a challenge. Between 2001 and 2009, patches of farmland became much shorter and slightly more distant from one another. One metric showed a slight increase in connectivity, but the measure is an index of size and distance, so the outcome corroborates a significant change in patch size and minimal change in distance between patches. The outcome could be the result of development that fragments large blocks of farmland into clusters of smaller agricultural holdings, separated by other land uses.

Table 4-10. Patch Shape and Contiguity Metrics for Anne Arundel County Forest and Agricultural Land in 2001 and 2009 (by author).

	Forested Land			Agricultural Land		
	2001	**2009**	**Change Notes**	**2001**	**2009**	**Change Notes**
Area-weighted Mean Patch Length/Contiguity (GYRATE_AM)	2917m	2885m	(Slight) Decrease in patch length	651m	549m	Decrease in patch length
Patch Shape Complexity (SHAPE_AM)	15	15	Minimal Change	4.24	3.46	Minimal change
Patch Aggregation (CLUMPY)	0.83	0.83	Minimal Change	0.85	0.85	Minimal change
Area-weighted Mean Distance to Nearest Like Patch (ENN_AM)	61m	61m	Minimal Change	93m	97m	Slight increase in distance to nearest like patch.
Area-weighted Mean Patch Size and Proximity Metric (PROX_AM)	9104	8807	Patches become smaller and more distant	278	321	Patches become (slightly) larger and closer

Overall

During the 2000 to 2010 study period, Anne Arundel County's Office of Planning and Zoning and Department of Recreation and Parks conducted a moderate level of green infrastructure planning. Together, they employed 51% of the programs and strategies included in the Green Infrastructure Planning Framework. The County's major strength is its *Greenways Plan*, which adds local values and detail to the State's 2001 Green Infrastructure Assessment. The Plan uses ecological criteria to identify a network of hubs, corridors, and critical connections that must be preserved to retain connectivity over time. However, the greenways delineated in the plan are advisory and do not enjoy regulatory protection.

Anne Arundel employs a Small Area Planning strategy, which is good for incorporating local knowledge and interests into sector plans, but makes planning for natural resources a challenge. Each SAP has its own goals and may or may not support green infrastructure or collaborate with neighboring districts to manage cross-boundary resources. Additionally, Anne Arundel is a suburban county with a modest degree of urban-rural division. Zoning provides some protection for rural agricultural and resource areas with zoning of 1 dwelling unit to 20 acres, but also allows a significant amount of sprawling low-density development.

The capital budget for Anne Arundel County includes funds for restoration and reforestation and sustained land preservation funding. The county is dedicated to land preservation. Nearly 64 percent of green infrastructure funds come from appropriations, far more than other counties in this study.

Between 2001 and 2009, Anne Arundel County lost 22% of its unpreserved agricultural base and 3% of forested lands. The county was successful in directing development away from high quality forested areas, but less successful with agricultural lands. The average ecological value of agricultural area developed during the study period was 21 and the value of preserved agriculture was only slightly higher at 26. This trend is likely influenced by the fact that farmland is easy to develop, but often relatively expensive, which attracts developers who must seek a return on their investment, while forested lands are difficult to develop and but less costly and thus attractive to preservation organizations.

A significant amount of Anne Arundel farmland was developed during the study period, and the difference in quality between developed and preserved agriculture was not large. Together, these results indicate that County actions were not effective in preventing *or* directing agricultural land conversion. The lack of success is manifested in changes in connectivity. Between 2001 and 2009, the distance between agricultural lands increased as patches became shorter and less contiguous. In contrast, the 3% of forested land that was converted during the time period had a smaller impact on connectivity.

LOW GREEN INFRASTRUCTURE PLANNING: CHARLES COUNTY

Charles County is the most rural of the three Maryland Counties, but grew the fastest during the study period. In response to the magnitude of population growth, Charles County's green infrastructure planning strategy was twofold, providing park and recreation land to meet the needs of new residents and leveraging state resources to protect farmland in the face of spreading residential development. During the study period, the county did little green infrastructure planning. Instead, it focused mainly on agriculture and piecemeal regulatory protection of sensitive and important natural resources (Charles County 2006).

Demographics, Economy, and Environment

In 2010, Charles County, Maryland had a population of 146,000, an increase of 21.6% over the 2000 population of 121,000. A majority of the growth occurred in the northern portion of the county which was greatly impacted by the "outward march of suburban Washington DC" (Charles County 1997). The county contains 460 square miles of land, surrounding but not including three incorporated towns, La Plata, Indian Head, and Port Tobacco Village. La Plata, the county seat, is the largest of the three with a 2010 population of 8,700. Charles County is due south of Washington DC, and one of the newest parts of the Washington Metropolitan Area. It borders Prince George's County to the north and the Potomac River and Virginia to the west. Major population centers such as Waldorf (67,700) and Bennsvile (11,900) are located in the far north of the county where population is spreading from DC, through Prince George's County, and into Charles.

Development is concentrated in the northern half of the Charles County, within commuting-distance of Washington, DC and surrounding job centers. Commuting options are limited. The county is not served by rail and the minimal bus system does not provide service to the Washington, DC Metro. In 2010, the majority of commuters (77%) drove alone, and the average commute time was 43 minutes (US Census 2010). There are few major employers in the county. The single largest is a Naval Support Facility in Indian Head. Located on a northern peninsula overlooking the Potomac River, it has 2,600 employees. Education and medical facilities are also important, but with fewer than 800 employees per facility, less prominent than in the other two counties described here.

Economic indicators show Charles County to be more prosperous than the state of Maryland as a whole. Between 2000 and 2010, median household income increased by 12% to $88,484, well above the state median of $70,000. During the same time period, unemployment more than doubled, from 2.6% to 6.2%, but remained below the 2010 the state average of 7.5% (Bureau of Labor Statistics 2013). Despite the economic challenges of the time, between 2000 and 2010, the housing market remained strong. In 2010, housing values were slightly above the state average ($321,400) at $343,800 (US Census 2000, 2010).

Charles County is rural. There are few major population centers in the southern two-thirds of the county; it remains a mix of agricultural and forested lands interspersed with a few small communities. Agriculture is locally important, but not a major industry. According to the Census of Agriculture, the market value of Charles County agricultural products sold in 2007 was $8.9 million, less than 1% of Maryland's $1.6 billion (United States Department of Agriculture 2009). Charles County has twice as much farmland as Anne Arundel County, yet it produces only a fraction of that county's overall farm product revenue. The difference is the quality and productivity of the farmland. While Charles County farms are larger, they produce less than half the revenue of Anne Arundel County farms on a per-farm basis, and a quarter of the revenue of Baltimore County farms. But what Charles County lacks in quality farmland, it makes up in forest. The county has a high overall ecological value, boosted by a healthy and extensive forest network of nearly 200,000 acres. Several forested areas are state or nationally recognized for their unique ecological importance. The county also has 183 miles of tidal shoreline, most along the Potomac River. The vast majority of shoreline remains natural or agricultural (Charles County 2006).

Green Infrastructure Planning in Charles County

The Department of Planning and Growth Management has the greatest impact upon green infrastructure planning in Charles County. The Department has a Planning Division staff of 20 that creates the Comprehensive Plan and Land Preservation and Recreation Plan, and has an Environmental Planning section that manages the latter in addition to the county's sensitive area, environmental, and agricultural preservation programs. The Parks and Recreation Division, part of the Community Services Department, also plays a significant role. The Division manages County parks and trails, several with natural resource-oriented amenities. Charles County has approximately 17 staff members with planning-oriented job descriptions (2010 CIP), for 1.2 planners per 10,000 population.

For planning during the 2000 to 2010 time period, Charles County receives a score of 51, representing 37% of the policies and strategies in the Green Infrastructure Planning Framework (Table 4-11). For Maryland, 40% is a moderate to low-level of green infrastructure planning. The main contributors to the score were the moderate degree to which the county valued areas of ecological quality and local importance (particularly farmland) and protected and supported green infrastructure through a collaborative and cooperative process. Main weaknesses included the degree to which programs and policies supported a variety of landscapes and ecosystem services, restored and mitigated damage to green infrastructure, and enacted land use planning strategies to protect an retain all scales of GI. The following sections provide an overview of planning in Charles County and describe the policies and strategies through which Charles County furthers each principle of green infrastructure planning. For a complete Green Infrastructure Planning Evaluation Framework for Charles County, see Appendix 4-A.

Table 4-11. Charles County Green Infrastructure Framework Results Summary

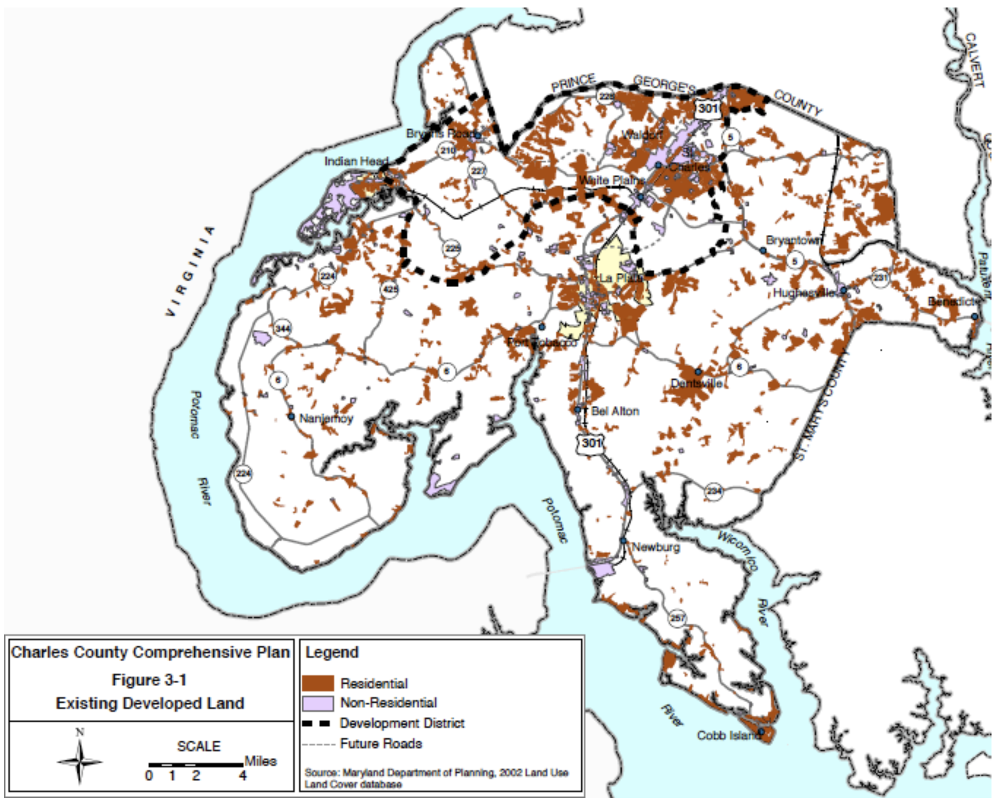
Green Infrastructure Principle	**Framework Score (Out of 20)**
Create linkages and foster connectivity	**7**
Value areas of ecological quality and local importance	**10**
Support a variety of landscapes and ecosystem services	**5**
Restore and mitigate damage to green infrastructure	**5**
Manage green infrastructure to support ecosystem services	**9**
Enact land use planning strategies to protect and retain all scales of GI	**5**
Protect and support GI through a collaborative and cooperative process	**10**
TOTAL (Out of 140)	51
PERCENTAGE	**37%**

Charles County's growth management strategy during the study period was to direct development to designated growth areas and use zoning and other tools to limit development beyond. By directing growth to Development Districts, the county hoped to retain the resource base and rural and agricultural character of the remaining 80% (by land area) of the county. The county took a piecemeal approach to protecting green infrastructure, based upon the review of subdivision and land development plans as they were submitted. The green infrastructure section of the County's 2006 Comprehensive Plan noted, "the focuses of these program[s] are on streams and their buffers, critical areas, forest land, steep slopes, and habitats of threatened and endangered species. The programs are not currently focused on creating an interconnected network of resources" (Charles County 2006, 8-23).

Between the 1970 and 1990 censuses, Charles County's population more than doubled, jumping from 48,000 to 101,000 as the Washington, DC metropolitan area expanded to include the northern portion of the county. The 1997 Comprehensive Plan was a response to the increased need for services, desire to retain "the rural nature and quality of life" that existed throughout much of the county, and need to ease the transition from a rural to a suburban county.

The county's designated growth areas were Development Districts, which were serviced by sewer and water and served as receiving areas for the County's TDR program (Figure 4-15). But the Districts were only lightly urbanized, so the county also had a slightly contrary strategy of protect remaining natural resources and rural character within them (ibid, 3-9).

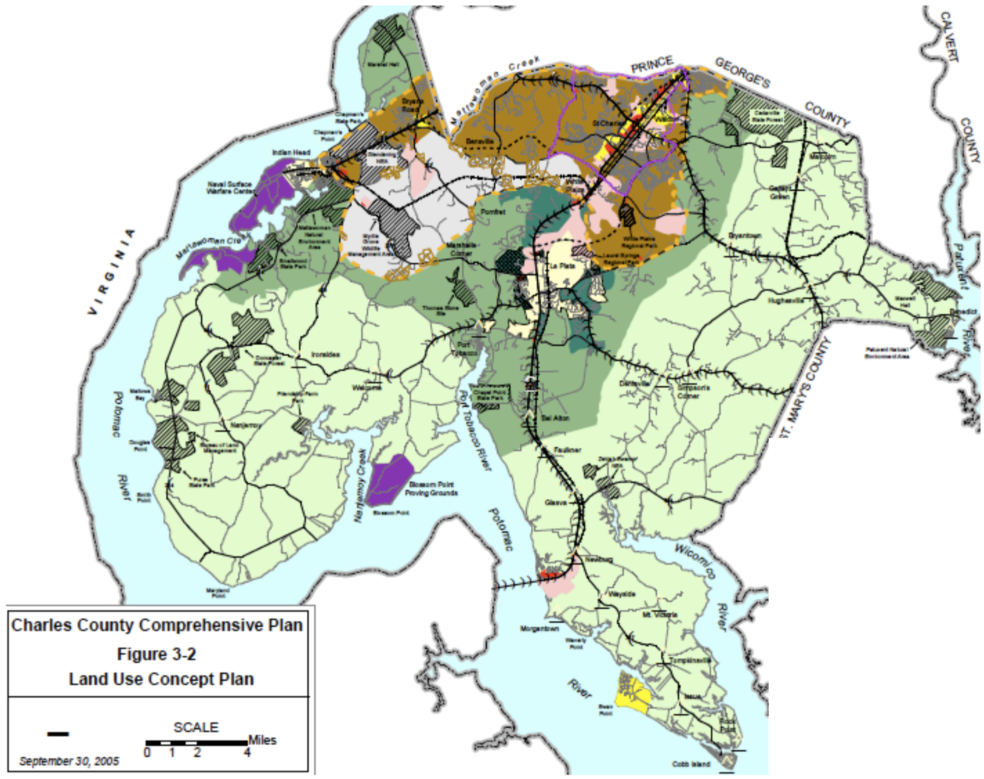
Figure 4-15. Development Districts and Residential Development in Charles County, MD in 2002 (from Comprehensive Plan 2006).



During the study decade, Charles County had three main conservation areas: the Chesapeake Bay Critical Area, the Resource Protection Zone overlay district, and the Zekiah Watershed Rural Legacy Area (Charles County 2006). The Agricultural Conservation and Rural Conservation zoning districts were also important rural designations. Each allowed development at a density of one dwelling unit to three acres (Figure 4-16). While the Agricultural Conservation District covered farming areas and the Rural Conservation District contained natural resources, open space, and rural character, the two had similar characteristics (ibid). For example, landowners within either conservation district were eligible to apply to become an Agricultural Land

Preservation District (Charles County 2000). In 2000, these ‘rural’ areas of Charles County – land outside Development Districts – contained 81 percent of county farmland and 37 percent of housing stock (Charles County 2006).

Figure 4-16. Rural Conservation (dark green) and Agricultural Conservation (light green) Districts in Charles County, MD in 2002 (from Comprehensive Plan 2006).



Agriculture is a small industry in Charles County, producing only $8.9 million a year in farm product sales (United States Department of Agriculture 2009). Farmland is distributed throughout the county and intermixed with other types of natural resources, particularly forestland. The dispersion creates land preservation contiguity challenges (Charles County 2006). During the study period, Charles County participated in the State’s MALPF, MET and Rural Legacy Programs. In 1998, the State approved the County’s Zekiah Watershed Rural Legacy Area. It covers 70,000 acres of hardwood swamp forest and critical habitat in the headwaters of the Wicomico River. The county also has a Forest Legacy Area along the Potomac River. The county’s overall land preservation goal was 64,000 acres.

In 1996, the Charles County Council approved a Transferable Development Rights (TDR) program. Under the program, development rights could be transferred from prime forest or farmland in a designated Agricultural Land Preservation District to a Development District. Sending participants were allocated one transferable development right per three acres. Parcels receiving development rights could be developed at a greater density while parcels sending development rights remained permanently preserved under a county easement. The program was been only moderately active. Assessments concluded that the reason is land economics. The county built up a 27-year supply of certified TDRs. Overall, buyer interest was high, but farmer/seller interest was low (Charles County 2006, IV-16). By 2010, the TDR program had preserved about 4,100 acres.

Finally, farm economies in Charles County were built on tobacco. In 2001, Maryland's Tobacco Buyout Program began paying farmers not to grow tobacco for human consumption. Part of the deal involved farmers signing an agreement that their farm would remain in agricultural production for ten years. Around 100 farms covering 10,000 acres of Charles County participated in the buyout. These farms were protected from development during the study period (Charles County 2006).

Create linkages and foster connectivity
The 2006 LPPRP noted that that Charles County is, "not currently focused on creating an interconnected network of resources" (Charles County 2006, V-5). However, several county programs did support connectivity. The main support for green infrastructure proximity, if not connectivity, in Charles County during the study period was land preservation criteria, but forest conservation and subdivision regulations also had an impact. Under the MALPF and Rural Legacy programs, the County prioritized properties that were adjacent to large contiguous blocks of land that were already permanently preserved through county, state, federal or private programs. While the County did not have specific areas designated for land preservation (Charles County 2006), preservation under the Rural Legacy program was targeted to the boundaries of the Zekiah Watershed Rural Legacy Area. The action made it more likely that those properties would be in close proximity to one another and helped counteract the dispersive nature of the MALPF program.

The county also emphasized connectivity through development review and site design. Forest Conservation Regulations ensured that landowners protected and enhanced connections to vegetated or forested patches on other sites. Subdivision regulations required that lands set aside for community parks and open space be as connected to existing nearby open spaces as possible.

Value areas of ecological quality and local importance
During the study period, Charles County protected high quality and locally important green infrastructure through Agricultural Preservation Districts, land preservation criteria, the Zekiah Watershed Rural Legacy Area, the Resource Protection Zone overlay district, and state-mandated regulations. Forest Conservation Regulations required that staff prioritize trees and plants in areas of high ecological value (i.e. wetlands, habitat areas, and streams and stream buffers) for retention through the development review and site planning process. Today, the county holds over 4,000 Forest Conservation easements resulting from those regulations (Charles County 2006). Additionally, Chesapeake Bay

Critical Area regulations protected sensitive and ecologically valuable areas within the Chesapeake Bay Critical Area while County Subdivision Regulations (1996) protected sensitive areas and habitat for rare, threatened, or endangered species, forest interior bird habitat, and waterbird nesting sites (Charles County 2006).

The agricultural and forestland preservation programs in which Charles County participated included criteria that supported productivity and ecological function through protection of large, high quality, blocks of land. To establish an Agricultural Land Preservation District and receive county tax benefits and rights to sell or transfer development rights, a parcel of land had to be part of a block of farmland, woodland, or pastureland greater than 50 acres and include high quality soils and/or woodlands. In prioritizing land for preservation under Maryland's Agricultural Land Preservation Fund and Rural Legacy Program, the county considered criteria such as soil class, soil productivity, and inclusion of wetlands, forested area, stream buffers, and state-identified green infrastructure (Charles County 2006). The county's Zekiah Watershed Rural Legacy Area is not specifically oriented toward agriculture. It included several locally and regionally significant natural resources that are eligible for preservation with Rural Legacy funds (Charles County 2006). The county also participated in *So. Maryland, So Good*, a Southern Maryland Agriculture Development Commission campaign to assist consumers in finding local products and farms (Maryland Department of Agriculture and Maryland Agricultural Land Preservation Foundation 2007).

The county's Resource Protection Zone also protected sensitive and important resources. It covered streams outside the Chesapeake Bay Critical Area, inclusive of associated wetlands and floodplains. As a buffer, it extended a minimum of 50 feet for small streams and 100 feet for larger waterways, but expanded to cover adjacent important features (Charles County 2006).

Support a variety of landscapes and ecosystem services
The emphasis of green infrastructure protection in Charles County during the study period was on agricultural land. The county established a local TDR program, participated in state-level MALPF and Rural Legacy programs, and passed Right-to-Farm legislation. Beyond these programs, the majority of Charles County's strategies were disjointed, and oriented toward protecting natural resources as required by the State. Comprehensive planning documents discussed several landscapes and identified 'unique environmental habitats' but did not identify landscapes or ecosystems that were important but underrepresented in protected areas. The County also did not designate scenic roads or views, or consider viewsheds in land preservation (Charles County 2006; Charles County 2006).

Restore and mitigate damage to green infrastructure
Between 2000 and 2010, green infrastructure restoration and mitigation in Charles County was carried out mostly where required under state and national wetland legislation, state Forest Conservation rules, and the Chesapeake Bay Agreement. Neither restoration nor reforestation was included in the Capital Improvements Program.

Manage green infrastructure to support ecosystem services
In the study decade, most green infrastructure management in Charles County occurred as part of statewide programs. The county had the greatest impact upon lands subject to Forest Conservation Regulations and within the Chesapeake Bay Critical Area and agricultural districts. Under the Forest Conservation Regulations, developers seeking subdivision or land development approval were required to provide an approved Forest Management Plan. Rules mandated that the plan discuss how trees will be added and removed, establish best management practices, and protect the forest stand over time in accordance with Maryland's Forest Conservation Act. Forest Plans were also required for harvesting more than one acre of timber in the CBCA or within 100 meters of shoreline or tidal wetlands (Charles County 2006). Development within the CBCA was carefully controlled and required a buffer management plan with similar provisions, in addition to restriction on impervious surface. Additionally, property owners who wished to establish an Agricultural Land Preservation District were required to work with the Charles County Conservation District to create an approved soil conservation and water quality plan.

Enact land use planning strategies to protect and retain all scales of GI
Zoning was a significant part of green infrastructure planning in Charles County, but the County's urban-rural distinction was not strong. Rural zones allowed for significant residential development and provided minimal support for green infrastructure networks. The majority of rural land was zoned Agricultural Conservation (AC) or Rural Conservation (RC), both of which allowed residential development at a density of one dwelling unit per three acres (Table 4-12). Land in either district was eligible to serve as a sending area for the County's TDR program. Clustering of development was permitted but not required. The large lot zoning led to fragmenting of farmland, forestland, and natural areas as low-density residential development spread throughout the AC and RC districts. The County attempted to downzone portions of the two zones in 2002, but met with community and political opposition (Charles County 2006, IV-14).

The objective of Charles County's strategy during the study period was to direct development to a single Development District. In 2001, 72 percent of new subdivision activity occurred within the District, but portions of it remained highly rural. To direct development away from such rural areas and towards other sections of the Districts, in 2000 the County rezoned several rural areas to RC(D), creating a new district with a density of one dwelling unit per ten acres. The RC(D) district had the side effect of pushing development not to other parts of the Development District, but into RC and AC districts where lower density development was allowed. By 2004, only 52.5 percent of development occurred within Development Districts (Charles County 2006, IV-14).

Table 4-12. Residential density by zoning district in Charles County, MD in 2005 (from Comprehensive Plan 2006).

	Dwelling Units Per Acre	
	Base densities for the respective district that may be permitted by right	Anticipated average densities for all residential development in the district
Urban Core	2	4
Development District Residential District	1[1]	2 to 4[2]
Mixed Use Districts	0 to 2[3]	2 to 6[2]
Deferred District	0.1	0.1
Village Centers	1	1
Rural Residential	1	1
Rural Conservation	0.33	0.2
Agricultural Conservation	0.33	0.2

Notes
1 The base densities in the areas of St. Charles, Newburg, and Swan Point are determined by existing agreements. Densities in planned development will be determined on a case by case basis.
2 To achieve these average densities, per-site densities (dwelling unit yield) allowed in portions of each planning district will be higher. Maximum residential densities may be achieved through floating zones, density bonuses of varying types, and/or transfer of development rights
3 The zero figure reflects the fact that the base district in some mixed use districts is non-residential.

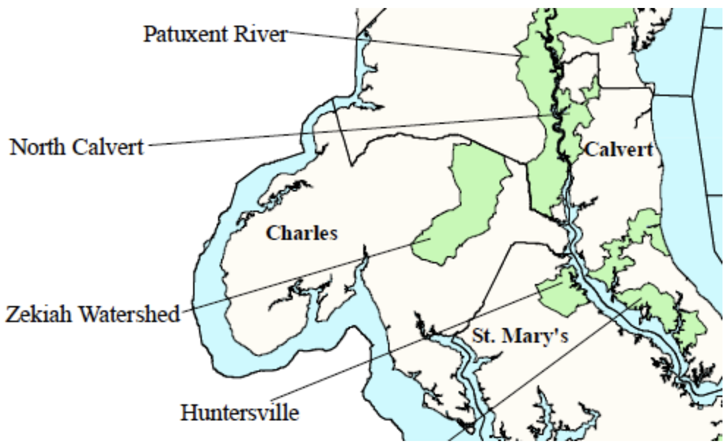
Charles County also used two overlay zones, the Critical Area Zone and Resource Protection Zone. The Critical Area zone, required by the State, established special protection for sensitive resources within the Chesapeake Bay Critical Area. The Resource Protection Zone (RPZ) covered stream valleys, steep slopes and any associated wetlands and floodplains. As previously discussed, it also included a 50 to 100ft buffer, depending upon stream order and proximity to other natural attributes. Agriculture and forestry were allowed within the RPZ, but most other disturbance and land clearing was prohibited or highly restricted (Charles County 2006).

Charles County's main strategy for protecting environmental resources was site-scale, and dependent upon the subdivision and land development review process (Charles County 1997). Through the county's site design procedure, staff worked with applicants to preserve environmental lands as indicated by the Forest Conservation Act, CBCA program, and overlay zones (slopes, wetlands, habitat areas). In keeping with Maryland's Forest Conservation Act, Charles County required applicants with parcels greater than 40,000 square feet (0.9 acres) to submit a forest stand delineation, create a forest conservation plan, and protect trees during development. Regulations also required that subdivision plans identify any important habitat and wetlands of special state concern. Staff and developers worked together to create a habitat protection plan and site design that minimizes the impact on these areas.

Subdivision regulations also required major subdivisions to set aside land for neighborhood/community parks and common open space. Any greenways or linear parks that were approved as part of a local or state plan were required to be dedicated by the developer and counted toward park and open space requirements. Regulations also required developers to set aside common open space that protects natural features and productive farmland.

Protect and support GI through a collaborative and cooperative process
Charles County's land preservation program relies on partnerships. General funds allocated for preservation were used mainly for matching, not direct preservation. Charles County worked with the State of Maryland on several programs that impacted green infrastructure during the time period, including Forest Legacy, Rural Legacy, MALPF, and Tobacco Buyout Programs. As in Anne Arundel County, Charles County's Rural Legacy Area stops at the county line and does not enjoy matching protection across the border in Prince George's County (Figure 4-17).

Figure 4-17. Rural Legacy Areas in the Charles County region. Rural Legacy Areas shown in green (from M-DNR 2010).



During the study period, there was only one private land trust in Charles County, the Conservancy for Charles County. The Conservancy acquired its first easement in 1999 and holds most of its easements (1,371 in 2006) with MET. The Nature Conservancy also worked in county during the study period and owns 2,500 acres of natural resource land. The Maryland Environmental Trust (MET) and Maryland Historic Trust were also active in the county (Charles County 2006).

Funding for Green Infrastructure
Charles County divided capital funding for green infrastructure into two budget categories, "Parks" and "General Government." CIPs from FY 2004 to FY 2010 show an average yearly green infrastructure expenditure of $2.6 million, around 3.8% of the CIP, annually (Table 4-13). Over the seven years, the county spent an average of nearly $2 million annually on land acquisition and right of ways, alone. The Parks category included a variety of recreation facility improvements, but also rails, green space, and open space. Main green infrastructure projects between 2004 and 2010 (exclusive of recreation upgrades and improvements) were park space in Development Districts and trail systems, with an average of $1.4 million per year, around 1.5% of the CIP annually. The General Government category included Agricultural Preservation and Rural Legacy acquisitions. The average yearly expenditure from FY 2004 to FY 2010 was $1.2 million, but neither category was funded in 2006, 2007, or 2008, which reduces the

seven-year average. Unlike Baltimore and Anne Arundel Counties, Charles County did not specifically include waterway improvement or green infrastructure restoration/management project expenditures.

Between 2004 and 2010, Charles County spent a small fraction of county funds (bonds, appropriations) on green infrastructure, and focused mainly on leveraging state and federal dollars. During the seven-year period, around 12% of annual green infrastructure funds came from county bonds or general funds; the remaining funds came from MALPF, Rural Legacy, and other state programs. The trend was particularly dramatic for park space in Development Districts and Rural Legacy programs. The county provided $1,000 in funding for parkland in Development Districts in 2007 and 2008, but received $400,000 and $2,000,000 from state sources such as Project Open Space**.** In 2009 and 2010 county provided 0.1% of the Rural Legacy's $3,000,000+ budget. The remainder came from the state.

Table 4-13. Funding for Green Infrastructure in Charles County, Maryland (Capital Improvements Program 2004-2010)

Charles County, MD	7-Yr Avg	7-Yr Avg (Percent of CIP)
Selected Parks, Preservation, and Greenways (Non-structural)	**1,388,000**	**1.5**
Land Preservation	**1,240,571**	**2.3**
Funds for Land and Right-of-way	**1,982,714**	**3.0**
Waterway Improvement (w/o dredging)	**0**	**0.0**
TOTAL GI	**4,611,286**	**6.8**
County GI Funds (Bonds and General)	**306,571**	**0.5**
Outside GI Funds	**4,304,714**	**6.3**
GI Funds from County (%)	**7**	

Charles County also contributed to green infrastructure protection through foregone tax revenue. Owners of land in agricultural preservation districts approved by the Maryland Agricultural Land Preservation Foundation were entitled to a county property tax credit for all agricultural land and farm improvements within the district. If the agricultural preservation district was stopped, the agricultural landowner(s) were required to repay the amount of the tax credit received.

Green Infrastructure Network Change in Charles County

Quantity

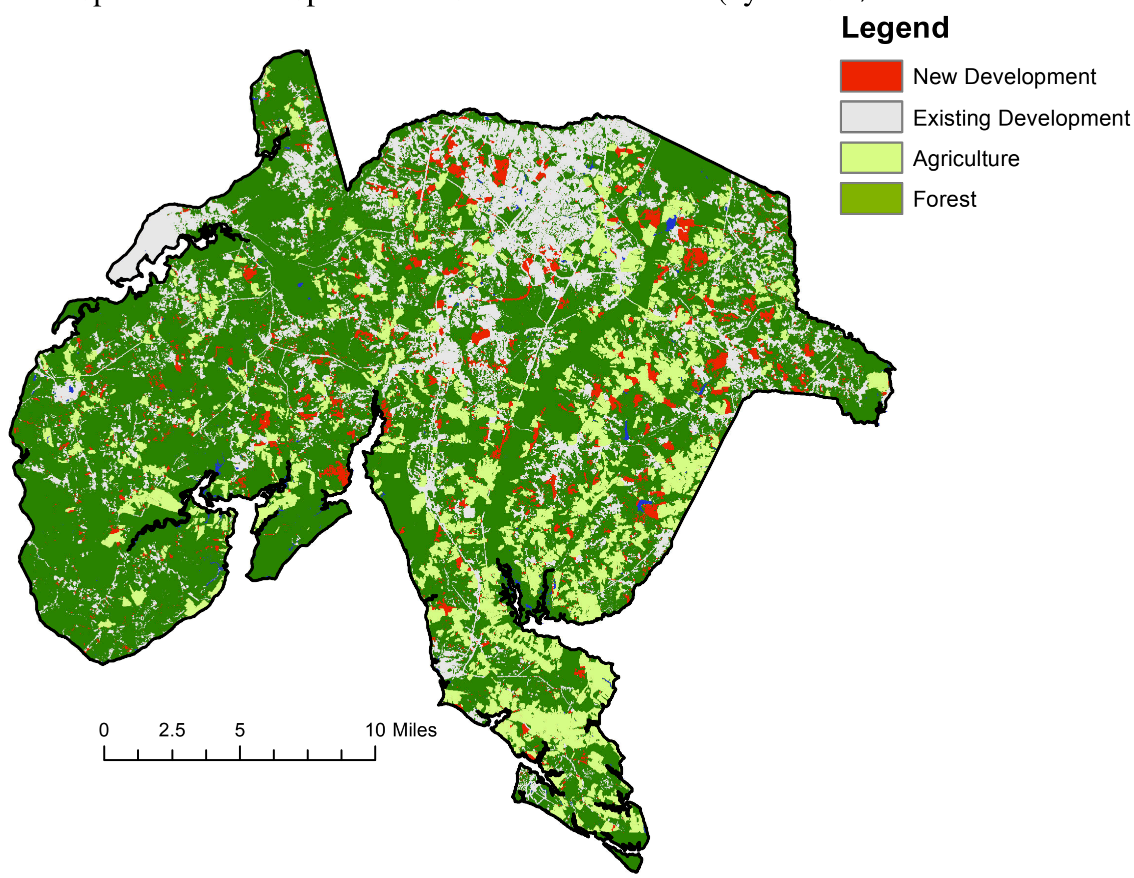
In 2000, Charles County was lightly developed, but growing rapidly. Between 2001 and 2009, developed land in the county increased by 25 percent (Table 4-14). Over the same decade, the county lost 14 percent of agricultural land and 4 percent of forested land to other land covers. The acreage of forest loss is roughly equivalent to the loss of agriculture, suggesting development was evenly distributed between the two green infrastructure types.

Table 4-14. Land Use Change in Charles County, 2001 to 2009 (by author).

	2001 (acres)	2009 (acres)	Change (%)
Water	3,165	3,165	**0**
Agriculture	45,583	39,157	**-14**
Forest	149,491	143,450	**-4**
Developed Area	50,750	63,216	**25**

New development in Charles County was dispersed throughout the county, but loosely concentrated in the northern, central, and western areas (Figure 4-18). The impact of the Resource Protection Zone and Zekiah Watershed Rural Legacy Area is evident in the linear corridor of green (Mattawoman Creek) that opens up to a hub on the northeastern side of the county.

Figure 4-18. Forestland, farmland, and developed area in Charles County in 2009. 'New Development' is development that occurred since 2001 (by author.)



Charles County began the study period with 6,260 acres of preserved land, and added an additional 13,600 by 2010 (Table 4-15). The county invested relatively little in land preservation, but leveraged significant funds through state programs. While Charles preserved the greatest area of land under MALPF, the concerted Rural Legacy effort is most notable. The county designated its first – and only – Rural Legacy Area in 1998, and started the study period with little preservation in the area. By 2010, over 3,000 acres of the Zekiah Watershed Rural Legacy Area were permanently protected.

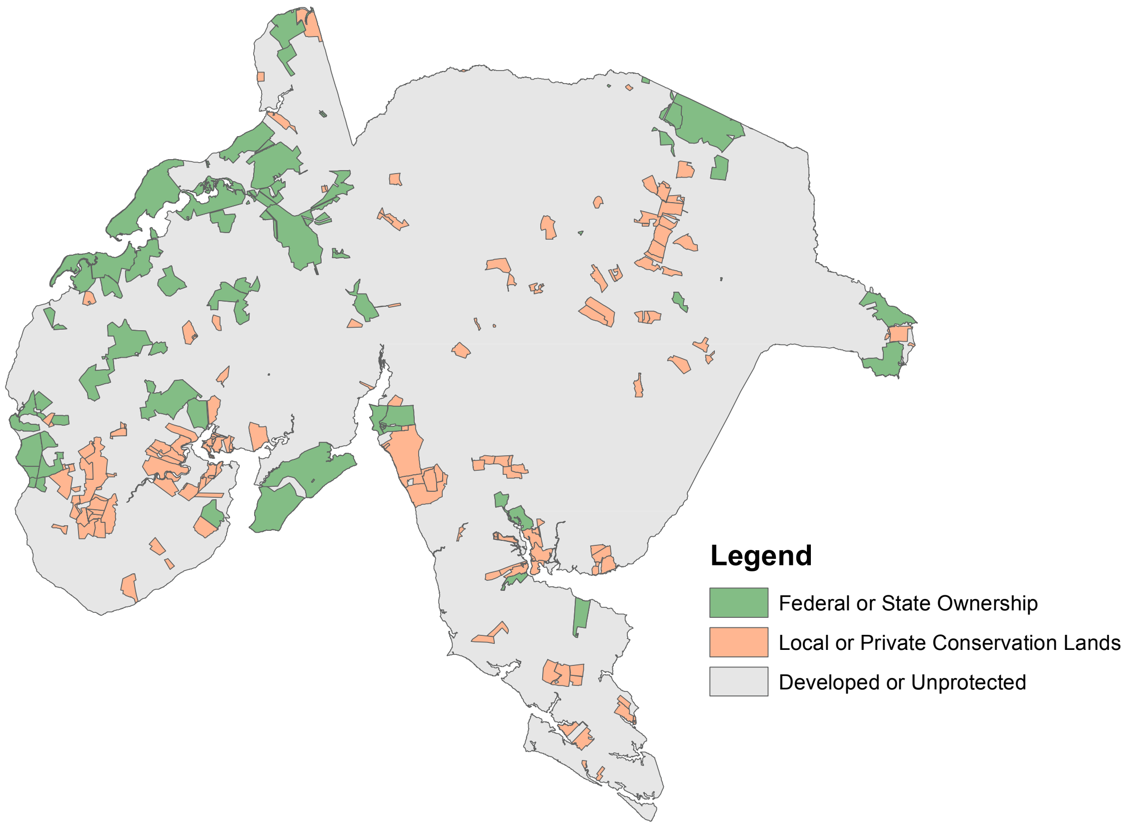
Table 4-15. Land Preservation in Charles County, Maryland (by author).

	2000	2010	Added
County (TDR)	1,183	4,138	**2,955**
MALPF	1,959	5,671	**3,712**
Rural Legacy	97	3,059	**2,962**
MET	3,019	6,989	**3,970**
TOTAL	6,258	19,857	**13,599**

Source: MALFP and MET Annual Reports, 2000, 2011

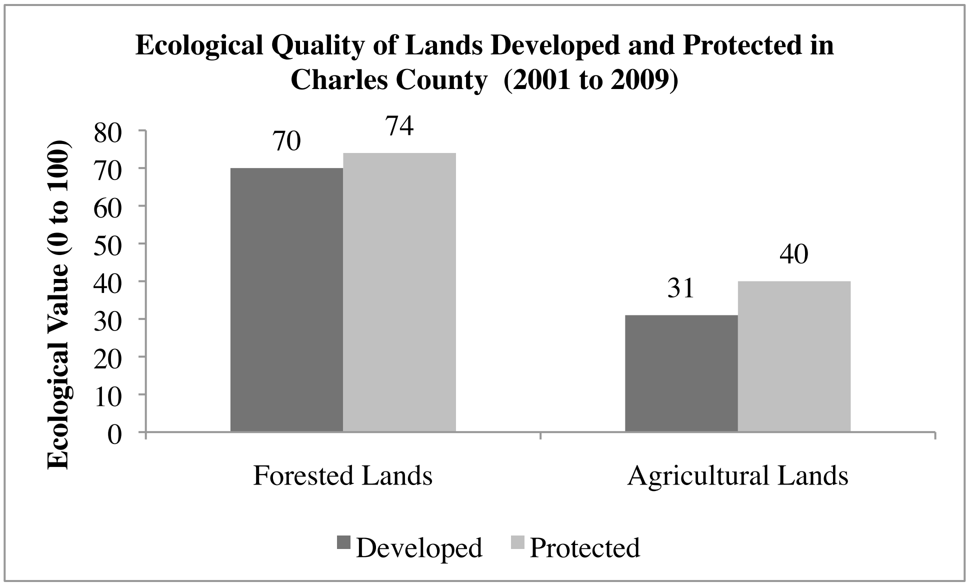
Local and private conservation lands in Charles County have a high degree of clustering (Figure 4-19). Preserved lands form five or six large protected areas. Despite that, connections between state/federal and local conservation lands are modest and large expanses of the county have no preserved land.

Figure 4-19. Federal, state, local, and privately-owned protected areas in Charles County, Maryland in 2010 (by Author).



Quality
In 2001, Charles County had a countywide average ecological value of 55. Light development and a large percentage of forest cover contributed to the relatively high number. The county was somewhat successful in directing agricultural development to low quality farmland. Agricultural lands developed during the study period had an area-weighted mean ecological value of 32, while protected areas had an average value of 40 (Figure 4-20). The county was less successful with forested lands. Protected forested lands were only slightly more valuable, from an ecological standpoint, than developed forested lands.

Figure 4-20. Ecological quality of land developed in Charles County between 2001 and 2009. Protected area averages include land that was preserved prior to 2001.



Connectivity
Between 2000 and 2010, development patterns in Charles County fragmented forest and agricultural lands. The county is heavily forested, so patches tend to be large with a high degree of contiguity. When large patches are fragmented, patch shapes become irregular rather than geometric and patch length increases. This counterintuitive change occurred in Charles where the average distance from the farthest edge of a patch to the center was 7,056 meters in 2001 and 7,176 meters in 2009 (Table 4-16). The increase in Patch Shape Complexity corroborates this finding. It indicates that patches of forested land became more complex with less core area. The strongest results for forested land show patches becoming significantly smaller and more distant. Changes in agricultural land were even more dramatic. As expected of a county that lost 14% of agricultural land to development, patches of farmland became significantly smaller, less contiguous, and farther apart.

Table 4-16. Patch Shape and Contiguity Metrics for Charles County Forest and Agricultural Land in 2001 and 2009 (by author).

	Forest			Agriculture		
	2001	**2009**	**Change Notes**	**2001**	**2009**	**Change Notes**
Area-weighted Mean Patch Length/ Contiguity (GYRATE_AM)	7056m	7176m	Increase in patch length	823m	678m	Decrease in patch length
Patch Shape Complexity (SHAPE_AM)	29	33	Patches become more complex, with less core area	4.23	3.42	Minimal Change
Patch Aggregation (CLUMPY)	0.89	0.88	Minimal Change	0.89	0.90	Minimal Change
Area-weighted Mean Distance to Nearest Like Patch (ENN_AM)	60m	61m	Minimal Change	118m	150m	Increase in distance to nearest like patch.
Area-weighted Mean Patch Size and Proximity Metric (PROX_AM)	57,502	50,979	Patches become smaller and more distant	254	167	Patches become smaller and more distant

Overall

During the study period, the Charles County Department of Planning and Growth Management conducted a low-level of green infrastructure planning. The County employed 37% of the strategies and policies included in the Green Infrastructure Planning Framework. Charles County's strength was its support of agriculture through land preservation and other programs. While the county had only one land trust, an inactive TDR program, and weak zoning (1:3), it leveraged significant state and federal funding for land preservation, particularly through an aggressive Rural Legacy effort and participation in the Maryland Tobacco Buyout. However, given the 14% loss of agricultural land during the study period, preservation did not keep up.

Aside from farmland preservation, Charles County did little green infrastructure planning. The County even stated in comprehensive planning documents that shifting toward green infrastructure planning, and the emphasis in connectivity that entails, would be a major change for the county. Charles focused mainly on piecemeal regulatory protection of sensitive and important natural resources, as required by the State. The County also did not include funds for reforestation or restoration in its capital budget, and invested relatively little of its budget in green infrastructure, in general. Some of the lack of investment may be due to the absence of a pressing need. While Charles County grew rapidly during the study period, it remains lightly developed with a significant natural resource base.

Only 4% of Charles County forestland was developed during the study period. Given the amount of forestland in Charles County the loss was significant and, at 6,177 acres, more than was preserved through any single land preservation program. The loss also went largely undirected; the average ecological value of developed forestland was only slightly lower than that of protected forestland.

Due to the abundance of forestland in Charles County, the 4% loss did not have a significant impact on the size and connectivity of forest patches. Agricultural land was more affected. Between 2001 and 2009, farmland patches became shorter, smaller, and less connected.

COMPARATIVE RESULTS

Between 2000 and 2010, the three Maryland counties had different green infrastructure planning outcomes. Baltimore County, which employs 62% of Green Infrastructure Planning Framework strategies, was most successful in retaining green infrastructure, protecting high quality lands, and retaining connectivity over time. Anne Arundel County (51%) and Charles County (37%) were less successful. This section outlines the main qualities of the three programs and assesses their comparative success in each area.

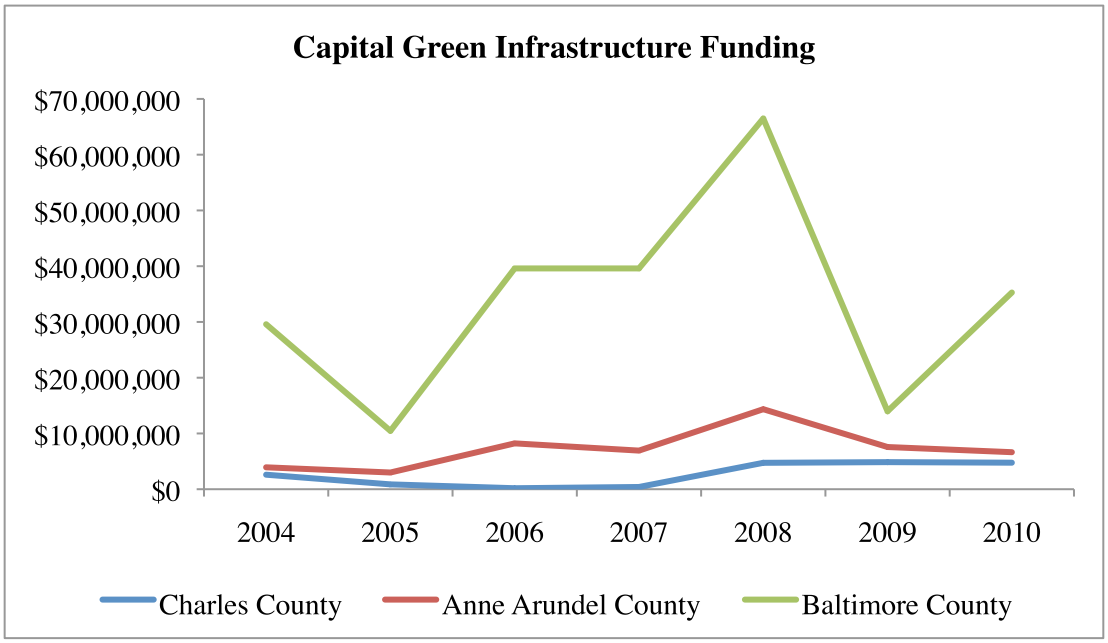
Planning

The major programmatic differences among the three counties were in growth management and green infrastructure delineation and networking. Baltimore County had a strong growth management strategy comprised of a rigid urban growth boundary surrounded by restrictive rural zoning. Anne Arundel had no growth boundary, but strong development districts and a mix of permissive (one dwelling unit per five acres) and restrictive (one dwelling unit per twenty acres) zoning. Charles County also had no growth boundary, but combined with weak development districts and permissive rural zoning (one dwelling unit per 3 acres).

The other major difference was in programs to delineate and protect greenspace networks. Baltimore County used greenways to protect stream corridors and adjacent sensitive resources. The county divided greenways into recreational and environmental - based upon resource quality - and protected them through broad stream valley preservation regulations. Anne Arundel County's strategy was analysis-based – rather than regulatory – and inspired by the Maryland Green Infrastructure assessment. The county used five ecology-based criteria to identify a series of important green infrastructure hubs and links. The network and recommended strategies were published in the award-winning *2002 Greenways Plan*. But the greenways served as guidelines and did not enjoy the same regulatory protection as Baltimore County greenways. Anne Arundel County also used a Small Area land use planning approach that led to uneven consideration of greenways in local plans. Finally, Charles County did not take a network approach to green infrastructure planning. County plans acknowledged that to do so would require a major shift in natural resources strategy.

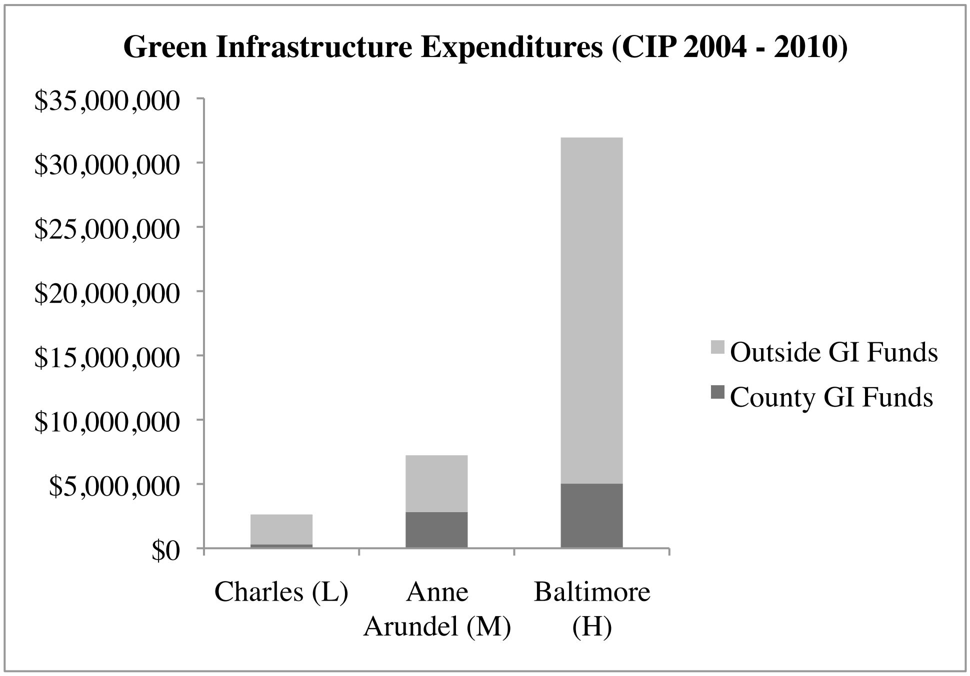
Funding and Land Preservation
Capital green infrastructure spending also varied across the three counties. As the most populous county, Baltimore had the largest green infrastructure budget with an average of $32M per year between 2004 and 2009, for an annual average of 8.2% of the capital budget. Anne Arundel spent an average of $7.2M per year, 3.5% of the capital budget and Charles spent $2.6M, 6.8% of the county's capital budget. Despite changing national economic conditions during the latter portion of the 2000 to 2010 study period, capital funding for green infrastructure increased overall in all three counties (Figure 4-21). Fluctuations in funding were caused mainly by budget tightening at the state-level.

Figure 4-21. Capital green infrastructure funding from FY2004 to FY2010 in Charles, Anne Arundel, and Baltimore Counties (by author).



Another major difference in funding among the three counties was the ratio of local to outside funding for green spaces (Figure 4-22). Anne Arundel County relied heavily upon its local land preservation program, and consequently invested a larger percent of county funds in green infrastructure than the other two counties. Only 12% of Charles County green infrastructure funds came from appropriations, and only 16% of Baltimore County funds did. Anne Arundel provided 40%.

Figure 4-22. Annual average green infrastructure expenditure in Charles, Anne Arundel, and Baltimore Counties between 2004 and 2010.



Partnering with state agencies was a successful strategy for Charles and Baltimore Counties. During the time period, they added 13,599 and 22,301 acres of preserved land, respectively (Table 4-17). Between 2000 and 2010, Charles County overtook Anne Arundel County in land preservation by 5,000 acres.

Table 4-17. Land preservation in Charles, Anne Arundel, and Baltimore County in 2000 and 2010.

	Charles (Low)			Anne Arundel (Moderate)			Baltimore (High)		
	2000	**2010**	**Added**	**2000**	**2010**	**Added**	**2000**	**2010**	**Added**
County	1,183	4,138	**2,955**	3,023	5,912	**2,889**	1,058	4,600	**3,542**
MALPF	1,959	5,671	**3,712**	3,765	4,596	**831**	15,640	22,151	**6,511**
Rural Legacy	97	3,059	**2,962**	0	926	**926**	407	6,672	**6,265**
MET	3,019	6,989	**3,970**	0	2,661	**2,661**	10,496	16,479	**5,983**
TOTAL	6,258	19,857	**13,599**	6,788	14,095	**7,307**	27,601	49,902*	**22,301**

Quantity
Based upon land use change from 2001 to 2009, Baltimore County was most successful in retaining both farmland and forested land (Table 4-18). Charles County, with a low level of green infrastructure planning, was more successful at retaining farmland, in the face of significant development pressure, than Anne Arundel. Some of the success is likely due to the county's aggressive agricultural land preservation program and the Maryland Tobacco Buyout, which preserved 10,000 acres of former tobacco land from 2001 to 2011. But Anne Arundel has only half as much farmland as Charles County.

Although Anne Arundel lost about 4,500 acres over the study period and Charles lost 7,500, the county's percentage loss is greater. Baltimore County, which has twice as much farmland as Charles County (and four times as much as Anne Arundel) lost 7,100 acres.

Table 4-18. Percentage land use change in select categories between 2001 and 2009 in Charles, Anne Arundel, and Baltimore Counties.

	Baltimore (High)	**Anne Arundel (Moderate)**	**Charles (Low)**
Water	0	0	0%
Agriculture	**-9**	**-22**	**-14**
Forest	**-3**	**-3**	**-4**
Developed Area	8	7	25

When you consider combined green infrastructure loss per new resident, Anne Arundel County slightly outperforms Baltimore County (Table 4-19). But while Baltimore County had marginally more developed area per capita, development was concentrated within the URDL rather than spread throughout the county as was the case in Anne Arundel County. The difference in the configuration of developed area impacted quality and quantity results.

Table 4-19. Land developed per capita between 2001 and 2009 in Baltimore, Anne Arundel, and Charles County, Maryland.

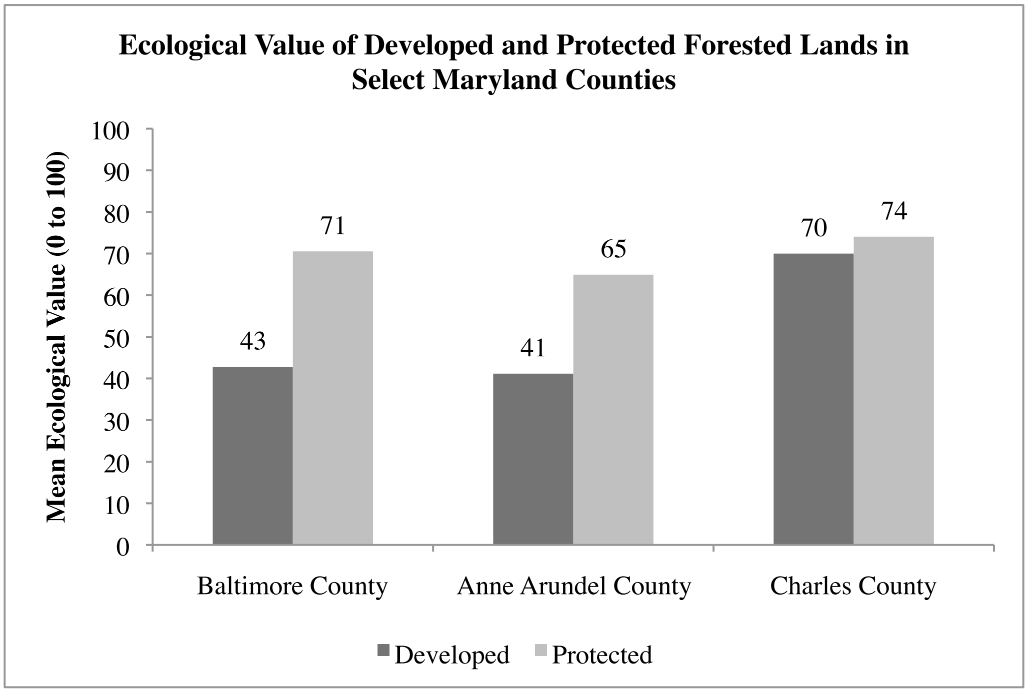
	Baltimore (H)	**Anne Arundel (M)**	**Charles (L)**
Population Added	51,000	48,000	25,000
Growth Rate	6.7%	9.8%	21.6%
Increase in Developed Area	8%	7%	25%
Land Developed (Per Capita Added)	**.18 ac**	**.15 ac**	**.50 ac**

Quality

One objective of green infrastructure planning is to create a network of high quality green spaces by preserving high quality lands and steering development toward lower quality areas. Counties that are successful in green infrastructure planning should exhibit a large difference in the ecological value of protected and developed land. Since the average ecological value of the three counties is different, inter-county comparisons of the average value of developed or protected land are not meaningful. The ratio of developed area value to protected area value is more informative.

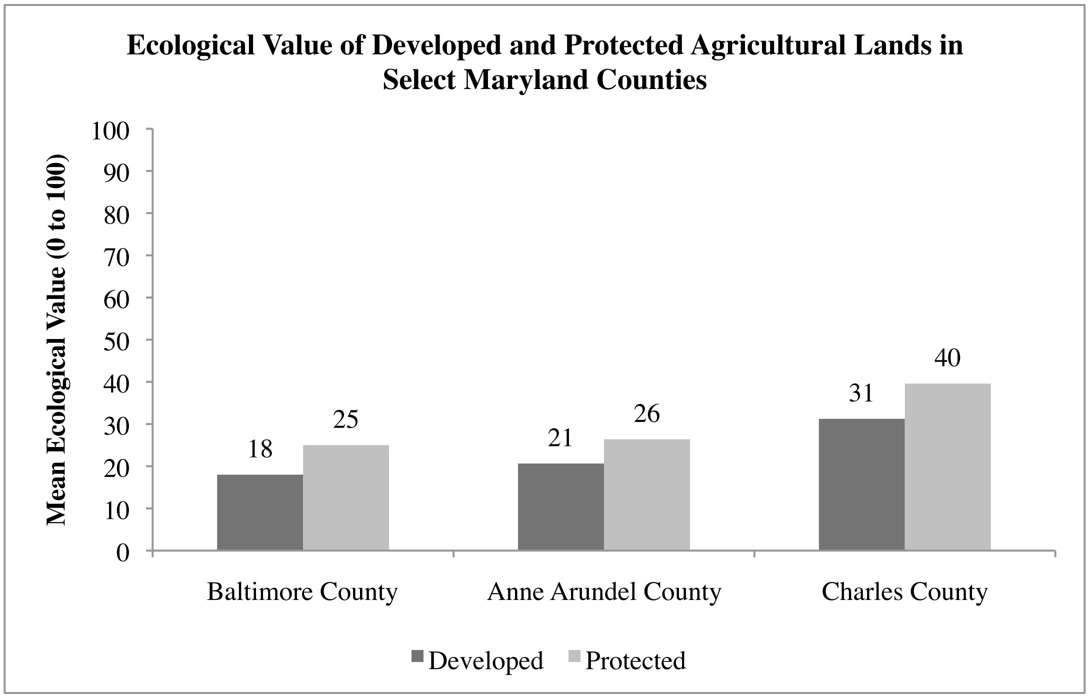
During the study period, Baltimore County exhibited the greatest difference in mean ecological value between forestland that was developed and protected, 30 (Figure 4-23). The difference in Anne Arundel was smaller at 24. Charles County was far less successful at guiding development. The difference in quality between forestland and was protected and developed between 2000 and 2010 was only 5.

Figure 4-23. Mean ecological value of forested land developed between 2000 and 2010 and protected prior to 2010.



The results for agricultural land are not as dramatic. Part of this is because there is less natural variation in the ecological quality of farmland. Compared to natural woodland, agricultural areas are highly degraded. In many ways, agricultural land is more developed than natural. Intensive management – plowing, planting, fertilizing, and harvesting – and construction of farm buildings undermine natural systems and makes lands less supportive of natural communities. However, some farmland does have natural resource value and agricultural land is usually a better neighbor for high-quality natural areas than residential development. Farmland is often used to buffer forested lands from developed areas and, as previously discussed, several land preservation programs consider the ecological value of agricultural lands in making preservation decisions. During the study period, the difference in ecological quality between farmland that was protected and farmland that was developed in both Baltimore County and Charles County was 8 (Figure 4-24). The difference in Anne Arundel County was slightly smaller at 5.

Figure 4-24. Mean ecological value of agricultural land developed between 2000 and 2010 and protected prior to 2010.



Connectivity

The third major facet of green infrastructure planning is connecting green spaces into a functional network. Counties that are successful in green infrastructure planning should retain greenspace connectivity, core area, and proximity between patches over time.

During the study period, Baltimore County exhibited the greatest stability in connectivity and patch metrics. Forested areas in the county became slightly smaller and more distant from each other, but the change was not large (Table 4-20). Anne Arundel experienced a similar, but more pronounced, change in forest patches. According to this analysis, forested patches in Charles County became more connected, but also fragmented into irregular shapes with less core area.

Table 4-20. Interpretation of change in landscape metrics for forested lands in Charles, Anne Arundel, and Baltimore Counties between 2001 and 2009. MC = Minimal Change; Darker Color = Greater Change. For full results see previous tables.

	Baltimore	**Anne Arundel**	**Charles**
Area-weighted Mean Patch Length/Contiguity (GYRATE_AM)	MC	Slight decrease in patch length	Increase in patch length
Patch Shape Complexity (SHAPE_AM)	MC	MC	Patches become more complex, with less core area
Patch Aggregation (CLUMPY)	MC	MC	MC
Area-weighted Mean Distance to Nearest Like Patch (ENN_AM)	MC	MC	MC
Area-weighted Mean Patch Size and Proximity Metric (PROX_AM)	Patches become (slightly) smaller and more distant	Patches become smaller and more distant	Patches become smaller and more distant

Baltimore County also experienced the least change in agricultural land, with only slight declines in patch length and distance (Table 4-21). Farmland in Anne Arundel County decreased in size and contiguity, but became only slightly further apart. Charles County exhibited the same changes as Anne Arundel County, but with a more far pronounced increase in the average distance between farms. The average nearest neighbor distance between agricultural patches in Charles County increased from 112 meters to 152.

Table 4-21. Interpretation of change in landscape metrics for agricultural lands in Charles, Anne Arundel, and Baltimore Counties between 2001 and 2009. MC = Minimal Change; Darker Color = Greater Change. For full results see previous tables.

	Baltimore	Anne Arundel	Charles
Area-weighted Mean Patch Length/Contiguity (GYRATE_AM)	Slight increase in patch length	Decrease in patch length	Decrease in patch length
Patch Shape Complexity (SHAPE_AM)	MC	MC	MC
Patch Aggregation (CLUMPY)	MC	MC	MC
Area-weighted Mean Distance to Nearest Like Patch (ENN_AM)	MC	Slight increase in distance to nearest like patch	Increase in distance to nearest like patch
Area-weighted Mean Patch Size and Proximity Metric (PROX_AM)	Patches become smaller and more distant	Patches become (slightly) lager and closer	Patches become smaller and more distant

HYPOTHESIS TESTING AND CONCLUSION

As stated in the previous chapter, a strong relationship between the policies and strategies associated with green infrastructure planning and on-the-ground green space outcomes will disprove the null hypothesis and support the alternative hypothesis that green infrastructure planning leads to better green space outcomes. For the purposes of this study, a ‘strong relationship’ means an overall trend that counties employing a ‘high’ level of green infrastructure planning outperform counties employing a ‘low’ level of green infrastructure planning in the three areas of analysis: retaining green infrastructure over time, protecting high quality areas, and connecting green infrastructure into functional network). If this relationship is strong, the level of green infrastructure planning (high/moderate/low) should match the level of county success (high/moderate/least) in each of the three areas. Table 4-22 shows this relationship.

Table 4-22. County level of success in retaining, protecting, and connecting forested and agricultural land between 2000 and 2010. Areas that do not follow the H/M/L trend are shaded.

	Forested Land			Agricultural Land		
	Baltimore (H)	**Anne Arundel (M)**	**Charles (L)**	**Baltimore (H)**	**Anne Arundel (M)**	**Charles (L)**
Retain	High	High	Least	High	Least	Moderate
Protect (High Quality)	High	Moderate	Least	High	Least	High
Connect	High	Moderate	Least	High	Moderate	Least

Based upon this analysis, the relationship is strongest in three areas. The first is at the highest level of green infrastructure planning, as exhibited by Baltimore County. Over the study period, Baltimore County was most effective at retaining forested and agricultural land, directing development to lower quality lands, and retaining connections between green spaces. Notably, Baltimore County grew more slowly than Charles or Anne Arundel, which helped the county to retain resource lands, but did not impact its success in retaining and connecting high quality lands. The difference in ecological quality between developed and protected forested lands and steady patch metrics are particularly indicative of Baltimore County's success. The second area in which the relationship is strong is connectivity. For both forested and agricultural lands, patch metrics show counties with a higher level of green infrastructure planning to be more effective at retaining connections between green spaces than lower-level green infrastructure planning counties. The final area with a strong relationship is protecting and retaining lands of high ecological quality, but only for forested land. The lack of a trend for agricultural lands may be related to the small amount of variation in the ecological quality of farmland or to Charles County's emphasis on agriculture.

The strength of these relationships supports the alternative hypothesis rather than the null hypothesis. The level of green infrastructure planning that a county employs appears to have an impact on a county's ability to retain green spaces, steer development away from ecologically valuable lands, and retain critical green infrastructure connections. In other words, it *is* 'good to be green' in Maryland. At the highest level, the benefits of employing many green infrastructure planning strategies are across the board. Baltimore County exhibits a high level of green infrastructure planning and leads the other two counties in retaining, protecting, and connecting green spaces. But at the low-to-moderate level of green infrastructure planning, benefits relate more strongly to the connectivity of green spaces and ability of counties to retain quality forested lands. Factors with a likely impact on these results are growth management strategies, land preservation programs and funding, and local identification and regulatory protection of county greenway networks.

CHAPTER 5: GREEN INFRASTRUCTURE PLANNING IN ALACHUA, LEON, AND MARION COUNTY, FLORIDA

INTRODUCTION

This chapter examines the green infrastructure planning programs and results of three Florida counties: Leon County (high-level), Alachua County (moderate-level), and Marion County (low-level). The chapter begins with background on the programs and policies that comprise Florida's green infrastructure planning framework. It then outlines each county's Green Infrastructure Planning Framework score, the plans, regulations, and policies that make up that score, and the results of each green infrastructure planning program. Key areas of assessment are:

1) Quantity: Loss of forested and agricultural land between 2000 and 2010,
2) Quality: Difference in ecological quality between protected and developed land, and
3) Connectivity: Change in connectivity and patch metrics from 2000 and 2010.

The analysis finishes with a comparative evaluation of the three counties. It concludes that counties that employ more green infrastructure policies and strategies *are* more effective at retaining and connecting green space than those that employ fewer. Furthermore, there is not enough agricultural land preservation data to understand whether green infrastructure planning has an impact on the difference in quality between protected and developed green space.

MAJOR STATE PROGRAMS

State policies and programs create a framework for local green infrastructure planning. In Florida, there are four main categories of regulations and programs that impact local green space planning: land preservation, water resources protection, growth management, and greenway planning.

Land Preservation

As a state with high biodiversity, a rich environmental heritage, and a fast-growing population, Florida has a history of valuing conservation and recreation land. Since the 1960s, Floridians have continually voted for land protection bond and tax initiatives. Early bond initiatives (1964, 1968) preserved recreation areas for the growing population. Later stamp tax and bond-funded initiatives, such as the Conservation and Recreation Land Program (1974), Save Our Coast (1981) and Save Our Rivers (1981) included more funding for land and water conservation. The most significant series of land protection programs began in 1990, when the Florida legislature passed Preservation 2000 (P-2000). P-2000 provided $300 million per year for ten years to preserve sensitive and important Florida environments and lands for recreation (Brock 1997).

In 1998, Florida residents voted to continue land preservation funding and issued an additional $3 billion for conservation and recreation land through 2008. Soon after, the legislature responded with the Florida Forever Act, the most significant state-level land preservation program during the 2000 to 2010 study period. The Act supports preservation of natural and cultural heritage and urban open space and recreation area, but also has broader environmental restoration and management goals. In 2008 voters extended the work for an additional ten years, doubling bond expenditures to $6 billion. An Acquisition and Restoration Council comprised of private citizens, natural scientists, environmental experts, and representatives from state agencies approves acquisition and management plans in line with the Act's goals and project areas. Ecological integrity is a major goal of Florida Forever land acquisition. The Council uses the Florida Natural Areas Inventory, discussed later in this section, as a decision-support tool. Main project areas include critical historic resources, climate change lands, partnership and regional incentive projects, and critical natural lands. Partnerships are also an important part of Florida Forever. Nearly all acquisition projects have multiple partners. Local governments frequently take part, often using Florida Forever funds to support their own land preservation programs (Florida Department of Environmental Protection 2012). A mid-2000s change to Florida Forever legislation made non-profit-governmental partnerships even more important. It allowed nonprofit organizations to submit grant applications and hold title to projects administered through the Florida Communities Trust. The move gave local government and non-profit communities the opportunity to work together to protect large or high-cost lands that would be beyond the funding limit for an individual organization (Tallahassee-Leon County Planning Department 2004). Since 2001, $2.87 billion in Florida Forever funding has protected more than 683,000 acres, statewide (Florida Department of Environmental Protection 2012).

In the second half of the 20th century, Florida's population grew rapidly. Much of the development occurred in flat, easy to develop areas on the periphery of cities, which tended to be farmland. In 2001, to help protect the viability of agriculture in Florida, the legislature passed the Rural and Family Lands Act. The Act called for an assessment of agricultural and resource lands and actions to protect them. But while the Act was passed in 2001, it was not funded for seven years. Finally, in 2008, as part of the Florida Forever reauthorization, the state released the Agriculture and Resource Conservation Assessment. The report detailed Florida's rapid loss of farmland, and five-fold increase in the loss rate from 1964 to 1997. In response, also in 2008, the state funded the Rural and Family Lands Protection Program (RFPP) to preserve farmland in the path of development to ensure that agriculture remains a viable industry and a strong part of Florida's economy. Notably, while RFPP is part of the Florida Forever reauthorization, and uses the same implementation mechanism - acquisition of development rights - its agricultural preservation goals make it distinct from other programs (Florida Department of Agriculture and Consumer Services 2004). However, the delay in funding the Act suggests that working landscapes are not a state-level priority. State programs are more oriented toward natural landscapes that better support water resources and biodiversity.

Florida also has a state-wide land trust, Conservation Trust for Florida (CTF). Founded in 1999, the organization supports state-level farmland and greenway efforts. CTF works with landowners and other partners to protect greenway and wildlife corridors, as recommended by the Florida Statewide Greenways Planning Project and Greenways Commission. The organization also helps farmland and ranchland owners to preserve their land in agricultural use with the objective of ensuring that future generations have access to affordable farmland (Conservation Trust for Florida 2013).

Water Resources Protection

Florida is known for its picturesque coastline, but the state's low-lying, humid, and subtropical characteristics contribute to an extensive inland network of wetlands, lakes, and streams. These water resources are an important part of Florida's environment and economy and the state has invested significant resources in protecting and improving them. In 1972, the Florida legislature passed the Florida Water Resources Act, which divided the state, along watershed lines, into large Water Management Districts (WMD). The 1975 Environmental Reorganization Act delegated additional authority to the five WMDs. Today, each WMD is responsible for administering water resources regulations, planning for water quality and availability, and preserving lands and natural systems that serve water-related functions. WMDs often receive land preservation funds through Florida Forever and Save our Rivers to preserve floodplains, riparian areas, and key upland and bottomland forests. Also relevant to supporting ecosystem services, the districts facilitate restoration and management of waterways, wetlands, and riparian areas (Florida Department of Environmental Protection 2012).

Four of the five WMDs impact land use within the study counties of Leon, Alachua, and Marion. Leon is completely within the Northwest Florida WMD, Alachua is divided between the Suwanee and St. John's WMD, and Marion is split between the Southwest Florida WMD and St. John's WMD. Since WMD boundaries are drawn along watershed lines, and not political boundaries, there are many counties that straddle WMDs. Since WMDs vary in programming and emphasis, the divisions can create inequities (ibid).

In 1984, in response to decades of wetland filling and degradation, the Florida legislature passed the Warren S. Henderson Wetland Protection Act. The Act protected remaining freshwater wetlands from drainage, construction, and agricultural or mining degradation by allowing the Department of Environmental Protection to adopt regulatory protections. At the same time, the federal government took action to protect wetlands, through a 1985 Farm Bill provision commonly called "the swampbuster." In the wake of these two pieces of legislation, conditions improved. By 2003, the National Wetland Inventory declared the rate of wetland loss in Florida to have slowed dramatically.

Wetlands were not the only surface water bodies impacted by development and resource use in the 1970s and 1980s. Other types of surface waters were also affected. In 1987, to preserve and restore the water quality of highly threatened surface water bodies, the Florida legislature adopted the Surface Water Improvement and Management Act (SWIM). Under SWIM, each Water Management District identifies priority water bodies, outlines plans to improve them, and carries out the plans. SWIM projects most often involve habitat and waterway restoration (Florida Department of Environmental Protection 2012).

Growth Management and Intergovernmental Cooperation

Most of Florida's state-level land preservation and water resources protection policies and programs were reactions to rapid population growth and unchecked development. But the state also attempted to address the problem pro-actively. State-level planning began in 1972, with the State Comprehensive Planning Act which created a state planning body and called for a state-wide comprehensive plan. The Act also created planning procedures for Developments of Regional Impact (DRIs). A DRI is a project that – because of its size or type – has the potential to impact more than one county. The Act gives requires state and regional planning councils to review the impacts of DRIs, paying particular attention to adequate and affordable housing (Florida Department of Environmental Protection 2012). Soon after, in 1975, the state passed the Local Comprehensive Planning Act, which required local governments to create and adopt comprehensive plans. The state provided comments on the plans but did not have approval authority (Ingram, Carbonell et al. 2009).

In 1985 the Florida legislature passed the Growth Management Act (GMA). The GMA is based upon consistency, concurrency, and compact urban form – referred to as the 'three Cs.' Under the Act, all incorporated areas and counties are required to complete comprehensive plans which are then reviewed by the state. Under the GMA, planning occurs at three different levels: by local governments, the state – through the Department of Community Affairs – and intermediate-scale regional planning councils. While the role of regional planning councils has diminished, the state has significant oversight of city and county plans. The arrangement can be described as "state-mandated, but locally implemented" (Ingram et al, 155). Local plans must address the goals and issues identified in the state comprehensive plan and be consistent with Chapter 9J – 5 (1986), a piece of legislation that established minimum criteria for local comprehensive plan content. If a local government plan is not consistent with the state plan and Chapter 9J-5, the state can withhold funding or provide its own plan for the area. A county or municipality is also barred from reviewing development proposals or issuing permits until a local comprehensive plan is in place. Once a plan is approved, implementing land development regulations and programs such as the zoning ordinance, subdivision regulations, and capital improvement program must support the plan. The relationship is enforced by legislation allowing impacted parties to challenge the connection in court (Ingram, Carbonell et al. 2009)

Approved comprehensive plans can be updated through two processes, small biennial amendments and the Evaluation and Appraisal Report Process. The Department of Community Affairs may challenge proposed amendments to existing local comprehensive plans, but a large backlog of plan amendments for review makes timely challenges difficult. The Evaluation and Appraisal Report (EAR) process is much more involved. The EAR takes a broad look at the objectives and policies of a comprehensive plan and future land use map to see whether the current framework is meeting the needs of the locality. If not, it identifies those emerging issues and recommends programs and amendments. The EAR is an analysis document and provides counties and municipalities the ability to course correct and to undertake evidence-based responses to changing conditions (ibid).

But, while Florida's Growth Management Act looks great on paper, most researchers agree that it has made little difference. According to a Lincoln Institute of Land Policy Study, land developed per capita increased in the decade after the GMA was enacted and around 70% of development occurred on greenfield sites. The authors suggest that the sheer magnitude of population growth, inconsistent support by the governor and state legislature, and lack of a clear mechanism for encouraging compact development (e.g. Maryland's priority infrastructure investment areas) contributed to the result (Ingram, Carbonell et al. 2009).

Moreover, in 2011, Governor Rick Scot signed the Community Planning Act, a bill that substantially reduced the power of the Growth Management Act and shifted authority to local governments. Under the new rules, the Department of Community Affairs became the Department of Economic Opportunity, a body with few review powers and half the staff. Most significantly, the regulations did away with the 1985 Act's concurrency and consistency requirements. Now, the state can question comprehensive plan amendments only if the proposed change could impact "important state resources or facilities" (Chapter 2011-139, Laws of Florida). While these changes took place outside of the 2000 to 2010 study period, they highlight the importance of understanding the role of local planning – particularly growth management - in green space outcomes. Since counties and municipalities in Florida are acting increasingly autonomously, it is critical that they have the information needed to make planning decisions that will be supportive of ecosystem services and the state's sensitive natural environment.

Greenway Planning

In addition to the regulations and programs described above, counties embarking upon green infrastructure planning in Florida can build upon procedural and environmental knowledge developed through the state greenway planning program.

In 1993, the Governor Chiles established the 40-member Florida Greenways Commission and charged the group with developing a greenway strategy comprised of ecologically-based conservation and recreation corridors to be protected with Preservation 2000 funds. The work emphasized connectivity and built on earlier collaborative nonprofit actions. The initial Greenways Commission Report stated that the goal of the project was to "link existing urban and rural 'green' areas like state and national parks and forests, rivers, and wetland systems to create a statewide 'green infrastructure'" (Florida Greenways Commission 1994, 3). The statement made Florida the first state in the country to work under the 'green infrastructure' banner. Over the following four years, with support from decision support modeling by the University of Florida and input by greenway experts, the general public, and affected private landowners, the Department of Environmental Protection (DEP) designed the initial iteration of the Florida Greenways and Trails System. Greenway system components have evolved over time as new information and technology have become available, but retain the goals and structure (Florida Department of Environmental Protection 1998).

What makes the Florida Greenways and Trails system unique is the emphasis on restoring and preserving connections throughout the state, from the panhandle to the Everglades. The 1999 Greenways Implementation Plan concluded that around 50% of the state is suitable for inclusion in the system and falls into ten main categories: 1) landscape linkages (large, linear), 2) conservation corridors (narrow, linear), 3) greenbelts (surround cities), 4) recreational corridors and linkages, 5) scenic corridors, 6) utilitarian corridors (utility rights-of-way, 7) reserves (large hubs), 8) regional parks & preserves (smaller hubs), 9) ecological sites (small but ecologically significant), and 10) cultural/historic/recreational sites (Department of Environmental Protection 1998, 6). In 1999, many of these areas remained unprotected. The major mechanism under the Greenways Implementation Plan was land acquisition, mainly using Florida Forever funds. Today, the Florida Greenways and Trails Acquisition Program receives around 1.5% of Florida Forever's annual appropriation directly, and even more indirectly as Water Management Districts and local governments preserve land in greenway areas (Florida Department of Environmental Protection 2013).

Given that funds are limited and needs are great, some prioritization was needed to guide the allocation of greenway funds. In 2002, the University of Florida built upon their original decision-support model to identify 'critical linkages,' and priority greenways, both statewide and within each Water Management District. A critical linkage is a greenway segment that is comparatively important in retaining statewide connectivity, threatened by conversion to non-natural land uses, and has a favorable land ownership pattern (e.g. few landowners). Critical linkages are the most important greenway segments to protect to further the goals of the Florida Greenways and Trails system. But the model also identified the relative importance of remaining greenways segments, ranking them priority class 1 (high) to priority class 6 (low) (University of Florida 2002).

FLORIDA COUNTIES: LEON, ALACHUA, AND MARION

Case selection methods described in Chapter 3 were used to identify the three counties in Florida that best fit within the period of the study (i.e. have aligning planning dates and horizons) and are most comparable in other ways: Leon County, a high-level green infrastructure planning county, Alachua a moderate-level, and Marion, a low-level. All three are fast-growing inland counties in the northern half of the state with populations between 250,000 and 330,000. During the study period, Marion grew the fastest, with a population increase of 28% from 2000 to 2010, compared to 15% and 13.5% in Leon and Alachua, respectively. The biggest difference among the three is size. Marion is also the largest and has the greatest amount of land within county jurisdiction. Discounting a large (555 square mile) national forest and the 49 square miles under municipal jurisdiction, Marion County contains 1,059 square miles. Alachua has three times as much municipal land, (151 square miles) and a total of 723 square miles under county control. Leon County is the smallest at 397 square miles of county jurisdiction. It contains a 167 square mile national forest and only one city, Tallahassee, which is 103 square miles (US Census 2000, 2010).

While the standard has since been relaxed, between 2000 and 2010, Florida required local governments to create comprehensive plans and implementing regulations in line with the objectives of the state plan. The requirement meant that county planning departments in the state had similar basic planning capacities. At the high point of staffing, Leon, Alachua, and Marion had similarly-sized planning departments. Leon had 36 in Planning, Alachua had 30 in Comprehensive Planning, and Marion had 25 in Planning and another 15 in the Zoning Department. So, despite differences in the county areas and levels of urbanization, planning staff resources are similar. Funding differences also play a role in green infrastructure planning and will be outlined in later sections.

This section describes the strategies and programs that comprise each county's green infrastructure planning program, outlines green infrastructure framework results, and describes land use change between 2000 and 2010.

HIGH GREEN INFRASTRUCTURE PLANNING: LEON COUNTY

Leon County plans in partnership Florida's capital city of Tallahassee and is a leader in green infrastructure planning in the state. The county has a strong greenway planning program and an innovative and cooperative infrastructure financing program called Blueprint 2000. The county also supports sensitive and high quality resources through the development process by strongly restricting urban infrastructure expansion and requiring environmental management permits.

Demographics, Economy, and Environment

In 2010, Leon County, Florida had a population of 275,000, an increase of 15% over the 2000 population (US Census). The rate is slightly slower than the State of Florida during the time period (17.6%) but faster than the United States as a whole (9.7%). The state capital, Tallahassee, is centrally located in Leon County and had a 2010 population of 181,400. The city is a significant presence in the county; it accounts for a sixth of land area and is the major economic center. In 2010, around two-thirds of Leon County residents (186,000) lived in the city's greater metro area. The two jurisdictions are so intertwined that complete city-county consolidation came to a vote four times between 1968 and 1992. Each time, residents rejected the measure by a margin of less than 10%. While overall governance remains separate, several services are combined. For example, Leon County and Tallahassee undertake comprehensive planning collaboratively through the Tallahassee-Leon County Planning Commission.

The vast majority of jobs in Leon County are in government and education. The State of Florida is most significant, employing around 10% of the population. The county also contains two large public universities, Florida State, and Florida A&M (Economic Development Council of Tallahassee/Leon County 2011). Because of the presence of major universities and state government, the population of Leon County is highly educated. Over 70% of Leon County residents have some college education, compared to 51% for the state and nation (US Census 2010).

Leon County was impacted by the recession of the late 2000s, but to a lesser extent than the state of Florida as a whole. Median household income (adjusted for inflation) did fall 15% to slightly lower than the state's median of $46,000, but the county's employment figures were supported by major anchor institutions and unemployment remained below the state average. Between 2000 and 2010, Leon County's unemployment rate increased from 3% to 7.9% while the state's jumped to 11.3%. The local housing market also remained strong. The median home value increased by 31% over the study period to $196,000, somewhat above the state average (US Census 2010).

Leon County is part of the panhandle region of Florida. The central and northern sections of the county are characterized by rolling forested hills, rather than the sparse coastal plain of much of Florida. The southern portion of Leon is only 20 miles from the Gulf of Mexico and more typical flat and sandy lowland (City of Tallahassee 2013).

There are no population centers in the far northern and southern portions of Leon; they are largely natural resource areas. Some land is agricultural, but agriculture is not a significant industry in the county. According to the 2007 Census of Agriculture, the market value of agricultural products sold in Leon County was only $4.4 million, a small fraction of Florida's $7.7 billion. The value makes the county 60th in the state (out of 67 counties) in agricultural production (United States Department of Agriculture 2009). Leon is better known for its forest resources. The southwestern section of the county is Apalachicola National Forest, the state's largest national forest at 571,000 acres (107,000 in Leon County). The state also has significant holdings. It owns and manages over 13,000 acres of forested land, also in the southern half of the county.

Green Infrastructure Planning in Leon County

In Leon County, the Planning Department had the greatest impact on green infrastructure planning over the 2000 to 2010 study period. The Department carried out traditional planning responsibilities such as comprehensive planning and plan updates, subdivision and land development regulations and review, site plan reviews, and zoning maps and codes. The Planning Department is separate from two other departments that also impact the quality and connectivity of green space, the Departments of Growth & Environmental Management and Public Works. Within Growth & Environmental Management, Development Services reviews development proposals for compliance with the Comprehensive Plan and Land Development Code while Environmental Compliance ensures that such proposals and other applications include sound environmental management practices and provides general support and recommendations on land use and environmental policy. The Department of Public Works includes Parks & Recreation, which develops, preserves, and manages Leon County park lands, including nature trails, greenways, and open spaces.

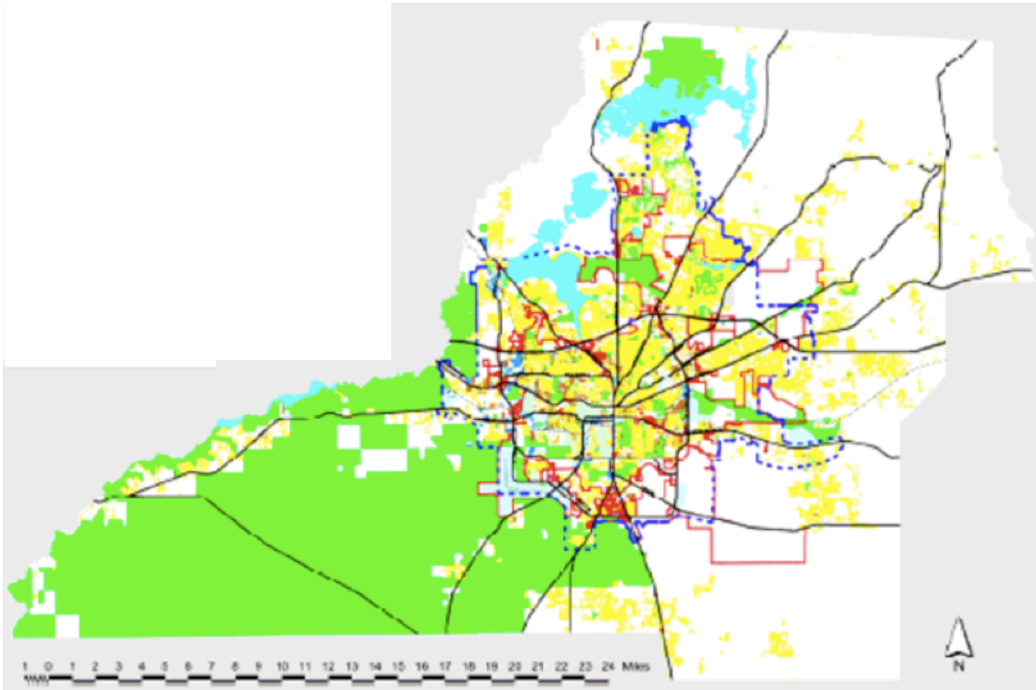
Leon County received a score of 88, representing 63% of the strategies, policies and programs included in the Green Infrastructure Planning Framework. In short, Leon County employs a high-level of green infrastructure planning (See Table 5-1). Compared with other Floridian and non-Floridian counties, Leon's scores are consistent over the seven principles, with no one principle heavily over- or under-emphasized. The county's strengths are in creating linkages and fostering connectivity, supporting the conservation of a variety of landscapes and ecosystem services, and managing green infrastructure to support ecosystem services. The county lags behind slightly in restoring and mitigating damage to green spaces. The following sections provide an overview of planning in Leon County and describe the policies and strategies through which Leon County furthers each principle of green infrastructure planning. For a complete Green Infrastructure Planning Assessment Framework for Leon County, see Appendix 5-A.

Table 5-1. Leon County Green Infrastructure Planning Framework Results Summary

Green Infrastructure Principle	**Framework Score (Out of 20)**
Create linkages and foster connectivity	**14**
Value areas of ecological quality and local importance	**11**
Support a variety of landscapes and ecosystem services	**14**
Restore and mitigate damage to green infrastructure	**11**
Manage green infrastructure to support ecosystem services	**14**
Enact land use planning strategies to protect and retain all scales of GI	**13**
Protect and support GI through a collaborative and cooperative process	**12**
TOTAL (Out of 140)	**88**
PERCENTAGE	**63%**

The Tallahassee-Leon County (T-LC) comprehensive plan (1990) "seeks to balance the management of growth with environmental protection but gives precedence to environmental protection" (Leon County 2001, vii). T-LC's major strategy was to concentrate development in urban areas adjacent to Tallahassee and design that growth to be limited, well-planned, and financially self-sufficient. The county's main strategies in accomplishing this were limiting urban services in rural areas through an urban growth boundary, rural and open space zoning, and protective Conservation and Preservation Areas (Figure 5-1). The comprehensive plan vision outlined the costs of growth and need for new development to pay its 'fair share.' The document asserted that "unwise land use decisions which ultimately require expensive environmental retrofitting, paid for by the general populace, must be eliminated" (ibid, vii). However, T-LC does have a history of low-density development, and the plan acknowledged that strict growth management is implausible. Overall, T-LC considered four objectives in siting development and identifying appropriate densities: (1) protection of conservation and preservation features; (2) compatibility with adjacent existing and future residential land uses; (3) access to transportation facilities in keeping with their intended function; and (4) the availability of infrastructure. Note that 'Protection of conservation and preservation features' was listed first. (Tallahassee-Leon County Planning Department 1990, I-23)

Figure 5-1. Tallahassee-Leon County 1999 Existing Land Use Map. Map by T-LC Planning Department 2006. Key: Green = Open Space, Yellow = Multi-family, Blue Dash = Urban Service Area, Red Line = Tallahassee City Limit, Aqua = Water



The most important landscape-scale effort to protect green infrastructure in Leon County was the Tallahassee-Leon County Greenways program, a voluntary land acquisition program launched by T-LC in 1994. T-LC defined greenways as "corridors of protected open space that are managed for conservation and/or resource-based ('passive') recreation… [that] connect both urban and rural 'green' areas… to create regional 'green' infrastructure" (Tallahassee-Leon County Planning Department 2004, 1). The program was inspired by earlier City of Tallahassee initiatives and intended to protect natural and cultural resources and provide open space and recreation areas through voluntary land acquisition mechanisms. By 2004, T-LC had acquired 4,600 acres under the program and drafted the Greenways Master Plan to provide further guidance and strategy.

The Greenways Master Plan supported the conservation goals of the T-LC Comprehensive Plan, expanded upon Blueprint 2000, and increased the rationality of green space planning in the county (Tallahassee-Leon County Planning Department 2004). The Plan laid out a community-wide system of interconnected greenways with conservation and recreation values. The system included 72,600 acres of public and private lands - 12% of the county's land base. Since the broader system was largely aspirational, T-LC also identified seventeen priority greenway projects, including approximately 7,900 acres of green space and 83 miles of trails. The Plan ranked projects from high to low priority, based upon each greenway segment's conservation value and development potential. Areas that were least developable under T-LC policies and regulations topped the list and were more likely to be protected than segments with low conservation values and high development potential. Blueprint 2000, Florida Forever, and the subdivision and land development process were the main implementation mechanisms for the strategy (Tallahassee-Leon County Planning Department 2004).

A second major program that supported green infrastructure in Leon County was Blueprint 2000. In November 2000, Leon county voters approved an extra penny of sales tax for land acquisition associated with 'holistic' infrastructure planning. Holistic infrastructure planning considers roadways, stormwater, greenways, and trails together. A major objective is to balance corridor improvement 'gray' projects with environmental 'green projects,' based upon the understanding that the two types of capital improvements are interdependent. The Blueprint 2000 Report proposed acquiring floodplain and greenways areas and several transportation projects that include greenway features and divided land acquisition costs into two categories: 1) lands to be acquired primarily for stormwater treatment and flood storage, and 2) lands to be acquired solely for greenspace and recreational values. Within those categories, projects were further divided into tier one and tier two. Tier one projects would be funded based upon conservative tax revenue estimates and tier two could be funded if tax proceeds exceed conservative results. All greenway projects included in the Blueprint 2000 report were consistent with the Greenway Master Plan (Economic and Environmental Consensus Committee 2000). As of 2007, the program had preserved about 3,000 acres in Leon County.

Create Linkages and Foster Connectivity
Connectivity was a major goal of green space planning in Leon County. The county used a hub and link framework and promoted an interconnected network of green infrastructure through the greenway program, land preservation, and development review process. The Comprehensive Plan (1990) and Greenways Master Plan (2004) were the main planning documents supporting connectivity during the study period. They referenced the importance of interconnected corridors of open space and the county's commitment to retaining green space linkages and preventing the fragmentation of habitat and open space. The Greenways Master Plan specifically outlined the importance of "connect[ing] both urban and rural "green" areas, such managed parks and forests and natural rivers and wetlands, to create regional "green infrastructure"' (Tallahassee-Leon County Planning Department 2004, 1) and went on to identify major green space hubs and map existing and potential greenway and open space areas.

An objective of the T-LC greenway program was to connect greenways with other types of protected and proposed open space. One motivation was access. Linkages between residential areas and parks and greenways enable residents to access green space, and move within the greenway network more easily. Other motivations included environmental quality and habitat contiguity. The county also promoted green space linkages through land preservation, but only indirectly. Planners identified important green space segments through the greenway program analysis - which emphasized the connections between newly protected areas and existing parks and preserved lands – and then added high priority greenways to the list for acquisition through the county's main program, Blueprint 2000.

Leon County also supported connectivity by considering green space configuration in the subdivision and land development process. The county encouraged clustering of development in subdivision layouts, and required that protected open space be connected within a development and to existing or proposed green space on adjoining properties (Tallahassee-Leon County Planning Department 1990). The environmental review portion of the development process also included connectivity provisions. In plan review, county officials examined impacts on threatened and endangered species and looked for preservation of not only habitat, but movement corridors. In addition, where mitigation occurred on-site, priority was "given to preserv[ing] the largest areas - considering adjacent off-site habitat - that are of highest quality and will most likely protect the population and its habitat by preventing fragmentation" (Leon Code Sec. 10-4.201). The same was true for other resource types, where priority was given for protecting large areas of high quality forest and their adjacent forestland, wetland, canopy roads, and floodplains in a way that minimizes overall fragmentation of local plant communities (Leon Code Sec. 10-4.202).

Areas of Ecological Quality and Local Importance
Tallahassee-Leon County integrated a wealth of ecological information and analysis into their long-term planning efforts. The T-LC Comprehensive Plan and Greenways Master Plan identified the county's ecological assets and environmentally sensitive areas. The Greenways Plan also mapped major anchors of the green infrastructure network and ranked potential greenway segments by their relative value and development potential (Tallahassee-Leon County Planning Department 2004). However, the county did not map environmentally sensitive areas during the study period, instead relying on the development review and environmental management permitting process to identify vulnerable areas in an ad hoc manner.

Between 2000 and 2010, the county identified and protected areas of high ecological quality and local importance through the environmental management permitting process, Conservation and Preservation Area restrictions, conservation easements, and landscaping requirements. T-LC also attempted to balance uses and values within its shared park system. The localities aimed for 50% of park natural features to remain undeveloped, as a system-wide average (Tallahassee-Leon County Planning Department 1990).

Any landowner wishing to undertake a development project in Leon County had to first obtain an environmental management permit. Under the Leon County Environmental Management Act (1990), most applications for site or development plan approval began with a pre-development environmental analysis. The analysis included a mapped Natural Features Inventory (NFI), measures to mitigate the impact of development on resources identified in the NFI based upon a table of standards, and an Environmental Impact Analysis. The latter included a conceptual development plan, assessment of the project's impact on species of concern, changes to vegetative cover, water resources, and other sensitive environmental resources in the NFI, and plans to eliminate or mitigate impacts, as necessary. Sites smaller than 20 acres that did not have Conservation or Preservation Areas were exempt from the NFI requirement (Leon County Code Sec. 10-4.200).

T-LC divided important natural areas into two types, Conservation and Preservation, and protected them through overlay zones that restricted development and required strict review and prevention or mitigation of impacts. T-LC's objective was to 'design with nature' (Tallahassee-Leon County Planning Department 1990, IV-6). The county required that, at a minimum, development have little to no disturbance or impact on the functioning of surrounding ecosystems.

Preservation Area features are more sensitive or important than Conservation Area features and were subject to stronger protections and greater development restrictions. Preservation Overlay features – as delineated through the environmental review process - included:
a) Wetlands and waterbodies and water courses;
b) Severe grades over 20%;
c) Native forests;
d) Undisturbed/undeveloped 100 year floodplain; and
e) Areas of environmental significance
f) Habitats of endangered, threatened and species of special concern.

Generally, the county prohibited development in Preservation Areas. But projects that did not impact the quality or functionality of ecosystems were allowed ad a density of 1 unit per 40 acres. T-LC required that preservation area features be protected with a conservation easement at the time of development. Easements were drawn to the limits of the feature that needed protection, including any applicable buffers, and donated to the county. For example, all native forests and habitats of threatened or endangered species had be protected with a permanent conservation easement, including a minimum 20-foot vegetated buffer (Tallahassee-Leon County Planning Department 1990). In many cases, T-LC required landowners to donate easements on environmentally sensitive lands as a condition of development. More than 3,000 acres of Leon County were protected through the "natural area set-aside" provisions of the county land development regulations (Tallahassee-Leon County Planning Department 2013).

Restrictions on development in Conservation Areas were not as strong as those of Preservation Areas. Development was allowed, provided conditions were met. For example, parcels with high quality successional forest could be developed provided site disturbance was less than 20% and overall density was no more than one dwelling unit per two acres. Conservation overlay features included:
a) Altered floodplains and floodways,
b) Altered watercourses and improved elements of the primary drainage system;
c) Altered wetlands;
d) Closed basins;

e) Significant grade areas (10% - 20%);
f) High quality successional forests;
g) Areas exhibiting active karst features;
h) Designated canopy road corridors.

To balance the needs of conservation and development, Leon County allowed density transfer, but only within a parcel. Offsite density transfer (e.g. transfers of development rights) was not allowed. On-site density transfer, or clustering, was a key part of the county's strategy for protecting Conservation and Preservation Areas. The design grouped development on less sensitive areas and minimized overall site disturbance, while allowing development at the original zoned density (Tallahassee-Leon County Planning Department 1990). The clustered design was intended to further support ecological quality by creating subdivisions with a single large contiguous green space rather than many smaller, lower quality, areas.

T-LC also protected natural ecosystems through landscape requirements. County code required that landowners seeking approval for development or redevelopment submit a landscape development plan comprised of an inventory of natural and environmentally sensitive areas, a reforestation plan, and a vegetation management plan. The objective was to ensure that landowners retained natural vegetation and forest communities in the development process rather than clearing and replanting. County code required that development activity retain a minimum of 25% of the area of a site in natural condition and at least 10% of the site's trees. Tree protection requirements also covered most mature trees not on single-family lots. Landowners received credit for preserving existing mature trees, but by the conclusion of development had to meet overall tree requirements - around 40 trees per acre for most sites and development types. Additionally, if the final site plan included forested areas or environmental constrains, the areas had to be protected with a permanent conservation easement (Leon County Code Sec. 10-4.340).

Leon County also provided recommendations for landscaping strategies that support natural systems. County Code outlined planting techniques to enhance wildlife habitat, promote forest creation, and facilitate stormwater management. The Code also prohibited use of plants on the state's invasive species list (Leon County Code Sec. 10-4.351).

Finally, Leon County attempted to protect natural resources along the urban-rural fringe by providing a conservation subdivision option. While the option took effect in 2006, relatively late in the study period, to created provisions to encourage landowners to permanently preserve at least 50% of a site as dedicated open space and to cluster development on lands with the least environmental significant (Leon County code Sec. 10-7.204). However, the provisions were not commonly used and had little effect (Brockmeier 2013).

The county's 2007 EAR called into question the degree of implementation of some of the plan's environmental quality objectives, most notably the protection of endangered species and associated habitat and the functionality the broader ecological systems in which development is permitted. However, the assessment also noted that many of the deficit areas had been incorporated into land development regulations (Tallahassee-Leon County Planning Department 2007, 2-56). The county – overall – had a high level of environmental quality consideration and attainment.

Support a Variety of Landscapes and Ecosystem Services
Tallahassee-Leon County planning documents from the study period discussed several less conventional types of green infrastructure. The county addressed canopy roads, lakes and streams, habitat, cultural resources, wetlands, floodplains, and silviculture, among others.

Canopy roads are scenic, historic, roadways with 'uncommon tree canopies' (Tallahassee-Leon County Planning Department 2004, 20). By the middle of the decade, the county had more than 75 miles of canopy roads, which are usually rural and undeveloped. The County protected them by ordinance and discouraged development that would increase traffic or require construction that could damage the trees (ibid).

The county also considered wetlands to be an important landscape. In addition to federal wetland protection standards, the county prohibited the removal or damaging of trees within 20 feet of wetlands - as identified through the environmental review process. At the time of development, landowners had to permanently protect wetland areas, and a 20-foot buffer, with a conservation easement (Leon County Code Sec. 10-4.322).

The Board of Commissioners also used special development standards for 'environmentally sensitive zones' such as those adjacent to waterways, wetlands, and floodplains. The standards outlined special development area restrictions and natural vegetation requirements for development of land adjacent to the county's five major lakes and up to 200 feet from the waterways' floodplains (Leon County Code Sec. 10-4.323).

Leon County also had special provisions for protection of cultural resources. As with important natural resources, subdivision or land development proposals that contained an identified cultural resource had to provide a cultural resource protection plan. Often protection of the resource involved a permanent conservation easement (Leon County Code Sec. 10-4.329).

Restore and mitigate damage to green infrastructure
During the study decade, Leon County's work in restoring or mitigating damage to green infrastructure occurred mainly through the development review process. The Environmental Management Act required developers to minimize impacts on ecosystems and to mitigate impacts that are unavoidable. In most cases, development impacts had to be mitigated on-site. The county provided a table of best practices for mitigation of development impacts on sensitive wetland, forest, and habitat environments. Restoration was also a part of the landscape development plan. Vegetation management plans often required restoring or enhancing on-site forests or habitat areas and reforestation plans

outlined forest restoration procedures. The county also required developers to restore important on-site wetlands to historic function at the time of development, if they were identified as degraded in the Natural Features Inventory (Leon County Code Sec. 10-4.322).

Manage green infrastructure to support ecosystem services
Leon County emphasized the management of natural resources, particularly at the greenway segment and site scales. Analyses related to greenway planning represented large-scale management of the green infrastructure network. Leon also required that applications for conservation subdivisions include a management plan for all protected open space and a dedicated source of funds to carry out the provisions of the plan (ibid). In addition, the county managed its greenway network properties to support natural resources and conservation values through actions such as reforestation and replanting, invasive species removal, and stream restoration (Tallahassee-Leon County Planning Department 2004). However, compared to where such practices could be, T-LC noted that, "greenway and greenway trails management, operation, and maintenance… is still in its infancy locally, [but] is rapidly evolving in response to citizen demands" (ibid, 59). Previously, little attention was given to the maintaining of greenway natural resource values, but – in the mid-2000s - the county was working to change that. T-LC management of greenway resources owned by State of Florida was much stronger. The county managed state greenways for ecological quality and resource-based recreation (ibid). This successful management of state resources showed that the county had a base of management knowledge and expertise that could be expanded to county-owned lands as the management structure and resources grow.

County code also outlined management requirements for important areas identified through the environmental management permitting process. T-LC required landowners with on-site Conservation and Preservation Areas to submit management plans and - if the areas were protected by a conservation easement – dedicate a fund for long-term implementation. In this way, each Conservation or Preservation Area conservation easement donated to the county represented an area managed for environmental quality. For example, as part of the site planning and development review process, T-LC required landowners to conduct an assessment of on-site wildlife habitat characteristics and possible impacts to threatened and endangered species and their habitat. The policy required that landowners of sites found to contain threatened or endangered species or 'species of special concern' submit management plans for review by the state and other interested agencies (Tallahassee-Leon County Planning Department 1990, IV-24). In addition, the county heavily managed lands in close proximity to waterways – particularly lakes - to retain vegetation, reduce flood damage, and protect water quality.

Enact land use planning strategies to protect and retain all scales of GI
At the county scale, Leon County's major planning strategies were the Urban Services Area and, to a lesser extent, rural zoning. Restrictions on infrastructure expansions combined with concurrency requirements were the county's main tools for managing growth. Over time, the actions concentrated green infrastructure at the edges of the

county. The county's monocentric growth may also have played a role. Tallahassee is the only incorporated municipality in Leon County, and the only significant city in the region, so restricting growth around Tallahassee did not undermine green infrastructure protection by increasing growth in other nearby towns.

During the study period, T-LC used a USA – located within the City of Tallahassee – to restrict development to areas where infrastructure already existed or would be soon expanded. It was county policy, in most cases, not to provide capital infrastructure beyond the USA or outside of existing communities designated for growth. In 1993, T-LC set the USA to be 50% larger than projected vacant land needs and to capture 90% of residential development at an average density of 2 dwelling units per acre. They expanded the boundary three times over the study period for a total of 125 acres. The county's 2007 Evaluation and Appraisal Report on the comprehensive plan showed the county nearly succeeded in meeting the 90% goal. Between 2002 and 2005, 86% to 88% of new residential and 97% to 99% of new commercial development located inside the USA (Tallahassee-Leon County Planning Department 2007).

T-LC also used traditional and overlay zoning to manage growth and protect canopy roads, historic resources, and natural and working landscapes. Land zoned Open Space provided for the resource protection and recreation needs of local communities. Open Space lands could be agricultural, green space, silvicultural, or perform stormwater management functions. Residential development was prohibited in Open Space districts, but structures that support the open space function of the lands were allowed (Leon County Code Sec. 10-6.658). The county also used several districts to limit development in rural areas. The Rural zoning district was intended to protect and promote farming and silvicultural activities and limit sprawl. But the zone allowed residential development at a relatively low density of one dwelling unit per 10 acres. The county also used an Urban Fringe zoning district for development at the periphery of the urban service boundary. The district allowed a mix of development and open space uses at an overall density of one dwelling unit per three acres (Leon County Code Sec. Sec. 10-6.610). Leon also had a Lake Protection Zone for the sensitive area surrounding, and watershed contributing to, Lake Jackson. The zone allowed a residential density of 0.5 dwelling units per acre (Leon County Code Sec. 10-6.616).

The county also used four overlay zones - canopy road, historic preservation, Conservation, and Preservation - to restrict development in sensitive and locally important areas. The canopy road overlay district protected trees that line the county's picturesque canopy roads and the historic preservation overlay preserved culturally important sites and buildings. Both were included in the county's official zoning map. The two other overlay zones were not. They were site scale rather than county-scale and existed only as identified through the development review process. As previously discussed, lands considered to be located within Conservation Areas are floodplains, slopes between 10% and 20%, and high quality successional forest, and lands within canopy roads, among others. Those within Preservation Areas are waterways, wetlands, slopes greater than 20%, native forests, floodplains, and the habitat of threatened and endangered species. The objective of the two zones was to minimize the impacts of development on the noted resources. Lands within Conservation and Preservation Areas were subject to additional development review and had to apply best practices in mitigating impacts on sensitive environments and ecosystems. For both overlay districts, development had to clustered on portions of a site not within the overlay. If an entire site was within the overlay, Conservation Areas could be developed at a density of no more than one dwelling unit per acre, and a Preservation Areas could be developed at no more than one dwelling unit per 40 acres (Leon County Code Sec. 10-6.700).

In 2006, the county added a Conservation Subdivision Ordinance to encourage landowners to preserve environmentally sensitive areas in the development process. T-LC was particularly supportive of conservation subdivisions in the Urban Fringe zoning district, the Lake Talquin Recreation/Urban Fringe district, and a few smaller sector plan areas. The county did not support conservation subdivisions within Rural land use categories, which it intended to keep rural. Conservation subdivisions have two sections, a reserve area and a development area. County code required that the reserve area account for no less than 50% of the parcel and be dedicated as permanent open space under a conservation easement. Provisions also required that landowners design reserve areas to be contiguous with nearby protected open space. In addition the county mandated that development occur on the least environmentally significant portion of the parcel. In Urban Fringe zoning districts, the minimum lot size in the development area was one-half acre (up to .8 acres in Lake Talquin), with a maximum density of one dwelling unit per three acres (Leon County Code Sec. 10-7.204). Between 2006 and 2010, Leon County approved three Conservation Subdivisions. One covered 203 acres of the Urban Fringe and included a 106-acre (52%) reserve and another – in the Lake Talquin Recreation/Urban Fringe – accounted for 27 acres with a 14-acre (52%) reserve. The third clustered subdivision, which was technically developed as a PUD under earlier subdivision regulations, was the largest, but the precise size and reserve area were not reported (Brockmeier 2013, personal comm.)

Protect and support GI through a collaborative and cooperative process
There are four important levels of collaboration in Floridian counties: internal, local, regional (Water Management District), state/national. Internally, the Leon County Planning Department coordinated with Growth & Environmental Management and Public Works Departments, in addition to the division responsible for development review. In many ways, Growth & Environmental Management and development review had as great an impact on the quality and location of green spaces throughout the county as the larger efforts undertaken by the Planning Department.

The existence of a joint Tallahassee-Leon County Planning Commission led to a high degree of city-county collaboration in local planning and decision-making. Large joint programs, such as Blueprint 2000, provided further incentive for collaboration in the realm of green space and infrastructure. Blueprint 2000 planning and management involved three committees, a Technical Coordinating Committee comprised of city and county staff, a Citizen's Advisory Committee comprised of scientists, environmental advocates, and interest groups, and an Intergovernmental Agency comprised of the Board of County Commissioners and City Commission. The main report, Blueprint 2000 and Beyond, also highlighted the importance of viewing proposals as 'community' projects and not dividing actions into "a city list and a county list" (Economic and Environmental Consensus Committee 2000, 10)

Cooperation between governments was also a part of green infrastructure planning in Leon County. Since 1991, the state has required that T-LC involve adjacent and interested government entities and organizations in the review of policies that impact shared natural resources. And under the T-LC Comprehensive Plan, the county is required to "work with all applicable private, local, state and federal programs" in the acquisition and maintenance of unique vegetative communities, as well as protecting and enhancing surface and groundwater." (Tallahassee-Leon County Planning Department 1990, IV-2)

The Northwest Florida Water Management District assisted T-LC in implementing the Greenways Master Plan and in complementing it through the acquisition of open space in the same system. NFWMD targeted acquisition resources to three areas within Leon County that support greenway efforts. For example, a partnership between Blueprint 2000 and NWFWMD provided $500,000 for five years to NWFWMD as matching funds to cost-share the acquisition of easements on properties located within the headwaters of the St. Marks River (Tallahassee-Leon County Planning Department 2004, 57). T-LC also benefited from state management actions on land owned by the Florida Fish and Wildlife Conservation Commission and Division of Forestry. The latter, in particular, has potential for greenway trail linkages (Tallahassee-Leon County Planning Department 2004)

Leon County's main non-profit collaborators during the study period included the Tall Timbers Land Conservancy, Apalachee Land Conservancy, Trust for Public Land, and the Natural Conservancy. The Tall Timbers Land Conservancy – part of the Tall Timbers Research Center, located in Tallahassee - has acquired over 140,000 acres in the Red Hills Region which runs from southern Georgia to northern Florida. Around 30,000 acres are in Leon County. TTRC has also assisted in negotiations to create and protect canopy roads in the county. Apalachee Land Conservancy, a smaller land trust, has also helped to protect the county's greenway network (Tallahassee-Leon County Planning Department 2004, 73)

Finally, Leon County also worked with the State of Florida to identify and protect green space resources. During the study period, Leon County received over $16 million in Forever Florida funds, through the Florida Community Trust program, to preserve 1,369 acres of land. Most were solo efforts, although the county did work with Apalachee Land Conservancy on one grant (Florida Department of Environmental Protection 2011).

Funding
Leon County's Capital Improvements Programs included two sections related to green infrastructure planning: Culture & Recreation and Public Works. Between FY2004 and FY2010, Leon County spent an average of $3.7 million per year on capital investments in parks and greenways, with a high of $6.8 million in 2009 and a low of $1.5 million the year prior. The county funded acquisition and development of four different greenways during the study period: Capital Cascades Greenway ($2.4 million), Miccosukee Greenway ($585,000), J.R. Alford Greenway ($72,000), and St. Marks Headwaters Greenway ($273,000) and allocated around $100,000 per year for greenway maintenance. In addition, the county spent nearly $2 million per year on waterway and wetland restoration, and Blueprint 2000 water quality enhancements (Leon County CIP FY2004 – FY 2011).

In 2000, Leon County residents voted to continue a one-cent sales tax extension and put the revenue toward road, stormwater, and park improvements. The majority, 80%, funds joint city/county Blueprint 2000 projects, but the remainder is split between Leon County and the City of Tallahassee. Leon County's revenue is a major source of funds for greenway and park acquisition and development. But green infrastructure is also funded through general funds allocated for capital improvements, and state and federal grants such as the federal Land & Water Conservation Fund. As previously mentioned, the county also benefited from state Florida Forever Funds. Construction funds from bond series in 1999 and 2005 also play a supporting role, and provide smaller amounts for park facilities and general improvements. In most years, park and greenway funding is split between the general fund and Blueprint 2000 revenue, with few outside funding sources (ibid). A notable exception is the county's cost-sharing partnership with the Northwest Florida Water Management District.

Green Infrastructure Network Change in Leon County
Quantity
Based upon land cover classification of Global Land Survey images from 1999 and 2009, during the study period Leon County lost 5 percent of its unpreserved agricultural base and 2 percent of unprotected forested areas to development (Table 5-2). Over the same time period, developed area increased by 22%, greater than the 15% rate of population growth. The majority of new development occurred in forested areas. Between 1999 and 2009, Leon County lost nearly 3,500 acres of forestland to development, compared to 1,000 acres of agricultural land.

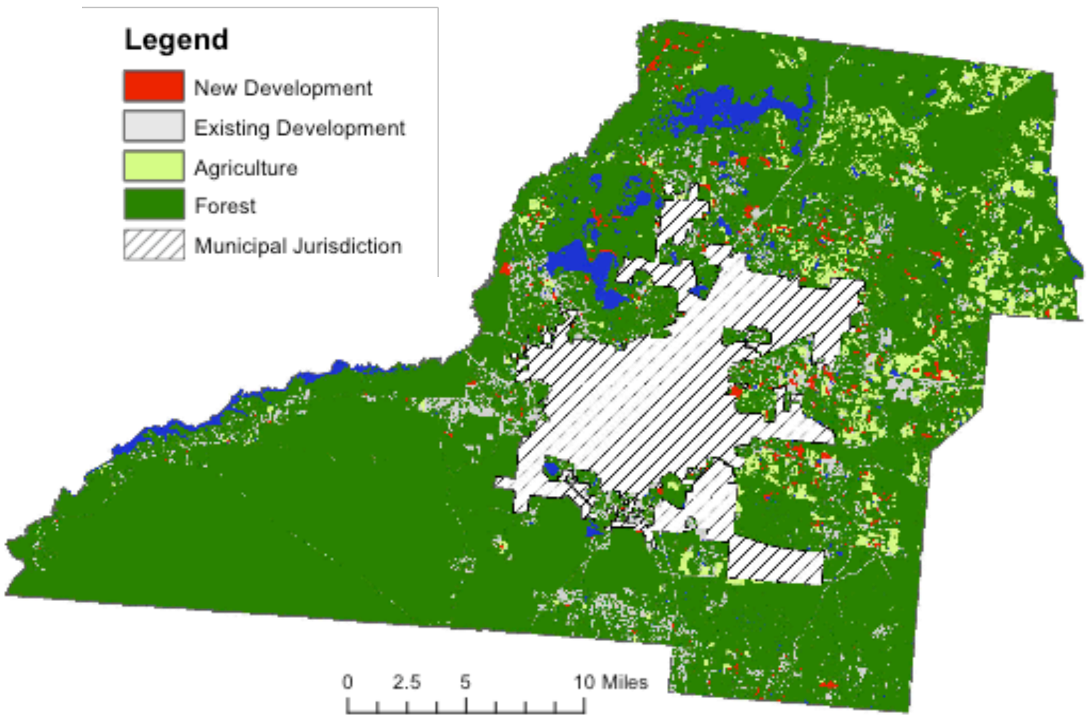
Table 5-2. Land Use Change in Leon County, 1999 to 2009* (by author).
Leon County Land Use Change

	1999 (acres)	2009 (acres)	Change (%)
Water	12,567	12,567	0
Agriculture	19,502	18,590	**-5**
Forest	185,736	182,285	**-2**
Developed Area	20,138	24,501	**22**

*Considers only privately-owned unprotected lands under county jurisdiction.

The majority of new development during the study period occurred in the central region of the county, within a commutable distance of the City of Tallahassee. Smaller patches of development also occurred in the county's relatively rural northwestern and southeastern corners (Figure 5-2). The far western part of the county, the 'toe of the boot,' is mostly state and national forestland and remained protected from development during the study period.

Figure 5-2. Forestland, farmland, and developed area in Leon County in 2009. 'New Development' is development that occurred since 1999 (by author.)



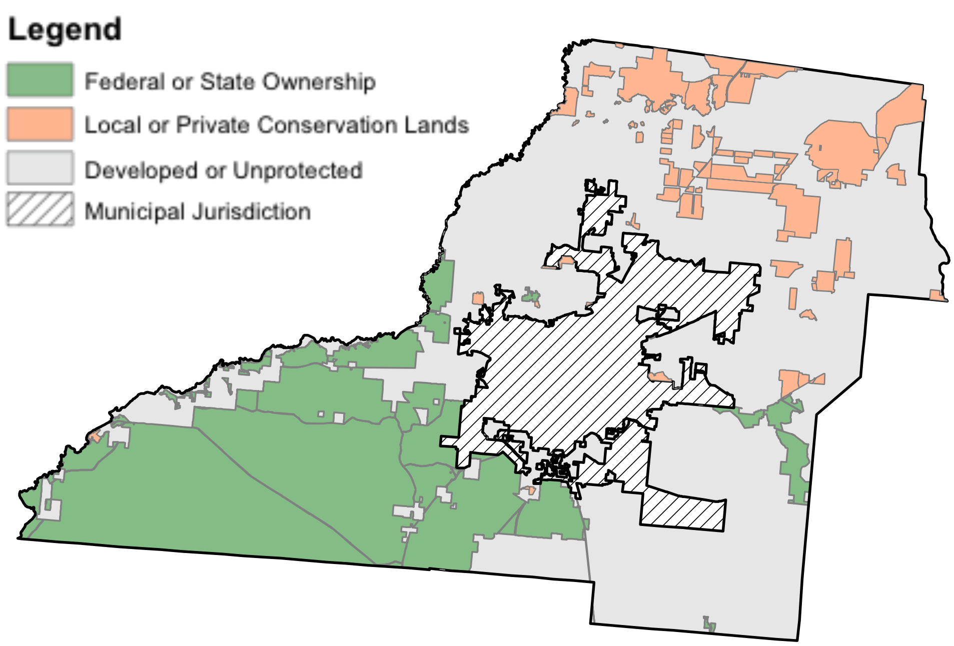
The most active preservation organization in the county is Tall Timbers Land Conservancy. The land trust holds conservation easements on 29,000 acres of land (Table 5-3). The majority of Tall Timbers easements cover former plantation lands, although a few protect sensitive water resources, and one – among the largest at 4,000 acres - is the Tall Timbers Research Station itself. The county and local Water Management District have also preserved several areas, mainly in the northern reaches of the county. Most Leon County conservation lands are parklands and greenways owned in-fee. County conservation easements are generally small, intended to protect sensitive natural areas in the development process.

Table 5-3. Land Preservation in Leon County, Florida in 2010.

	Acres
Leon County	2,683
Apalachee Land Conservancy	357
Tall Timbers Land Conservancy	28,992
Northwest Florida Water Management District	576
State of Florida	13,393
National Forest	107,000
TOTAL	**153,000**

Local and private conservation lands are grouped together in the north of the county, within the same district, if not technically adjacent (Figure 5-3). Several of the northern conservation lands are large, with significant core area, and many are adjacent, which enhances the overall connectivity and quality of the county's green infrastructure network. However, there is little interaction between state and federal lands and more local conservation lands. They function largely as separate systems. In addition, many of the northern conservation lands are protected by Tall Timbers Land Conservancy rather than local government. Local government initiatives, particularly Blueprint 2000, emphasize lands in more populated areas.

Figure 5-3. Federal, state, local, and privately-owned protected areas in Leon County, Florida in 2010 (by Author). Land conservancy properties are grouped with 'local or private.'

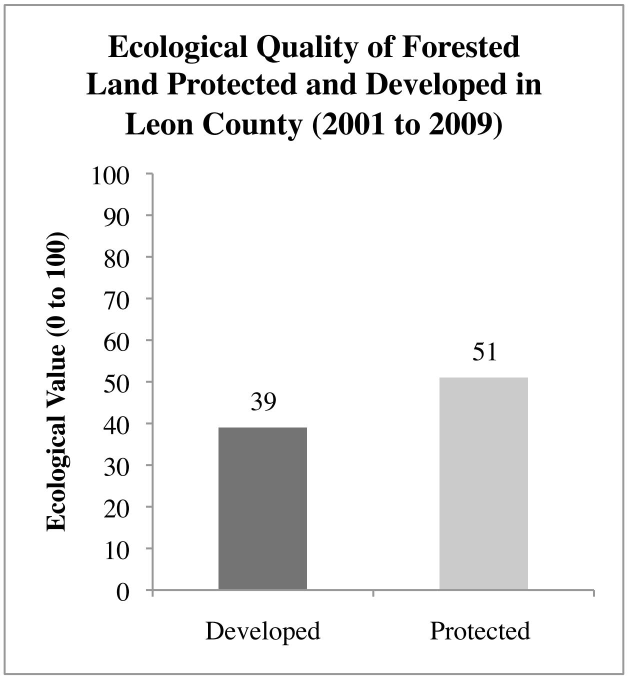


Quality
In 2001, as part of the State's Green Infrastructure Assessment, the Maryland Department of Planning created a GIS layer containing the relative ecological value of land throughout the state. One way to understand the ecological value of lands in other states is to recreate the method. For Florida, the ecological value layer includes information on sensitive and important resources such as wetlands, critical habitat, interior forest, streams, and proximity to development and roadways to form a single layer that indicates the ecological importance of land in each Floridian county on a scale of 0 (least ecological value) to 100 (most ecological value).

An important objective of green infrastructure planning is to protect sensitive and high quality resources by a) preserving them or b) directing development to other areas. A county's success in these areas can be measured by the ecological value of protected and developed lands. Developed areas should have a relatively low ecological quality while protected land should have a high ecological value. Leon County does not have enough protected agricultural land to successfully compare the quality of protected and developed farmland, so the assessment includes only forested land. Additionally, due to inequities in the amount of state and national forest land in counties in Florida (i.e. two have thousands of acres, one has almost none), the analysis includes only lands preserved by local and regional organizations such as Water Management Districts, land trusts, and local governments. Since federal and state natural resource holdings in Florida tend to be mature, high quality forest, they can skew results if they occur in the sample unevenly.

During the study period, Leon County was moderately successful in directing development to ecologically marginal areas. In 2009, the area-weighted mean ecological value of local, state, and federally protected forested lands in the county was 51. The mean ecological value of land developed between 2001 and 2009 was significantly lower, at 39. (Figure 5-4)

Figure 5-4. Mean ecological quality of forested land protected and developed in Leon County between 1999 and 2009. Protected area averages include local conservation land that was preserved prior to 1999.



Connectivity
A third objective of green infrastructure planning is to retain lands that form a network of large, interconnected, green space. A county's success in this area is indicated by stability in the connectivity and patch attributes of green infrastructure over time. Increasing connectivity is not usually feasible, but local governments can retain existing connections by preserving critical linkages and planning development in a way that does not fragment the network.

Landscape ecology metrics provide information on the spatial configuration of landscapes. A patch is an area of continuous landscape, such as farmland or forested area. Metrics noted here discuss the average patch shape for each type of green infrastructure, as well as connectivity and proximity.

During the study period, Leon County's forest network was remarkably stable. Results even show a slight increase in the Area-Weighted Proximity Index, a measure of patch size and proximity (Table 5-4). Results for farmland show some loss of connectivity. Over the study period, the average distance between patches increased by 17 meters and, as indicated by the Area-Weighted Proximity Index, patches of agricultural land became slightly smaller and further apart.

Table 5-4. Patch Shape and Contiguity Metrics for Leon County Forest and Agricultural land in 1999 and 2009 (by author).

	Forested Land			Agricultural Land		
	2001	**2009**	**Change Notes**	**2001**	**2009**	**Change Notes**
Area-weighted Mean Patch Length/Contiguity (GYRATE_AM)	20,699m	20,724m	MC	340m	341m	MC
Patch Shape Complexity (SHAPE_AM)	38	39	MC	3.3	3.3	MC
Patch Aggregation (CLUMPY)	0.94	0.94	MC	0.8	0.8	MC
Area-weighted Mean Distance to Nearest Like Patch (ENN_AM)	60m	60m	MC	129m	146m	Increase in distance to nearest like patch
Area-weighted Mean Patch Size and Proximity Metric (PROX_AM)	4,519	4,748	Patches become (slightly) larger and closer	87	77	Patches become (slightly) smaller and more distant

Overall

Between 2000 and 2010, the Leon County Planning Department and Department of Growth & Environmental Management conducted a high level of green infrastructure planning. The county's activities covered 63 percent of the policies and strategies included in the Green Infrastructure Planning Framework. The county's greenway program and use of infrastructure-oriented growth management strategies – such as the USA – contributed to the high score. Leon was also dedicated to strong development review through the environmental permitting process and protection of identified resources with Conservation and Preservation Areas overlays. Provisions requiring permanent protection and management planning for sensitive resources also contributed to the score. Finally, the diversity of green infrastructure types that T-LC and partners identify and protect – canopy roads, former plantation lands, wetlands, floodplains, habitat areas, forests, trails, etc – is also a key aspect of the county's green infrastructure strategy. The county's main weaknesses are rural zoning, which allows significant development, and slow local land preservation. While the program has been active, Blueprint 2000 has not resulted in preservation of large green space parcels.

The county's green infrastructure network remained relatively stable over the study period, despite a 22% increase in developed area. Around 3,500 acres of forested land was converted to other uses, but the change had no impact upon the connectivity of the county's forest network. Patch metrics show that the county actually gained connectivity over time. The result is most likely due to reforestation of open spaces in former agricultural areas or large-lot subdivisions that were new and bare in 1999, but grew in over the time period and presented as forested in 2009. The county was also fairly successful in steering development to lower quality forest areas. The average ecological quality of developed forestland was 12 points lower than that of protected forestland. Since the county has far less agricultural land than forested land, the 1,000 acres of farmland lost to development had an impact on connectivity. Metrics show agricultural patches becoming smaller and further apart over the time period.

MODERATE GREEN INFRASTRUCTURE PLANNING: ALACHUA COUNTY

Alachua County has strong environmental protection regulations, but from 2000 to 2010, employed only a moderate level of green infrastructure planning. The county's weak rural zoning and lack of a landscape-scale green space strategy did not support a cohesive network of green infrastructure. However, Alachua did have a strong land preservation program with a dedicated funding source and regulations protecting important habitat and mature trees, both of which contributed to the quality and level of protection of green space resources in the county.

Demographics, Economy, and Environment

Between 2000 and 2010, the population of Alachua County increased by 13.5% to 247,000. While faster than the United States as a whole, the rate was slower than the booming state of Florida's 17.6% (US Census). Alachua County contains nine incorporated municipalities, but only one with a population greater than 10,000. That city, Gainesville, had a 2010 population of 124,000. Gainesville is the county's economic center, and identified by the US Census as the principal city of the two-county Gainesville, Florida Metropolitan Statistical Area, which includes unincorporated Alachua County and adjacent Gilchrist County (ibid).

Education and medicine are major employers in Alachua County. The University of Florida, the state's largest public university, is the largest single employer in the Gainesville MSA with nearly 15,000 jobs. The county is also home to several major medical centers, including Shands Hospital with over 12,500 employees (Gainesville Area Chamber of Commerce 2009). Influenced by the prevalence of higher education facilities and medial careers, the county has a high level of educational attainment. Nearly 70% of the over-25 population has at least some college education, greater than the state average of 51% (ACS 2010).

Alachua County was impacted by the recession, but to a lesser extent that the state of Florida, as a whole. Between 2000 and 2010, the county's unemployment rate increased from 3% to 7.9% while the state's grew more dramatically, from 3.8% to 11.3% (BLS 2000, 2010). Median household income also fell, but only slightly, by less than 2%. Despite moderate economic challenges, the housing market remained strong. Inflation-adjusted home values increased 43% over the time period to $188,000, a value in line with the median home value for the state of Florida (US Census).

Agriculture is a locally important industry in Alachua County, but not a major economic driver. According to the 2007 Census of Agriculture, the market value of agricultural products sold in Alachua County was $92.1 million, about 1% of Florida's $7.7 billion.

The county ranks 16th in the state in livestock sales value and 19th in crop value, out of 67 counties (United States Department of Agriculture 2009). Alachua is better known for its forest resources. While the county has few federal lands, Paynes Prairie Preserve State park is the largest protected area at over 21,600 acres. In all, the state manages almost 40,000 acres of the county for recreation and natural resource protection, mostly in the county's heavily wooded southeastern quadrant. The St. Johns River Water Management District also owns land in that region, most prominently the Lochloosa Wildlife Conservation Area at 10,600 acres and the adjoining Georgia Pacific-Lochloosa Conservation Easement at 16,700 acres. The county's two water management districts manage 61,000 acres of Alachua County for its water quality benefits.

Green Infrastructure Planning in Alachua County

The Alachua County Growth Management Department (GMD) is responsible for the majority of planning in the county. GMD conducts traditional urban planning tasks such as maintaining the county's comprehensive plan and land development regulations. The Environmental Protection Department (EPD) also plays an important role in green infrastructure planning. EPD conducts environmental planning and development review and manages the county's land conservation and management programs, including Alachua County Forever.

Alachua County had a score of 77, representing 55% of the policies, programs, strategies in the Green Infrastructure Planning Framework. Alachua County employed a moderate-level of green infrastructure planning during the 2000 to 2010 study period (Table 5-5). The county's strengths are in managing green infrastructure to support ecosystems services and enacting land use planning strategies that protect green infrastructure of all scales. The county lags behind in policies and strategies that create linkages and foster connectivity and in collaborative and cooperative processes. The following sections provide an overview of planning in Alachua County and describe the policies and strategies through which Alachua County furthers each principle of green infrastructure planning. For a complete Green Infrastructure Planning Assessment Framework for Alachua County, see Appendix 5-A.

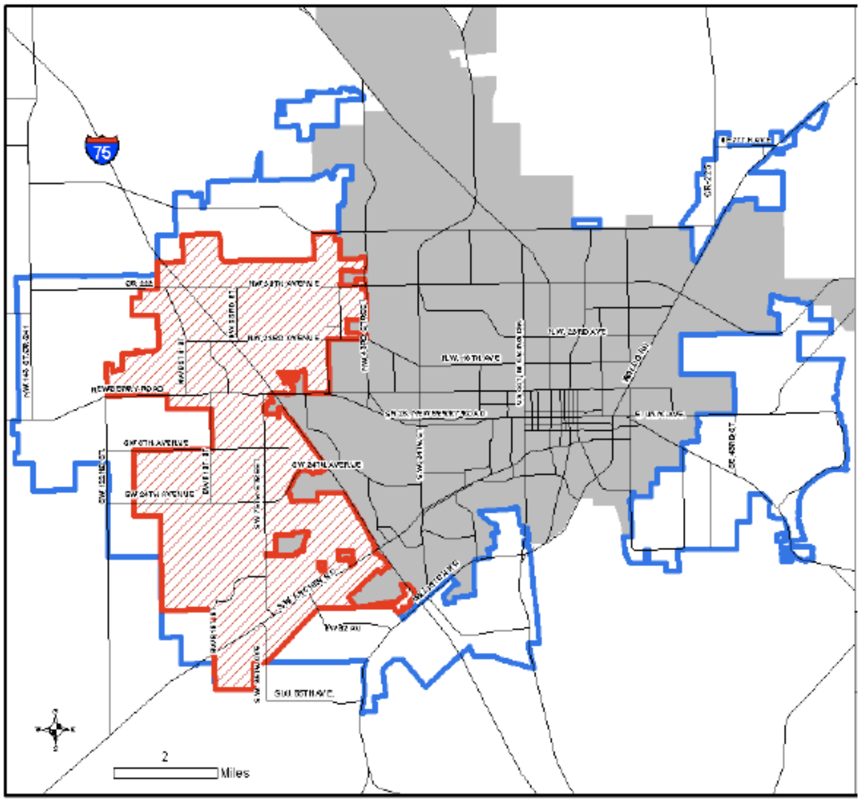
Table 5-5. Alachua County Green Infrastructure Planning Framework Results Summary

Green Infrastructure Principle	Framework Score (Out of 20)
Create linkages and foster connectivity	**8**
Value areas of ecological quality and local importance	**11**
Support a variety of landscapes and ecosystem services	**10**
Restore and mitigate damage to green infrastructure	**10**
Manage green infrastructure to support ecosystem services	**14**
Enact land use planning strategies to protect and retain all scales of GI	**12**
Protect and support GI through a collaborative and cooperative process	**12**
TOTAL (Out of 140)	**77**
PERCENTAGE	**55%**

In 2001, Alachua County adopted significant amendments to its comprehensive plan in hopes of managing growth extending from the City of Gainesville into rural areas. Among other changes, the county added an Urban Services Line around Gainesville, mandated that new developments connect to sewer and water, and required that development in rural areas be clustered to preserve at least 50% of a site's land area as open space (Shires 2001). But developer interests are strong in Alachua, and the changes faced legal opposition from a group of landowners claiming the amendments limited their ability to make use of their property. Twice over the following three years, judges held that the plan complied with Florida law and by 2005 the plan and implementing codes and ordinances finally took effect (Chestnut 2005).

Alachua County's major planning objective was to contain development within the Urban Cluster and Urban Service Area and protect natural resources beyond (Figure 5-5). The Urban Cluster covers 37,000 acres adjacent to the City of Gainesville. The county delineated the area in 1991 as the portion of the county to which growth, public services, and infrastructure investment would be directed. The Urban Cluster line has been relatively stable over the years, with only a few small expansions, and effective at containing development. Between 2002 and 2009, 91% of approved dwelling units were located inside the Urban Cluster (Alachua County Department of Growth Management 2009). The much-challenged 2001 comprehensive plan amendments added a second boundary, the Urban Service Area (USA), which covers 16,000 acres of urbanized land within the Urban Cluster. The objective of the USA is to promote high-density, mixed use, and transit-oriented development – particularly infill - in its coverage area. In short, the Urban Cluster minimizes the expansion of development – and urban services – into rural areas, while the USA increases the level of urbanization in key previously-developed areas of the county (Alachua County 2010).

Figure 5-5. Alachua County Urban Cluster and Urban Service Area boundaries. Map by Alachua County Department of Growth Management (2010).
Key: Red = Urban Service Area; Blue = Urban Cluster; Grey = Municipal Boundary.



Outside of the Urban Cluster and USA, Alachua protects natural resources mainly through rural zoning, development review, and land preservation. The majority of land outside the two boundaries is zoned for rural or agricultural uses (See Figure 5-6). While the rural zones themselves are not restrictive – they allow development at a density of one dwelling unit per five acres – the county's cluster 2001 provisions were an improvement.

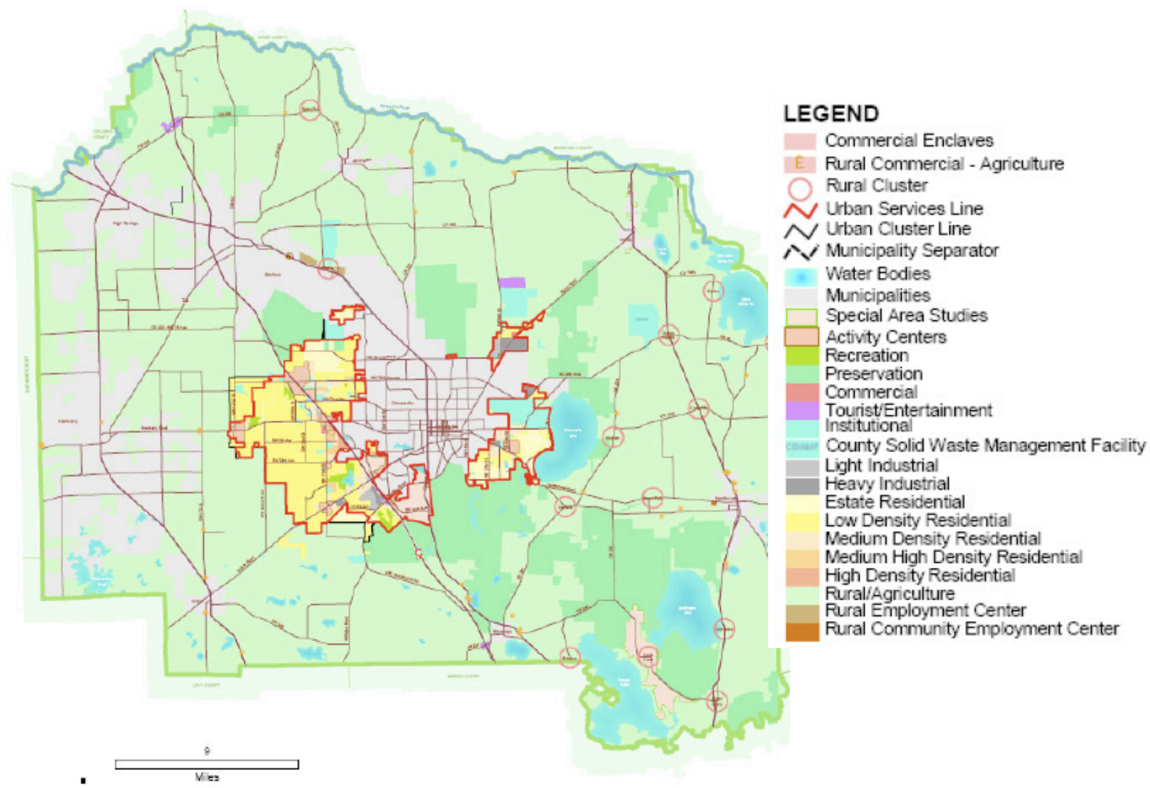
Alachua County also has an active land acquisition program, Alachua County Forever. In the 1990s, the county lagged behind others in the region in conservation. It had no land acquisition program and made few investments in conservation land. A 1999 poll showed that 84% of residents were concerned their unprotected natural assets could be lost forever. Acting on their concern, in 2000, residents approved the Alachua County Forever General Obligation Bond Tax by voter referendum. The property tax is dedicated to debt service on conservation land acquisition. In addition to purchasing conservation easements, funds are used to create management plans and provide public access (Alachua County 2001). In 2002, the board of county commissioners approved a series of steps to guide land acquisition selection, including site scoring criteria based mainly upon ecosystem services criteria:

- Environmental Values: Protection of Water Resources

- Environmental Values: Protection of Natural Communities and Landscapes (Diversity, rarity, system connectivity, protected property adjacency, size)
- Environmental Values: Protection of Plant and Animal Species (Quality, diversity, rare species habitat, native-species, migration/breeding site)
- Social/Human Values (Recreation potential, urban planning benefits)
- Management Issues (Feasibility)
- Economic/Acquisition Issues
  (Alachua County Resolution 02-017)

By mid-2000, most local workshop attendees agreed that Alachua County Forever was a successful program, although it could benefit from an increase in funding (Alachua County Department of Growth Management 2007). Between 2000 and 2010, the county protected 18,218 acres of land through the program (Alachua County 2010).

Figure 5- 6. Alachua County Future Land Use Map. Light green is rural/agricultural and bright green is preserved area (Map by Alachua County Department of Growth Management 2007)



Create linkages and foster connectivity
Early 2000 comprehensive planning documents for Alachua County described the importance of connectivity as it relates to habitat and recreation areas, but landscape-scale connectivity was not a major theme. For example, data and analysis supporting the comprehensive plan's conservation element mentioned the interconnectedness of the county's recreation and open space network, but viewed that system as functionally separate from – or even potentially hazardous to – the quality of the natural environment.

As we coordinate the acquisition of environmentally sensitive lands with our network of recreation and open space facilities, we must identify the kind and degree of human access which natural systems in these areas can support. As we link these natural areas into an interconnected system, we must consider the broader implications of that linkage. Opening areas to human contact can be detrimental if development is allowed to proceed in a manner that fragments natural systems.

The county's connectivity focus was plant and animal habitat. Alachua County's comprehensive plan included a broad objective of protecting species diversity and distribution by "protecting significant plant and wildlife habitats, providing for habitat corridors, and preventing habitat fragmentation" (Alachua County 2005, C-39). While there is little evidence the county followed through with the rule at the county scale, planning documents also contained a provision stating that the county should preserve corridors that connect significant plant and animal habitat throughout the county (Alachua County 2005). Notably, during the study period, the county did not have a landscape scale conservation strategy that included green infrastructure hubs and important corridors or links. But by the end of the decade, the idea had become part of the county's planning strategy. Alachua's 2009 Comprehensive Plan Evaluation and Assessment Report (EAR) discussed potential strategies for creating a green infrastructure network, such as prioritizing protection of mapped ecological corridor areas and preserving linkages between green space hubs (Alachua County Department of Growth Management 2009).

Alachua County has supported connectivity at the county scale through land preservation prioritization and at the site scale through retaining habitat and other system connections in the development process. As discussed in the previous section, Alachua County Forever, the county's land acquisition program, included a number of criteria to guide selection of conservation properties. The second category of criteria, "Environmental Values: Protection of Natural Communities and Landscapes" included questions related to a candidate parcel's role creating a network of green space. Considerations included whether or not a candidate property is functionally connected to other natural communities, adjacent to properties that are already preserved or in public ownership, and relatively free of internal fragmentation (e.g. roads or power cuts) (Alachua County Resolution 02-017).

On a smaller scale, the county required landowners developing parcels with conservation areas (sensitive or important resources) to retain vegetation and "logical contiguous boundaries to eliminate or minimize fragmentation to the greatest extent practicable." When delineating the protected areas that would surround important conservation features, landowners were required to consider – among other factors - contiguity with adjacent habitat, habitat corridors, wetlands, and floodplains and whether the size and shape that will minimize fragmentation (Alachua County Code Section 406.97)

Value areas of ecological quality and local importance
Alachua County's comprehensive plan identified and mapped important environmental resources and proposed resource-based indicators to assess natural resource gains or losses. The plan's Future Land Use Map included some sensitive resources, in addition to preservation areas (Alachua County 2005). Alachua also identified strategic ecosystems, areas on private lands with unique and high quality natural communities.

Between 2000 and 2010, the county enhanced green infrastructure through conservation and preservation areas, development review, and land preservation requirements. Alachua County designated private land with sensitive and important natural features as conservation areas. Conservation areas included wetlands, waterways, floodplains, endangered species habitat, significant geologic features, and strategic ecosystems. Conservation and agricultural uses were preferred in such areas, but county code did allow development if it was clustered on less sensitive areas of a parcel and did not exceed the overall zoned density for the site. The county required landowners developing a parcel with a conservation area to transfer density from the conservation area to a non-conservation area on the same property or on an adjacent property under the same ownership (Alachua County 2005).

As part of the development review process, the county required landowners to identify conservation areas and delineate protective conservation management areas. A site's conservation management area included the entire extent of the conservation area and any buffers and linkages needed to protect the quality of the resource. Alachua County required conservation management areas to be permanently protected by a conservation easement or other legal instrument that runs with the land. County code required the property owner or easement holder to manage the conservation management area in the long term to protect its ecological value and function (Alachua County Code Section 406.100).

During the study period, protected public lands in Alachua County were called preservation areas. Preservation areas included green infrastructure hubs such as state parks and conservation land owned in fee or less-than-fee by local governments or water management districts. Lands protected from development by conservation easement could be designated as preservation areas if they were managed for the conservation of environmental resources. The county required preservation areas to have a long-term management plan created by a public agency (Alachua County 2005)

To minimize edge effects, Alachua County required development on the periphery of conservation and preservation areas to include vegetated buffers. Requirements varied by site, but ranged from an average of 50 feet (minimum of 35) for small surface waters and wetlands with no listed species to an average of 150 feet (minimum 100) for designated Outstanding Florida Waters (Alachua County 2005). The county also had a special overlay zone – the Preservation Buffer Overlay District – that restricted development in the area immediately surrounding preservation areas.

Under county code, landowners applying for land use change or development approval in Alachua County had to provide an inventory of natural resources. The county required that the inventory include an assessment of the quality of the resources, the impact of the proposed development, mitigation measures, and a maintenance or monitoring plan with particular attention to the county's natural resource indicators. The Alachua County Environmental Protection Department and relevant regional, state, and federal agencies were also notified for comment. Parcels greater than two acres were subject to special review for 'listed plant and animal species habitat' and for 'significant plant and wildlife habitat.' If it was possible that development would impact important habitat, applicants were also required to submit a detailed habitat survey and management/protection plan (Alachua County Code Sections 406.10, 406.20).

Alachua County also protected natural resources through tree and native vegetation regulations. In most cases, the county prohibited landowners from removing mature trees and existing native vegetation without a permit. In addition, development plans needed to ensure that at least 20% of the pre-development tree canopy would remain after development and that, within 20 years, at least 30% of the site would be under mature canopy.

Finally, the majority of the county's criteria for selecting properties for acquisition through the Alachua County Forever Program emphasized ecological quality. The county prioritized properties that contained rare/important species or geologic features and diverse, high quality, natural communities (Alachua County Resolution 02-017).

Support a variety of landscapes and ecosystem services

The county emphasized mature trees, native vegetation, and plant and animal habitat in rules and regulations impacting green infrastructure, but scenic roadways, historic resources, wetlands, floodplains, and strategic ecosystems were also important aspects. The county's zoning ordinance included a Scenic Road Corridors Overlay. The Overlay protects the land immediately surrounding thoroughfares with scenic, historic, or cultural significance. The county's comprehensive plan also included a Historic Preservation Element with provisions that encourage synergies between historic and natural resources. For example, "complimentary environmental, natural, and other features may be used as factors for determining the boundaries of potential historical or archaeological districts" (Alachua County 2005, HP-3).

The Alachua County Code also included sections specifically oriented toward surface waters and wetlands, floodplains, and strategic ecosystems. All three are included in conservation area delineations, but enjoy further protections under county regulations.

Surface water and wetland policies require landward buffers that vary by site importance and sensitivity, but range in size from an average of 50 feet for small waterways and wetlands with no listed species to an average of 150 feet for Outstanding Florida Waters. The regulations also require that development results in no net loss of wetlands and no impact on listed species and their habitat (Alachua County Code Sections 406.43, 406.44). The county also has a specific set of regulations for preserving the hydrological function of 100-year floodplains. In the development process, landowners must preserve floodplain area ecological functions such as water purification, water supply, and wildlife habitat and connectivity (Alachua County Code Section 406.53).

Finally, the county has identified and protected strategic ecosystems through development review and the Special Area Planning Process. In 1996, consultant KBN/Golder Associates completed an ecological inventory of Alachua County. The inventory identified a number of important, but sensitive, ecosystems that the county should take special care to protect. Under 2005 regulations, the county can require that up to 50% of a property be protected because it includes a strategic ecosystem (Alachua County Code Section 406.35). Where strategic ecosystems occur on agricultural or silvicultural lands, the county works with landowners to manage critical areas for ecosystem function (Alachua County Code Section 406.34). For strategic ecosystems located in growth areas, the county prefers to create protective Small Area Plans. Development applications within strategic ecosystems that are not subject to a Small Area Plan follow conservation areas rules and must cluster development on less sensitive portions of a site and show that the development will not impact ecological resources (Alachua County Code Section 406.38).

Restore and mitigate damage to green infrastructure

Alachua County has required property owners to mitigate the impacts of development on conservation and preservation areas, broadly, and more specifically on trees and native vegetation, and wetlands. The Alachua County code of regulations included a section on "Avoidance, Minimization, Mitigation and Monitoring" that outlined general natural resource mitigation requirements. Most importantly, mitigation was an acceptable option only where the county could determine the result would be "no actual net loss of the resource function or value" (Alachua County Code Section 406.114). Mitigation proposals submitted to the county usually compensated for resource impacts by protecting twice the area of a comparable resource type. The county preferred onsite mitigation, through replanting or relocating movable resources, but offsite was possible if the former was not feasible. Mitigation projects had to be monitored for two years to ensure their success. Fee-in-lieu of land was also an option. Collected funds contributed to the environmentally sensitive lands fund, which the county used to purchase and manage resource lands (ibid).

Two resource types had more specific mitigation requirements: trees and native vegetation, and wetlands are more specific. Alachua County regulations protected mature trees and required that removal or alteration of regulated mature trees be mitigated, preferably on site. In most cases, the county required tree replacement at a ratio greater than 1 to 1, in accordance with a provided guidance table. For example, according to the table, if a tree between 11 and 14 inches in diameter was removed, it had to be replaced by 4 trees. At least 50% of replacement trees had to be the same species as the tree removed (Alachua County Code Sections 406.13, 406.15). For wetland impacts that were unavoidable or in the public interest, landowners could also mitigate rather than prevent losses. The county required that mitigation of impacts occur within Alachua County, and within the same watershed, if possible. Mitigation also had to comply with the Uniform Wetland Mitigation Assessment Method that is part of the Florida Administrative Code (Alachua County Code Section 406.48).

Manage green infrastructure to support ecosystem services

Alachua County regulations have required management plans for preservation areas, significant plant and animal habitat, trees and vegetation, and preserved portions of clustered subdivisions. In Alachua County, publicly-owned protected areas with resource conservation values were classified as preservation areas. All preservation areas were required to have long-term management plans (Alachua County 2005). This requirement included lands acquired through Alachua County Forever, which became preservation areas, post-acquisition. A public agency had to create a plan for each preservation area that included identification of important resources and buffers, goals for the property, public access proposals or limitations, management actions, and an implementation schedule, unless the property had a conservation easement, in which case that document could serve as management plan (Alachua County 2005).

Two of Alachua County's more specific management emphases during the time period were significant/listed plant and animal habitat and trees and native vegetation. As part of the development review process, landowners of parcels with significant or listed habitat had to work with qualified professionals and state agencies to develop a habitat management plan. The plan needed to include measures necessary to maintain biodiversity and the value of habitat conservation areas, including, where necessary, replacing invasive vegetation with native vegetation (Alachua County 2005). In addition, the county required landowners to manage their property for mature native vegetation. For example, property owners had to increase (or retain) canopy cover to 30% and remove prohibited or discouraged non-native vegetation from a parcel prior to the final development inspection (Alachua County Code Section 406.12)

Between 2005 and 2010, cluster development was one of Alachua County's main open space protection strategies. At least 50% of clustered subdivisions in rural areas were required to be protected in perpetuity as open space. The county also required that the protected area portion of each clustered subdivision (often including a conservation management area) have a management plan to retain the land's conservation values over the long term (Alachua County Code Section 407.77).

Enact land use planning strategies to protect and retain all scales of GI

Between 2000 and 2010, Alachua County used urban service boundaries, traditional and overlay zoning, and cluster development to keep development compact and retain green infrastructure. The county first enacted an Urban Cluster boundary in 1991 to create a line beyond which urban services would not be extended and followed it up with an Urban Services Area in 2005. Together, the two encouraged compact development in areas that were already serviced by sewer, water, and other urban services.

Outside the urban service boundaries, one of Alachua County's main tools for protecting rural resources was zoning. But, during the study period, the majority of land outside the Urban Cluster was within the Agricultural (A) zoning district, which had a maximum residential density of 1 dwelling unit per five acres. Notably, the county's 2005 zoning code included more protective zones for agricultural (1 dwelling unit per 20 acres) and silvicultural lands (1 dwelling unit per 40 acres), but the zones were only available as part of a TDR program, which was not formally established until 2008 (Alachua County Code 403.04). According to 2005 comprehensive plan documents, "At present, TDRs have not been shown to be a viable alternative in Alachua County" (Alachua County 2001, C-19). Since the TDR program was not active until after 2010, its effects are outside the bounds of this study.

During the study period, Alachua County was faced with mitigating the threat of conventional 5-acre lot subdivisions while allowing residents sufficient economic use of their land. The county addressed the issue by requiring clustered development of land designated as Rural/Agricultural on the Future Land Use Map. Under the county's subdivision regulations, larger developments – those with more than 25 lots - were required to cluster development such that at least 50% of the parcel remained as open space. Open space could be working landscape, natural landscape, or a stormwater facility, but had to be protected in perpetuity by a mechanism that runs with the land and subject to a long term management plan (Alachua County Code Section 407.70). As part of the settlement that allowed the 2001 comprehensive plan amendments to take effect, the county added additional benefits for landowners required to cluster development. The incentive took the form of bonus units (Alachua County Department of Growth Management 2009). Each landowner using a conservation subdivision design automatically received two bonus units, and could gain additional bonus unit for each 10 acres of conservation area protected in open space and for each 20 acres of non-conservation area protected as open space (Alachua County Code Section 406.03(c)).

However, as in Leon County, the cluster regulations did not have a significant impact. Two clustered subdivisions were approved, in 2007 and 2008, respectively, but they were not constructed and the approvals expired. Both would have been large, 440 acres and 354 acres, respectively, with 308 acres and 175 acres of open space (Bardi 2013, personal comm.) In 2001 Alachua County had a surplus of large lots - about 5,000 undeveloped five-acre parcels - that were not required to cluster development because they had already been platted (Shires 2001). The development of these lots could explain the lack of clustered development under regulations that require clustering.

The county also employed two overlay districts that impacted green infrastructure, a Preservation Buffer Overlay District and a Scenic Road Corridors Overlay District. The

Preservation Buffer Overlay District included all land within 660 feet of land designated as Preservation on the Future Land Use Map of Alachua County or any adjacent locality. The objective of the District was to carefully consider the type, proximity, and impact of development adjacent to Preservation areas. Development within the Preservation Buffer Overlay District required notification of agencies responsible for the Preservation area in question and a minimum buffer of 100 feet from the area's boundary. The buffer had to be maintained in a natural state (Alachua County Code Section 405.33). The objective of the Scenic Road Corridors Overlay District was to protect the area immediately surrounding roadways with significant scenic, historic, archaeological, and cultural resource attributes. The overlay extended 100 feet from a designated road's right-of-way and served to preserve the area's scenic quality by preventing actions such as development and tree removal that would undermine it (Alachua County Code Sections 405.37, 405.38).

Protect and support GI through a collaborative and cooperative process
The Alachua County Growth Management Department and Environmental Protection Department worked together to plan for and protect green infrastructure, particularly through the development review process. The county and bordering municipalities and counties reviewed each other's comprehensive plans and coordinated with the local metropolitan planning organization in regional collaborations. The county's two water management districts, the Suwannee River Water Management District (SRWMD) and St. John's River Water Management District (SJRWMD), were also major partners in the county's long-term water supply planning and water quality protection efforts. The water management districts were also responsible for stormwater management and land preservation that protects water resources, as funded through Florida Forever, among other sources.

During the early part of the study period, cooperation between the County and the City of Gainesville was limited to plan review, making green space and trail connections and - on occasion - applying jointly for state funding. The relationship deepened toward the end of the study period when the annexation of a large strategic ecosystem spurred dialog and eventually a more unified approach to protecting resources within the areas immediately surrounding the City (Alachua County Department of Growth Management 2009). The county's 2009 EAR described communication between the county and municipalities on resource protection comprehensive plan amendments as, 'good,' but noted that most dialogue was reactive. There was little proactive cooperation in protecting strategic ecosystems and other natural resources along the municipal-county boundary (ibid).

In 2000, Alachua County had one land trust, Alachua Conservation Trust. Alachua Conservation Trust was (and is) the most active in the county and aimed to preserve natural and cultural lands in and around Alachua. Of the 11 Florida Forever projects within Alachua County during the study period, two were by the county, in partnership with Alachua Conservation Trust, and four were by the Trust alone. In 2001, two new land trusts formed: Conservation Trust of Florida and Santa Fe Land Trust. The former worked to protect natural and working landscapes and to help rural landowners maintain traditional industries while the latter was formed to help preserve a wildlife corridor along the Santa Fe River and is oriented toward sensitive lowlands and wetlands (Alachua County 2001).

State funding, through Florida Forever grants, was a major boon to land preservation in Alachua County during the study period. While the county could fund local land preservation directly, Florida Forever dollars were also useful as matching funds to enable projects. Between 2000 and 2010, Florida Forever funds preserved 14,632 acres of Alachua County at a cost of $30.5 million - spread over 11 projects. Alachua County applied for four of the grants alone and for three others in partnership with organizations such as land trusts or local municipalities (Florida Department of Environmental Protection 2011).

Funding

Alachua County's Capital Improvement Programs of the time included green space as 'parks and recreation.' Between FY2005 and FY2010, Alachua County spent an average of $837,000 per year on capital investments in parks and preserves. The value is low because there were several years within the study period where the county concentrated on improvements to existing parks rather than acquiring and managing new parks and preservation areas. The county did this mainly during the lean economic years of FY2008 – FY2010 because improvements such as new restrooms and community center upgrades would not yield new operating costs like new parkland would. For example, in 2006, the county spent $1.4 million from the general fund to support five green infrastructure projects and in 2007 the county spent $2.2 million on six projects. But in 2009 and 2010, the county funded only one project each year, and using Alachua County Forever Funds rather than general appropriations. In all, over the study period, the county funded seven parks and three preserves, using a combination of appropriations and dedicated Florida Forever tax revenue (Alachua County CIP FY2004-FY2010).

Alachua County benefited from two different land acquisition funding sources between 2000 and 2010, Alachua County Forever and Florida Forever. Alachua County Forever was funded by a dedicated property tax, as approved by voters in 2001. The average property owner's cost per year was $33 or $660 over the course of the 20-year program. By 2009, the county had protected more than 17,000 acres through the program. The State of Florida, through Florida Forever, was also an important conservation partner. Between 2000 and 2010, Florida Forever invested $30 million in Alachua County to preserve 14,600 acres. Both programs also yielded matching funds from a variety of sources in addition to contributions from donors (Florida Department of Environmental Protection 2011).

Green Infrastructure Network Change in Alachua County

Quantity

Between 2001 and 2009 – the satellite image dates – Alachua County lost 3% of its unprotected agricultural land and 16% of forestland (Table 5-6). The county's developed area increased by 22%, almost 10% greater than the county growth rate of 13.5%. The majority of developed land was forested (4,700 acres), but agriculture also represented a significant portion with about 2,500 acres lost.

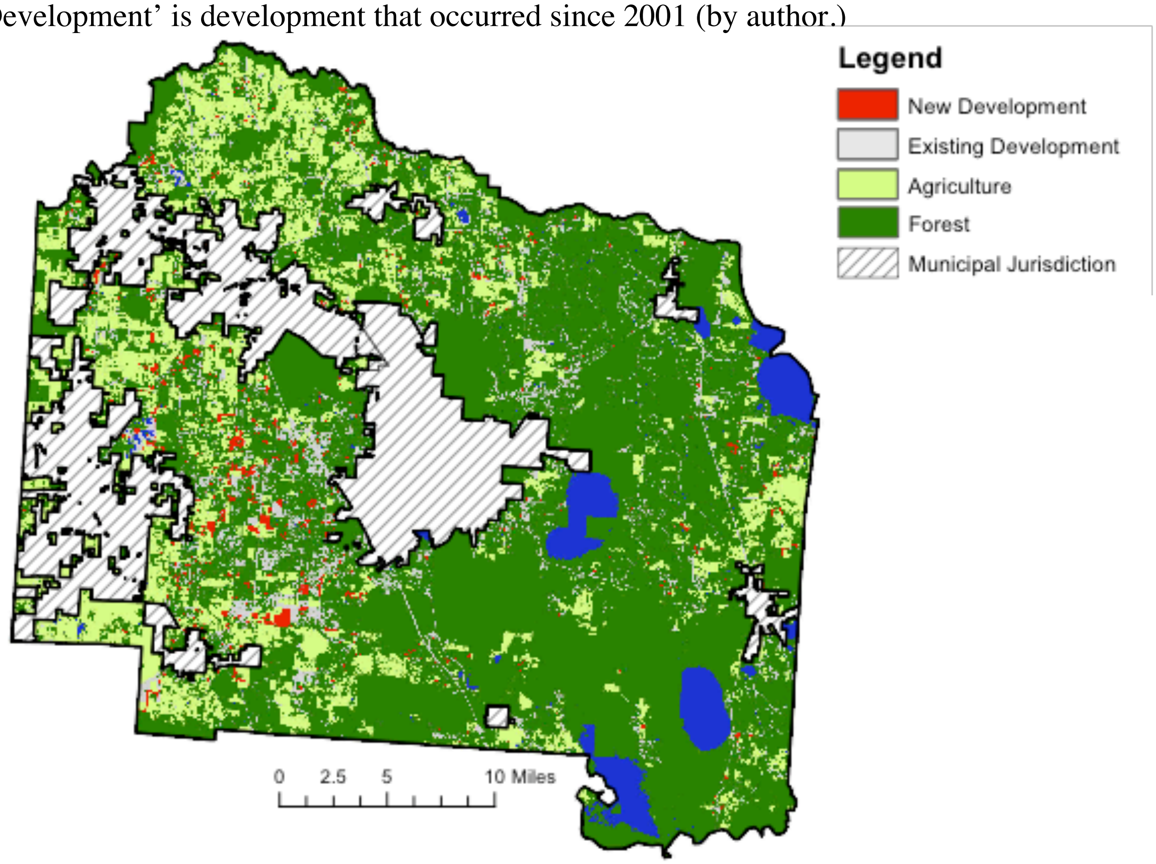
Table 5-6. Land Use Change in Alachua County, Florida from 2001 to 2009* (By Author).

Alachua County Land Use Change

	2001 (acres)	2009 (acres)	Change (%)
Water	21,559	21,559	0
Agriculture	98,031	95,519	**-3**
Forest	29,028	24,360	**-16**
Developed Area	32,566	39,745	**22**

*Considers only privately-owned unprotected lands under county jurisdiction.

Figure 5-7. Forestland, farmland, and developed area in Alachua County in 2009. 'New Development' is development that occurred since 2001 (by author.)



The majority of development occurred in the western region of the county, between the municipal jurisdictions of Gainesville and Newberry (Figure 5-7). Smaller pockets of development did occur outside of the main concentration, mainly on the periphery of agricultural or previously developed areas.

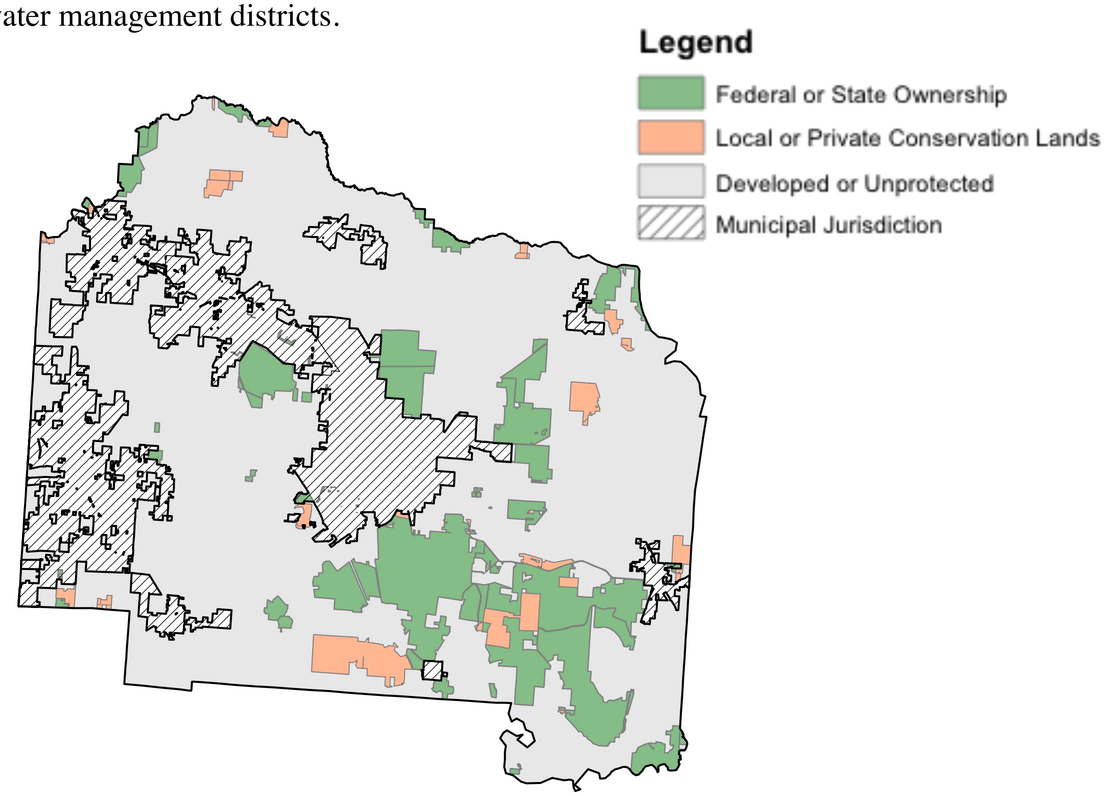
Since it launched Alachua County Forever in 2001, Alachua has protected over 18,000 acres, primarily of forestlands. Several nonprofits have also been active in the county. The Florida Audubon Society and The Nature Conservancy own conservation lands and Alachua Conservation Trust, the county's most active land trust, holds four conservation easements totaling 1,200 acres.

Table 5-7. Preserved Land in Alachua County, Florida in 2010.

	Acres
Alachua County	18,218
Alachua Conservation Trust	1,207
Water Management Districts	61,066
State of Florida	39,141
National Non-profits (TNC, etc)	839
TOTAL	**120,471**

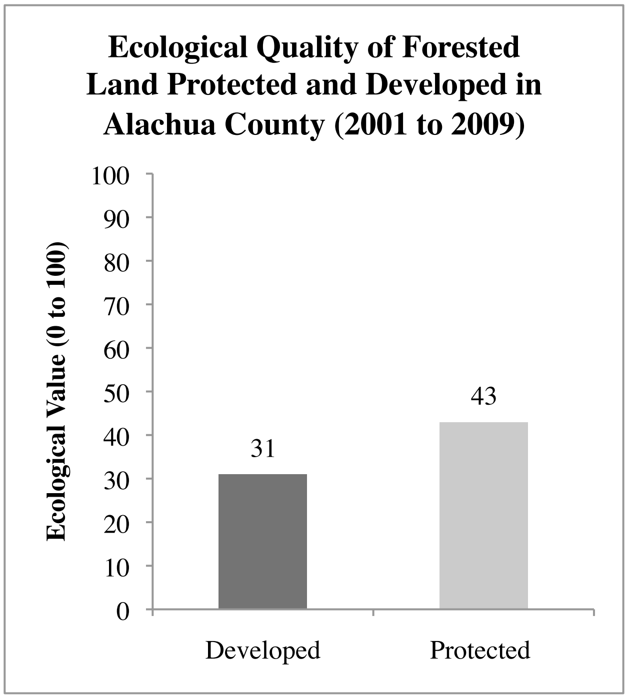
Much of Alachua County's local conservation land is spread throughout the county with little connection to other protected lands. But there is a cluster of state, water management district, and county lands in the southeastern section of the county. The large block of preserved lands supports green space quality, boosts countywide connectivity, and helps to protect water resources in the area,

Figure 5-8. Federal, state, local, and privately-owned protected areas in Alachua County, Florida in 2010 (by Author). 'Local or private' includes county lands jointly owned with water management districts.



Quality
The area-weighted mean ecological value of protected forested lands was 43. The value is higher than the average value of forested land developed during the study period, 31 (Figure 5-9). The difference indicates that the county was moderately successful at directing development of forested lands towards those with less ecological significance.

Figure 5-9. Mean ecological quality of forested land protected and developed in Alachua County between 2001 and 2009. Protected area averages include local conservation land that was preserved prior to 2001.



Connectivity
Between 2001 and 2009, the level of fragmentation of forested land in Alachua County increased significantly. Patch metrics indicate the greatest changes were in shape rather than proximity. Proximity measures such as Euclidian Nearest Neighbor show minimal change (Table 5-8). The result suggests that forested patches became smaller and more irregularly shaped but not much further apart, a pattern than usually arises from many small developments nibbling away at a resource rather than broad sweeping changes. The county also experienced a loss of connectivity of agricultural patches. Between 2001 and 2009, patches became smaller and an average of 3 meters further apart. In addition, the average distance from the edge of an agricultural patch to the center in 2001 was 1,130 meters. That value increased slightly by the end of the study period, likely due to an increase in the irregularity of patch shapes caused by development. The decrease in Area-Weighted Proximity Index – which indicates that patches became smaller – corroborates this finding.

Table 5-8. Patch Shape and Contiguity Metrics for Alachua County Forest and Agricultural land in 2001 and 2009 (by author).

	Forested Land			Agricultural Land		
	2001	**2009**	**Change Notes**	**2001**	**2009**	**Change Notes**
Area-weighted Mean Patch Length/Contiguity (GYRATE_AM)	12,760m	12,077m	Decrease in patch length/ contiguity	1,130m	1,177m	(Slight) Increase in patch length/ contiguity
Patch Shape Complexity (SHAPE_AM)	36	34	Minimal Change	17	17	Minimal Change
Patch Aggregation (CLUMPY)	0.9	0.9	Minimal Change	6.8	6.9	Minimal Change
Area-weighted Mean Distance to Nearest Like Patch (ENN_AM)	60m	60m	Minimal Change	74m	77m	Patches become (slightly) more distant
Area-weighted Mean Patch Size and Proximity Metric (PROX_AM)	118,783	68,838	Patches become much smaller and more distant	808	685	Patches become smaller and more distant

Overall

During the study period, the Alachua County Growth Management and Environmental Protection Departments conducted a moderate level of green infrastructure planning. The county's actions covered 55% of the policies and strategies included in the Green Infrastructure Planning Framework. The county's land preservation program and dual urban growth boundaries contributed to the score. Alachua also had a strong development review process, requiring a resources inventory and specific protections for forest resources and sensitive and endangered species. The county's programs over the study period had two main weaknesses, zoning and landscape-scale planning. While Alachua County did mandate clustering, the strategy was not used, and background rural zoning of one dwelling per five acres provided little protection of rural resources during the study period. Additionally, between 2000 and 2010, Alachua County had no landscape-scale conservation or preservation plan. So while land preservation prioritization and development review considered connectivity, there was no broader plan to ensure that individual planning decisions preserved the most important connections or added up to a coherent county-wide network of green infrastructure.

Alachua County's green infrastructure network was fragmented by development over the study period. About 4,700 acres of forested land and 2,500 acres of agricultural land were converted to developed uses. The change led to smaller patches of forested land and agricultural areas that were smaller and more distant from one another. But the county was fairly successful in directing development of forested land to more marginal areas and away from high quality resources. The average ecological quality of forested land developed between 2001 and 2009 was 12 points lower than that of protected forested land.

LOW GREEN INFRASTRUCTURE PLANNING: MARION COUNTY

Marion County has significant and high quality rural resources, including a large national forest, the Cross Florida Greenway, and a thriving horse farming industry. But, from 2000 to 2010, the county employed a very low level of green infrastructure planning. The county's land use planning and zoning practices encouraged sprawl and did little to prevent development from fragmenting natural and working landscapes. The county also did not consider connectivity or conduct landscape-scale green space planning. However, the county did use regulatory protections to the minimize impact of development on trees and listed species and, in 2004, adopted a transfer of development rights program to preserve agricultural resources.

Demographics, Economy, and Environment

Marion County grew rapidly between 2000 and 2010. The rate of population increase, 28%, was greater than the booming state of Florida (17.6%) and nearly triple that of the nation (9.7%). The county's 2010 population exceeded 330,000 as new residents moved into central portions surrounding the county seat, Ocala. Marion County contains five incorporated municipalities, but only Ocala – with 56,000 - has more than 5,000 residents. In 2010, the population of unincorporated Marion County topped 267,000 (US Census).

While the education and medical fields are major employment industries in Marion County, they are less significant than in other parts of the state. Between 2000 and 2010, Marion County was more characterized by manufacturing and construction jobs. Nearly 10% of residents were employed in construction, compared with 5% for Leon and Alachua Counties, and 11% were employed in manufacturing, compared with 2% and 4% for Leon and Alachua County, respectively. The overrepresentation of construction and manufacturing jobs meant the late-2000 recession hit Marion County hard. Between 2000 and 2010, unemployment jumped from 4% to 13.5%, greater than the average for the hard-hit state of Florida (11.3%) (BLS 2000, 2010). During the same time period, median income fell 9%, below the state median of 46,000. But bolstered by population growth and a strong early-decade construction industry, housing units still increased 34%. However, overall home value declined and – with a 2010 median value of $141,800 – remained well below the state average of $187,400 (US Census).

Marion County is primarily rural in character and agriculture has always been an important industry. High value horse farms keep agricultural land values up and contribute to Marion County's rank as the second most valuable livestock farming county in the state. According to the 2007 Census of Agriculture, the market value of agricultural products sold in Marion County in that year was $173.74 million, about 2% of Florida's $7.7 billion. Over $128 million of the sales were from horse farms, making the county first in the state in horse farm sales value and third in the nation. The remaining agricultural sales were mainly in cattle, nurseries, and tree fruits and nuts (United States Department of Agriculture 2009).

At more than 1,500 square miles, Marion is a large county by Florida standards, and about a third of it (555 square miles) is Ocala National Forest. Ocala is the oldest national forest east of the Mississippi River (established in 1908) and the most visited in the state. It is important not only for its high quality forest resources, but as a recharge area for the increasingly depleted Floridian Aquifer. Two-thirds of the Ocala National Forest area is within Marion County, where it runs the length of the county's eastern border. The county also includes two state parks, Silver River State Park and Rainbow Springs State park which comprise nearly 5,700 acres, The Marjorie Harris Carr Cross Florida Greenway also crosses the county with 42,800 acres of managed open space that is largely open for recreation (Marion County Parks and Recreation Department 2007).

Green Infrastructure Planning in Marion County

The Marion County Planning Department had the greatest responsibility for green infrastructure planning during the study period. The department was responsible for traditional urban planning tasks such as comprehensive planning, visioning, and development review. However, the late-2000 economic downturn impacted Marion County coffers and the county cut positions nearly every year after 2006. The Marion County Zoning Department - responsible for development review and for maintaining and enforcing the land development code - was also affected. The Parks & Recreation Department, which has a Natural Resources Division also played a role in green space planning. Parks & Recreation helped to plan for and manage green spaces in Marion County. They maintained the Parks and Recreation Master Plan, which drove parkland acquisition and development during the study period.

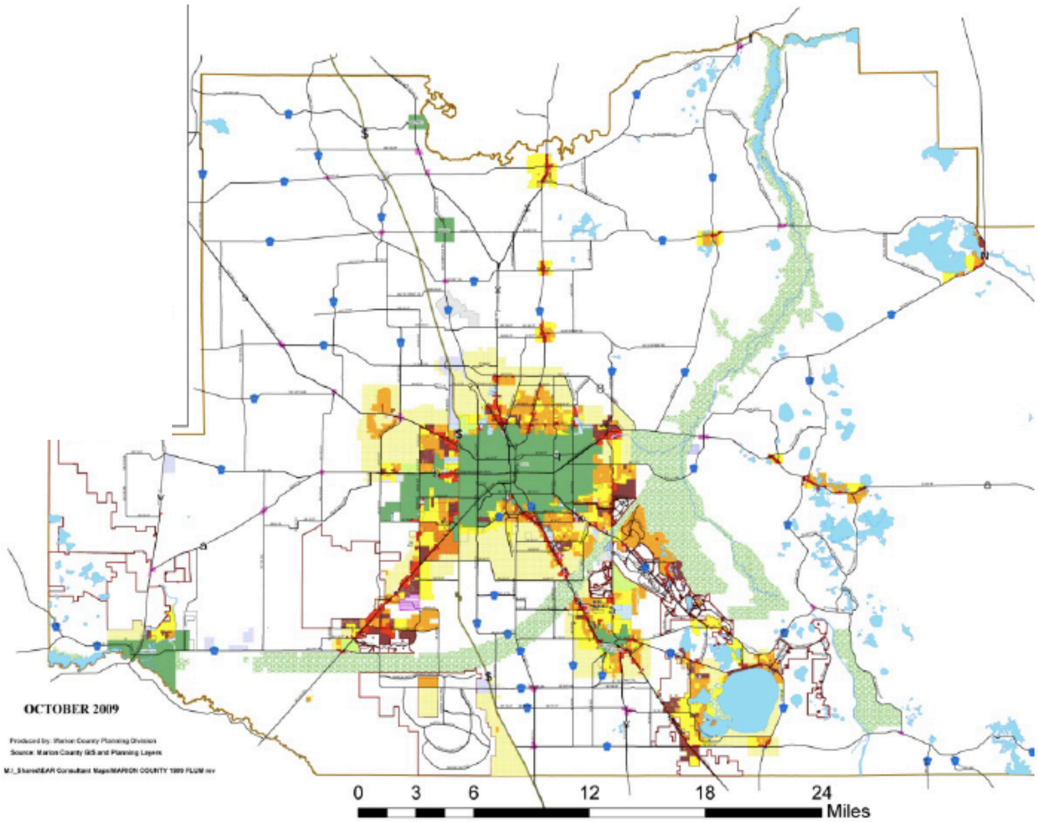
Marion County had a score of 42, representing 29% of the policies, programs, and strategies in the Green Infrastructure Planning Framework. In sum, Marion County employed a low-level of green infrastructure planning during the 2000 to 2010 study period (Table 5-9). The County's strengths were in managing green infrastructure to support ecosystem services and protecting and supporting green infrastructure through a collaborative and cooperative process, where it had policies comparable to the other two Florida counties. Marion County's weaknesses were in planning for linkages and connectivity and in restoring and mitigating damage to green infrastructure. The county also included few policies or strategies that supported a diversity of green infrastructure. The following sections provide an overview of planning in Marion County and describe the policies and strategies through which Marion County furthers each principle of green infrastructure planning. For a complete Green Infrastructure Planning Assessment Framework for Marion County, see Appendix 5-A.

Table 5-9. Marion County Green Infrastructure Planning Framework Results Summary

Green Infrastructure Principle	Framework Score (Out of 20)
Create linkages and foster connectivity	**3**
Value areas of ecological quality and local importance	**7**
Support a variety of landscapes and ecosystem services	**6**
Restore and mitigate damage to green infrastructure	**4**
Manage green infrastructure to support ecosystem services	**9**
Enact land use planning strategies to protect and retain all scales of GI	**6**
Protect and support GI through a collaborative and cooperative process	**8**
TOTAL (Out of 140)	**41**
PERCENTAGE	**29%**

Marion County's comprehensive plan was originally adopted in 1992. But under Florida's comprehensive planning rules, the county plan was updated in both major and minor ways. The last major update – one accompanied by an official Evaluation and Appraisal Report (EAR) – was in 1998. The 1992 plan was oriented toward meeting the new state growth management requirements and protecting property rights and not toward directing growth in a way that would yield a particular result. Marion County's general objective was to direct development toward the areas immediately surrounding the City of Ocala while retaining the remainder of the county as resource land (Figure 5-10).

Figure 5-10. 1999 Marion County Future Land Use Map. Map by Marion County Planning Department (2009). Key: Yellow/Orange/Red = Growth Area; White = Rural; Dark Green = Municipal Land; Light Green = Cross Florida Greenway.

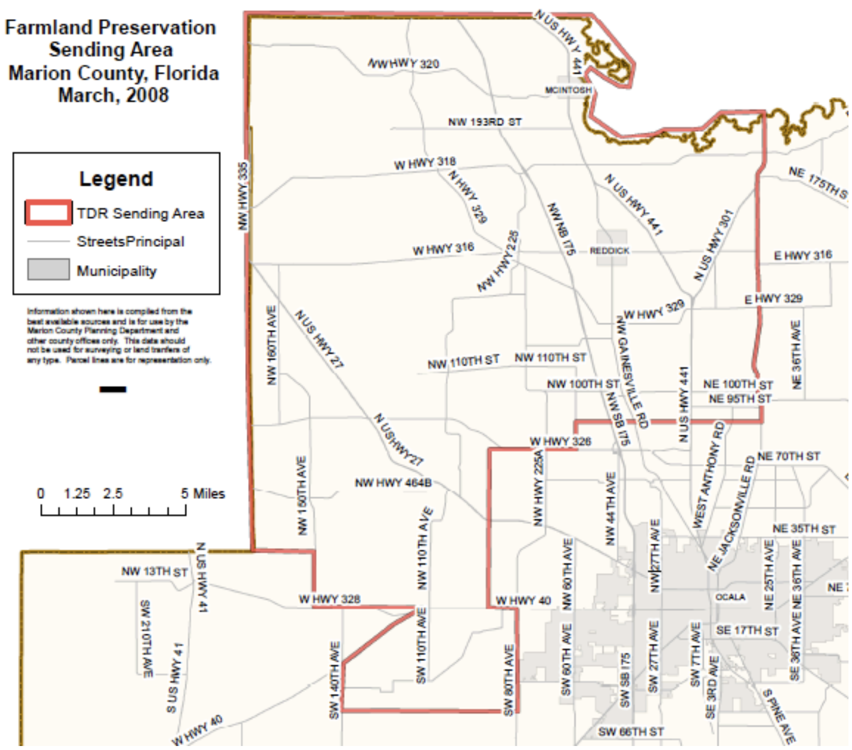


By 2000, Marion County had experienced significant sprawl, but much of the defining rural lifestyle remained. These bastions of rural living served as "a reminder of what many parts of central Florida were like forty or fifty years ago; landscapes that no longer exist in many locales" (Marion County Planning Department 2009, 1-3). Attracted in part by the countryside, residents flocked to Marion County. Between 2000 and 2010, the population grew by 28%. By mid-decade, residents attending workshops identified, "protecting the environment (particularly water resources) [and] maintaining open space and agricultural lands" as major concerns (Marion County Planning Department 2009, 2-59). Residents also voiced a desire for growth management amid concerns about becoming 'suburbia' like Tampa or Orlando (ibid).

Until 2011, the Florida Department of Community Affairs (DCA) reviewed local comprehensive plans to ensure that they met state objectives. All comprehensive plan amendments – major and minor – had were reviewed and approved by DCA. During the study period, agency frequently found Marion County's amendments 'Not in Compliance' due to their support of sprawl. The state was troubled by the lack of county policies that effectively bounded and directed development and by the county's approving Future Land Use Map amendments that were not ‘needed’ and served only to exacerbate the spread of development. Rather than large sweeping text amendments, the majority of Marion County comprehensive plan changes were small map amendments that moved individual parcels from a ‘rural’ to a ‘residential’ land use category so they could be developed more intensively. The county submitted enough of these that DCA found ‘Not in Compliance’ that, in 2008, Marion ‘agreed’ not to pursue any further residential amendments until the sprawl issues were addressed (ibid).

Marion County enacted 33 changes to comprehensive plan text between 1998 and 2009, but few impacted conservation or open space planning. The county’s conservation policies have remained fairly constant since the last major plan update in 1998. The most significant change was the transfer of development rights program. The county passed the policy in 2004 to direct development toward designated growth areas and protect the agriculture-rich northwestern quadrant of the county in the face of sprawl (Figure 5-11). By late-2009, the county had protected 3,198 acres of agricultural land through the program with a goal of 5,000 acres by 2015 (Marion County Planning Department 2009).

Figure 5-11. Sending Area for Marion County’s Transfer of Development Rights Program. Map by Marion County Planning Department (2008).



Create linkages and foster connectivity

Between 2000 and 2010, connectivity was not a consideration in Marion County comprehensive planning documents. And while the county completed a plan overhaul in

2010, the resulting document still did not openly discuss connectivity – or its opposite, fragmentation. But while comprehensive plan policies and strategies did not emphasize connectivity, the Parks and Recreation Master Plan (2007), and several smaller corridor studies, did. In identifying the county's many park and open space types, the Parks and Recreation Master Plan noted that the primary goal of greenways is connectivity and that green corridors can be used to create a network of open space. The Plan also underscored the results of two corridor studies, one for SR 200 and one for US 27, which emphasized the need for open space connectivity and its associated quality of life benefits. The Parks and Recreation Master Plan continued on to note the success of the Cross Florida Greenway and potential for expanding it into a more complete network, both within Marion County and through connections to northern neighbor Alachua County. In addition, while the Parks Plan did not specifically mention the importance of connectivity within the document, an appendix describing important Marion County natural areas noted that, "connectivity and diversity are essential in successful natural settings" (Marion County Parks and Recreation Department 2007, Appendix 1). Additionally, while connectivity was not a significant part of development review in the county, there were several county code provisions which required landowners submitting applications for development to consider whether the property was part of a wildlife corridor or contiguous to a previously protected area.

Areas of ecological quality and local importance

Marion County's comprehensive planning documents from the study period emphasized the importance of protecting several environmental features - wetlands, floodplains, native vegetation communities, listed species habitat and state and federal land - but mapped few. And while the 1999 Future Land Use Map included a Natural Reservation section, it did not delineate all protected areas or even all state and federal resource lands. It did include the Cross Florida Greenway, a major – and highly visible - component of the county's green infrastructure network (Figure 5-10).

Between 2000 and 2010, Marion County protected sensitive and important resources through overlay zones, subdivision and land development regulations, and a Transfer of Development Rights Program. The county used two different overlay zones, an Environmentally Sensitive Overlay Zone and a Floodplain Overlay Zone. The Environmentally Sensitive Overlay Zone covered land surrounding rivers, springs, and lakes in addition to natural habitats, native vegetation, and important upland areas. Generally, the Zone extended one half mile landward from important lakes and springs and 500 feet landward from hydrologically connected wetlands and tributaries. Proposals for development in the area had to be accompanied by a site analysis to ensure that development did not negatively impact sensitive resources and natural communities. The Zone did not broadly impact the underlying density of a site, except in 100-year floodplains where density could not exceed one dwelling unit per acre. In addition, county code required that development in the Zone be clustered, where possible (Marion County Code Section 6.2). Another overlay, the Floodplain Overlay Zone, covered areas with a special flood risks, but allowed most types of development, providing they met standards for developing in potentially flooded areas and did not alter the natural floodway or stream channel (Marion County Code Section 6.3).

Marion County also required a Modified Environmental Assessment Study (MEAS) for developments or redevelopments meeting specific criteria. Projects involving non-residential land uses, greater than 40 acres or 20 dwelling units, water frontage in an Environmentally Sensitive Overlay Zone, and/or containing habitat for listed plant or animal species had to submit a MEAS to the Zoning Department for review. County code required that the MEAS contain an inventory of plant and animal communities, the distribution of native habitat and vegetation types, wildlife populations, whether the property contained a wildlife corridor, and mitigation and maintenance strategies for on-site resources, at a minimum. The county also required that when a site proposed for development contained listed species or their habitat, the MEAS needed to be accompanied by a habitat management plan detailing how impacts would be prevented or mitigated. Off-site mitigation in the form of monetary contributions or land donations was allowed, in some cases, but only at a one-to-one ratio (Marion County Code Section 8.1.4)

The county also had general environmental and conservation standards for development. County code required that development in floodplains adhere to Floodplain Overlay Zone restrictions. It also mandated that development of wetland areas not within the Environmentally Sensitive Overlay Zone be clustered on upland portions of the site, or on uplands and adjacent wetlands if not enough upland land was available to meet allowed densities. If the wetland area occurred on Rural Land, the density was restricted to 1 dwelling unit per 10 acres provided the landowner had obtained the proper state and federal permits (Marion County Code Section 8.1.4)

Marion County also protected natural resources through landscape standards and tree preservation regulations. The standards applied to all development as part of the subdivision design or site planning process. Tree protection standards noted that 'every reasonable effort should be made to minimize tree removal,' particularly through modifying site design to preserve large trees. With a few exceptions, landowners wishing to remove a tree greater than six inches in diameter at breast height had to obtain a permit and provide a Tree Removal and Preservation plan that includes the location of trees to be removed and their replacements. Landscape standards exempted single-family homes and duplexes, but required that new and expanded development retain existing native and non-invasive species to the greatest extent practical (Marion County Code Section 8.2.10)

In addition to the natural resources noted above, Marion County protected locally important working landscapes: agricultural lands. The county launched a transfer of development rights program in 2004 to protect large blocks of high quality farmland. Marion delineated a Farmland Preservation Area (sending area), but did not enforce its use. In reality, any landowner of an agricultural parcel greater than 30 areas was eligible to sell their development rights. Development rights could then be transferred to urban reserve areas closer to the City of Ocala. The size requirement helped to ensure that preserved farms were large enough to be viable. Landowners received one development credit per acre of land put under conservation easement. Once development rights were sold, the land was protected under a permanent conservation easement (Marion County 2008).

Support a variety of landscapes and ecosystem services

Between 2000 and 2010, Marion County emphasized listed species, species habitat, and native vegetation and trees, but the county's particular emphasis was agricultural land. In 2004, when the county's agriculturally-oriented transfer of development rights program began, it was unusual for the state. Floridian counties typically focus on high quality ecological lands rather than heavily managed – some would say degraded – farmland. But Marion County so valued its agricultural industry and rural areas that it passed one of the first TDR programs of its kind in the state to protect them. The county also protected scenic roads, wetlands, floodplains, and the Cross Florida Greenway during the study period. The Board of County Commissioners passed the first scenic road ordinance in 1997, which designated 27 segments as scenic roads. During the study period, scenic roads were protected from widening and other actions that could disrupt views or damage critical trees and vegetation (Marion County Ordinance 97-1).

The county also had specific policies for review of developments that could impact wetlands and floodplains and for protection of the resources themselves. The Environmentally Sensitive Overlay Zone protected wetlands and a designated buffer landward, while floodplains were protected by their own Overlay Zone. In addition, while landowners were encouraged to cluster development away from wetland and floodplain areas, the two had specific density restrictions, even where they occurred in planned development expansion areas. Wetlands had a base density of one dwelling per five acres, while floodplains could be developed at up to one dwelling unit per acre (Marion County Code Section 5.5).

Finally, the Cross Florida Greenway is a unique feature of Marion County. The Parks and Recreation Master Plan proposed building upon the CFG to create a countywide greenway system. As a start, county code required that developments along the CFG be set back at least 50 feet to minimize impacts upon the resources (ibid).

Restore and mitigate damage to green infrastructure

Marion County had specific mitigation requirements for impacts on trees and listed species and their habitat. County code required that trees removed through the land development process be preapproved and mitigated, preferably on-site. Replacement tree species had to be representative of the species removed and designated as 'conservation trees' in the public record of Marion County. A fee-in-lieu of mitigation was permitted, in some cases. The county also required mitigation of impacts on listed plant or animal species and their habitat. If, during the study period, an MEAS or site study discovered that a parcel proposed for development contained listed species or their habitat, mitigation was a condition of the development order or building permit. As with trees, on-site was preferred, but off-site actions such relocating species to similar habitat, contributing to the county parks program for the acquisition of similar habitat, or directly preserving equivalent land were also common. Most critically, county code required that monetary contributions or land donations be sufficient to replace the habitat functions of the area to be developed. The ratio of disturbance-to-replacement value and acreage had to be at least one-to-one ((Marion County Code Section 8.2.10, 8.2.12).

Manage green infrastructure to support ecosystem services
In addition to managing county park land – and several municipal parks – the county participated in the management of the Cross Florida Greenway and required landowners seeking development approval to submit management plans for designated open space and listed species. County code required that site plans submitted to the Department of Zoning for approval designate open space area and provide a management plan for the area and any associated lawn, pasture, park, or natural space. In addition, if a site proposed for development contained listed species or their habitat, the landowner had to submit a habitat management plan along with the broader MEAS. The county required the plan to detail how the species would be protected from the impacts of development and managed in the long term as a viable population (Marion County Code Section 8.2.11, 8.2.12).

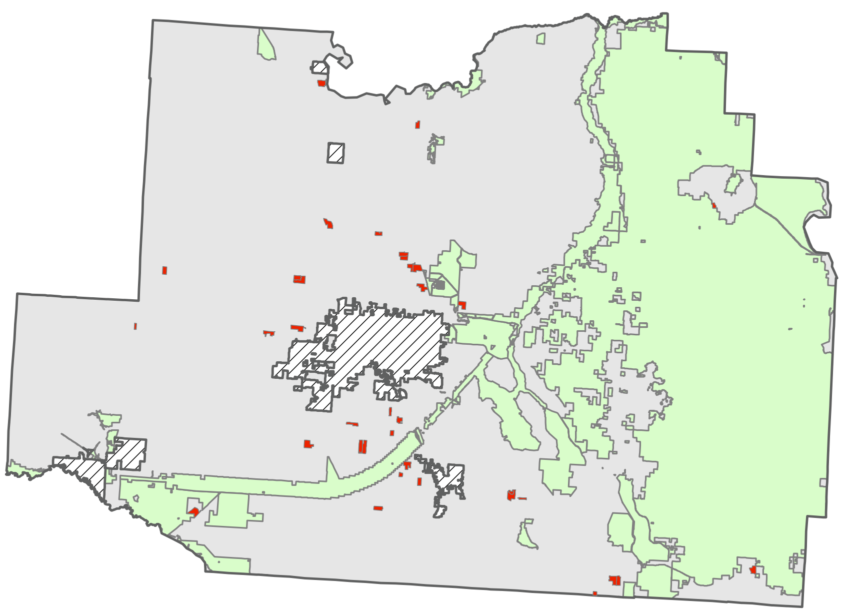
Enact land use planning strategies to protect and retain all scales of GI
Marion County has struggled to limit the sprawl of urban development. The county's Future Land Use Map included no boundary for the expansion of urban services and few policies that addressed the issue. The county's major strategies between 2000 and 2010 were rural zoning, overlay zones, clustering, and subdivision and land development regulations.

The vast majority of rural Marion County has been zoned Rural Land, which allowed residential development at a density of one dwelling unit per ten acres. The majority of development did occur at that density. So while the zone was intended to protect the county's significant agricultural resources, it led to large-lot rural-residential sprawl. In addition, between 2000 and 2010, the vast majority of the area around the City of Ocala was zoned for low- and medium-density development. Low-density zones, mostly Residential Estate, allowed densities of up to 1 dwelling unit per acre, while medium density areas permitted up to 4. Many parcels were changed from Rural Land to low or medium-density residential through the comprehensive plan amendment process. None of them was part of planned urban expansions. In addition, while low-density development grew, there was relatively little compact development. Less than 2% of residential permits during the study period were for multi-family housing and even fewer were for mixed-use developments (Marion County Planning Department 2009).

One of the county's more prominent zoning tools of the time was the Urban Reserve Area Overlay. It covered over 30,000 acres zoned Rural Land immediately surrounding the City of Ocala. The Overlay was intended to provide space for controlled urban expansion and a buffer between urban and rural land uses. But between 2000 and 2008, 5,700 acres of Rural land and 4,700 acres of Urban Reserve Area were converted to non-rural land uses – a total of nearly twenty square miles – an unsustainable rate of development. In addition, by opening up more than 30,000 acres to development in one large block, the Urban Reserve Area Overlay encouraged leapfrog development rather than a slow expansion from the core. The county's 2009 EAR describes the Urban Reserve Areas as, "a magnet drawing developers away from infill areas" (Marion County Planning Department 2009, 3-40).

Like many counties in Florida, Marion County allowed clustering in rural areas to protect environmental resources and open space. Clustering rules required that development be grouped on 40% of a parcel with the remaining 60% permanently protected as open space. The base density in rural areas was 1 dwelling unit per ten acres. Through clustering, landowners could increase that density up to 150%, or 1 dwelling unit per 6.6 acres – considering the 60% protected area. Clustering was required in higher density rural land use zones such as Hamlets (Marion County Planning Department 2009). Hamlets could be developed at a maximum density of one dwelling unit per acre in return for protecting 60% of the site as protected open space. While there was no elective clustering during the study period, the county approved 26 Hamlets, for a total of 3,460 acres. The developments yielded approximately 2,075 acres of protected open space, mostly agricultural land. The hamlets were spread throughout the central portion of the county with little connection between protected open space and other preserved lands (Figure 5-12).

Figure 5-12. Hamlet developments (maximum density of 1 du per 5 acres) in Marion County, Florida between 1999 and 2010. Red = Hamlet; Green = State and Federal lands.



One major issue with Marion County's land use strategy during the study decade was urban services provision. County policies supported the extension of urban services – both sewer and water – to rural areas which blurred the urban/rural distinction. From

2000 to 2005, Marion County issued 14,420 septic tank permits, nearly 3,000 per year. In fact, during much of the study period, sewer and water were more available in large developments in outlying areas than in central portions of the county. Even in urbanized areas, Marion 'promoted' but did not require sanitary sewer hookups (Marion County Planning Department 2009).

Also related to controlling urban expansion, Marion County had an additional tricky planning issue during the study period, vacant platted lots. Previously-platted, but undeveloped, lots were – and continue to be - scattered throughout the county, often in undesirable locations. Together, low and medium density residential areas account for 90% of these vacant parcels. In 2007, there were 38,500 acres of land platted under the county's 'urban residential' land use category. Even in 2007, before the economic downturn, 17,000 acres (44%) of them were vacant, many of them part of large developments of regional impact. In addition, while the county boomed between 2000 and 2007, 30,000 vacant lots were located in subdivisions in which there was zero development (Marion County Planning Department 2009).

Finally, the county's subdivision and land development regulations also contributed to land preservation, but on a much smaller scale. Developers were required to set aside a minimum of 350 square feet of permanent open space per unit. Subdivision regulations required the land to be protected permanently through a conservation easement or other mechanism. A fee-in-lieu was also allowed. Notably, the required area was much lower than most Florida counties, which usually require a percentage rather than a relatively small, flat area (Marion County Planning Department 2009).

Protect and support GI through a collaborative and cooperative process
Between 2000 and 2010, Marion County Planning, Zoning, and Parks & Recreation Departments collaborate in planning and implementing long range planning related to parks and green space. Broader in-county coordination posed further challenges. For example, in the 2009 EAR, the county noted that no two departments or agencies within the county used the same population projection and methodologies, which results in redundant, confusing, and widely varying results.

Marion County informs adjacent counties of major land use plans and decisions and submits information on potential re-zonings or comprehensive plan amendments for comment. But the majority of collaboration between neighboring local governments has occurred through regional agency boards rather than directly. There was little joint planning between the county and municipalities. County planning considered municipal plans and zoning, but did not weight them heavily. The disconnection was a particular challenge for green space strategies such as the transfer of development rights program, which, ideally, would designate urbanized municipal districts as sending areas. One notable exception occurred when, in the late 2000s, the city of Ocala transferred the operations and maintenance of all of its parks to the county. The action was intended to save Ocala management funds, but the new unified county management also enhanced green space planning coordination (Marion County Planning Department 2009).

In the study decade, the county worked with two different regional bodies, the Water Management Districts and the Withlacoochee Regional Planning Council. Marion is within two Water Management Districts, the St. Johns River WMD and the Southwest Florida WMD. They review Marion plans and impact studies and are active in water resources planning and land preservation. Marion County also collaborates with other local governments in the region through the Withlacoochee Regional Planning Council. The Council is one of eleven in the state and intended to promote collaboration and strategic planning, particularly in the areas of economic development and natural resources. Marion helps to fund the Council's operation. During the study period, it provided around $100,000 annually.

Marion County also collaborated with the State of Florida, in addition to several counties and The Nature Conservancy, to manage the Cross Florida Greenway. The Cross Florida Greenway is 110 miles long and ranges from 275 meters to a mile wide. While the state owns most of it, a large portion runs through Marion County. The county considered the CFG in development review and provided other types of supportive planning and management (ibid). However, while Marion worked with the state to manage the CFG, the county received little funding for land preservation. Marion County received one Florida Forever grant in 1992, but none since then (Florida Department of Environmental Protection 2013). Notably, the county also had no active land trusts during the study period.

Funding

Marion County's Capital Improvement Programs have included green infrastructure under the 'parks and recreation' category. Between FY2004 and FY 2010, Marion County spent an average of $1.18 million per year on capital investments in parkland planning, design, and acquisition, an average of 1.5% of the capital budget annually. However, the value is inflated by large investments in 2004, 2005, and 2006. The high was in 2006, when Marion County spent over $4 million on five projects. Beginning in 2007, park expenditures were more modest. Between 2007 and 2010, the county funded only one or two projects a year for at an average of $160,000. The drop in funding coincides with late-decade cuts in both the capital and operations budgets. County Capital Improvement Programs also included a Clean Water Program, but the majority of projects supported infrastructure upgrades rather than restoration (Marion County CIP FY2004-FY2010).

The majority of funding for green infrastructure during the study period came from general appropriations, the Pennies for Parks Program, and the Parks & Recreation Fees Fund. Marion County voters passed Pennies for Parks, a recreation and environmental land purchase program, in 1988. With the referendum, residents approved bonding up to $20 million for the purchase of parks and green space. The bulk of the remaining funds were used in construction of two large projects in early 2007 (FY2006) (Curry 2007), but at least $600,000 in interest remained at the end of the study period (Marion County Board of Commissioners 2012). A second major park funding source, the Parks & Recreation Fees fund, was comprised of fees collected for use of select Marion County park facilities. The fund totaled around $500,000 annually. Prior to 2007, Park & Recreation Fee proceeds were simply added to the general fund, but they now contribute to The Parks & Recreation Fee Fund and are used to leverage grant funds and make site improvements (Marion County Parks and Recreation Department 2007).

Green Infrastructure Network Change in Marion County

Quantity

During the study period, the population of Marion County grew by 28% and developed land in the county increased by 34 percent (Table 5-10). Over the same decade, the county lost 4 percent of agricultural land and 45 percent of forested land to non-resource uses. Development of forested land was almost twice that of agricultural land. Between 2001 and 2009, the totals came to 16,500 acres of agricultural land and 26,900 acres of forested land lost. The difference in percentages is dramatic due to the disparity in acreage of agricultural and forested land. With around 200,000 acres of agricultural land – much of it horse farms – the county ranks as one of the most agricultural in the state. So, while more than 16,000 acres were developed, the percentage is relatively modest. By contrast, development nearly halved the amount of unprotected forested land in the county.

Table 5-10. Land Use Change in Marion County, Florida from 2001 to 2009* (By Author).

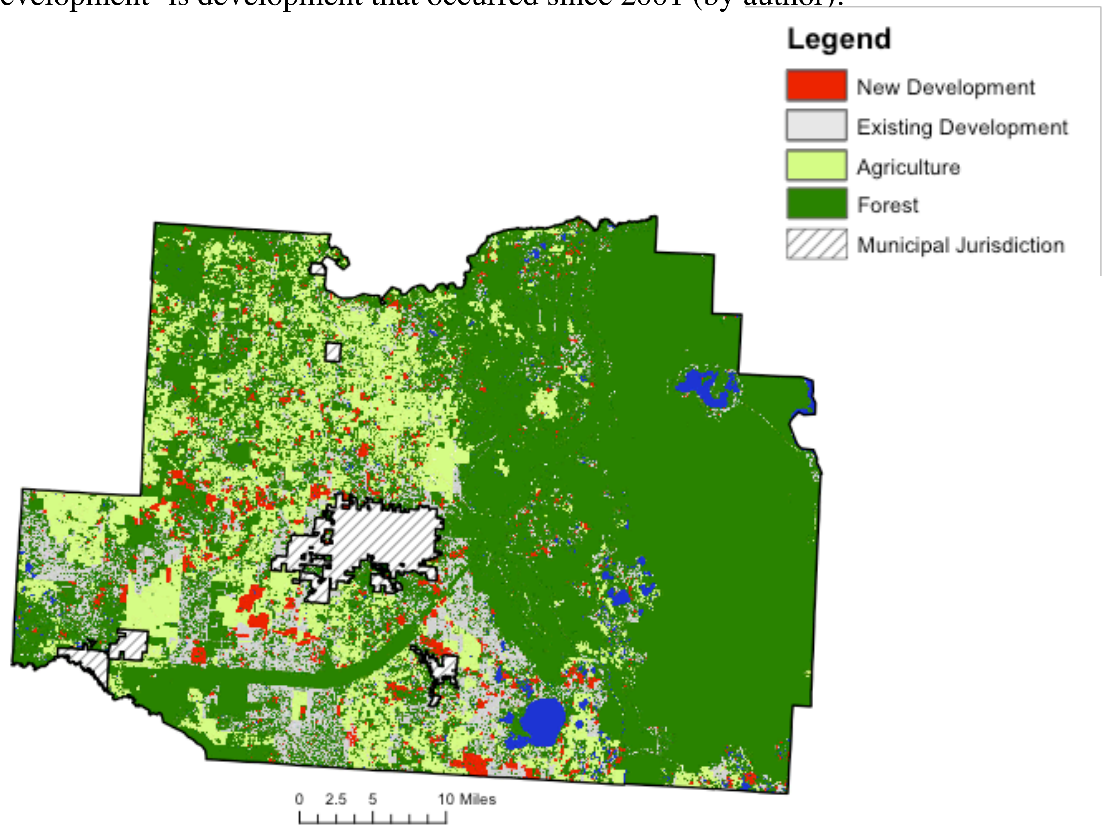
Marion County Land Use Change

	2001 (acres)	2009 (acres)	Change (%)
Water	18,844	18,844	0
Agriculture	207,993	191,431	**-4**
Forest	60,140	33,232	**-45**
Developed Area	92,773	136,243	**34**

*Considers only privately-owned unprotected lands under county jurisdiction.

There was little discernable pattern to development in Marion County between 2001 and 2009. The largest developments, and densest concentration of development, occurred in the area surrounding the City of Ocala (Figure 5-13). But there were also concentrations of new development in the south central and northern reaches of the county. The 2009 map also shows large resource areas that experienced no change, due to protection via government ownership. The most prominent is Ocala National Forest, which comprises the eastern third of the county, but the more linear Cross Florida Greenway is also evident. The few developments within the two protected areas occurred in in-holdings. The two features are also shown in Figure 5- 14, which shows county protected areas.

Figure 5-13. Forestland, farmland, and developed area in Marion County in 2009. 'New Development' is development that occurred since 2001 (by author).



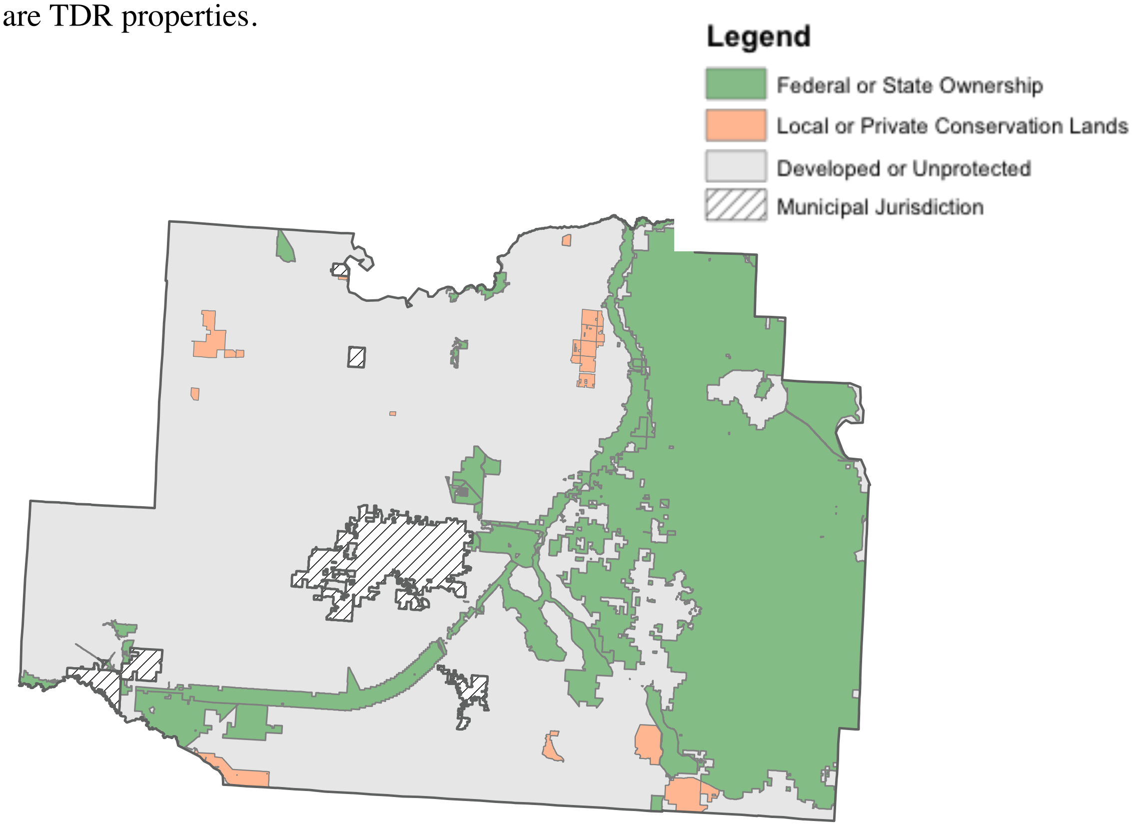
Marion County has a large amount of high quality resource land, but most of it is state and federal. Until the 2004, county land protection efforts were modest. The Pennies for Parks bond raised only $20 million, much of it used for park facility upgrades rather than land preservation. Natural resource quality was not an emphasis. Local land preservation began in 2005 with the transfer of development rights program. The program yielded two easements in 2005, two in 2008, and two in 2009, for a total of nearly 3,200 acres.

Table 5-11. Conservation Lands in Marion County. From Parks and Recreation Master Plan (2007). Updated with recent Transfer of Development Rights program data (2009).

Conservation Land	**Acres**
Ocala National Forest	276,000
Silver River State Park	4,215
Rainbow Springs State Park	1,472
Cross Florida Greenway	42,765
Other State Lands	22,706
SJRWMD Lands	18,129
SWFWMD Lands	10,757
Marion County Lands (Owned or Managed)	3,198
TOTAL	**379,242**

Local conservation lands in Marion County show limited clustering. There are two connected TDR properties in the northwest and connections between conservation areas and state and federal protected lands in the southeast (Figure 5-14). One clustering strategy - delineating a sending area for the TDR program – exists, but is not enforced. The largest property protected through TDR, the 1,958 acre Plum Creek parcel, is outside of the receiving area boundary.

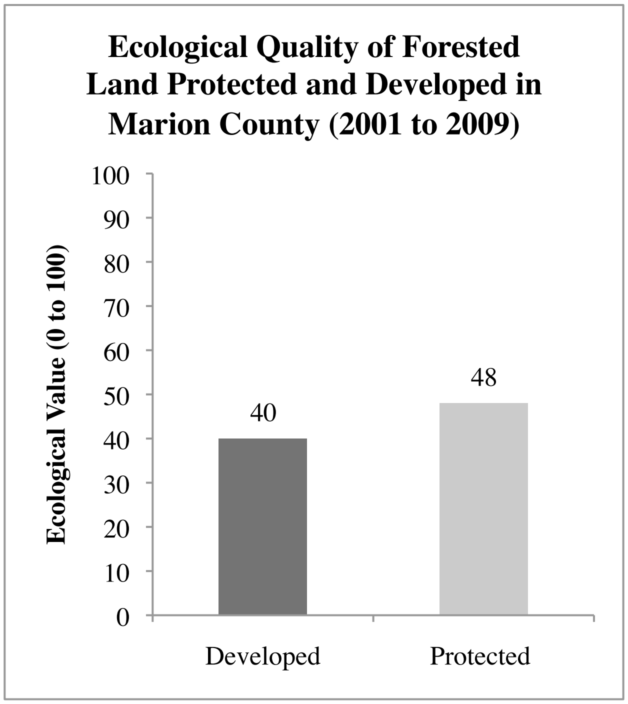
Figure 5-14. Federal, state, local, and privately-owned protected areas in Marion County, Florida in 2010 (by Author). Local conservation lands in the northern half of the county are TDR properties.



Quality

Over the study period, Marion County was somewhat successful in directing development of forestland to lower quality areas. Forested lands developed during the study period had an area-weighted mean ecological value of 40, while protected areas had an average value of 48 (Figure 5-15). The average does not include western TDR lands, which are largely agricultural.

Figure 5-15. Mean ecological quality of forested land developed and protected in Marion County between 2001 and 2009. Protected area averages include local conservation land only.



Connectivity

Between 2001 and 2009, rapid development in Marion County led to fragmentation of forests and agricultural lands. Patches of forested land became slightly shorter and smaller, although not much further apart (Table 5-12). Agricultural lands were more strongly impacted. The average length of an agricultural patch decreased by 500 meters and the average distance between patches increased slightly.

Table 5-12. Patch Shape and Contiguity Metrics for Marion County Forest and Agricultural land in 2001 and 2009 (by author).

	Forested Land			Agricultural Land		
	2001	**2009**	**Change Notes**	**2001**	**2009**	**Change Notes**
Area-weighted Mean Patch Length/ Contiguity (GYRATE_AM)	17,111m	16,944m	(Slight) Decrease in patch length/ contiguity	2,981m	2,473m	Decrease in patch length/ contiguity
Patch Shape Complexity (SHAPE_AM)	39	38	Minimal Change	13	12	Minimal Change
Patch Aggregation (CLUMPY)	0.88	0.88	Minimal Change	0.88	0.89	Minimal Change
Area-weighted Mean Distance to Nearest Like Patch (ENN_AM)	61m	61m	Minimal Change	65m	68m	(Slight) Increase in distance to nearest like patch
Area-weighted Mean Patch Size and Proximity Metric (PROX_AM)	49,110	48,251	Patches become smaller and more distant	4,802	4,492	Patches become smaller and more distant

Overall

From 2000 to 2010, the Marion County Departments of Planning and Zoning conducted a low level of green infrastructure planning. The county's actions covered just 29% of the policies and strategies included in the Green Infrastructure Planning Framework. The county's strengths were in agricultural land preservation – through the new transfer of development rights program – and development regulations for trees, waterways, and listed species. During the study period, the county did not conduct landscape scale green infrastructure planning, or protect ecologically significant lands outside of development review. Marion County also had few land use planning strategies that controlled sprawl and protected natural resources. The Urban Reserve Area attracted sprawl and leapfrog development, and rural zoning led to the spread of large-lot development. Most county-level natural resource protection was reactionary, and occurred only when land was proposed for development.

Development in Marion County between 2000 and 2010 had a significant impact on green infrastructure. The county lost 45% of its of forested land (29,600 acres) and 4% of its agricultural resources (16,500 acres). Furthermore, the impact on agricultural land connectivity was significant, greater, even, than the impact on forestland connections. There are three likely reasons for the outcome. First, there is simply more agricultural land to choose from in the county. Without regulations that impact the location of development, subdivision can occur wherever (formerly) agricultural landowners are willing. Second, agricultural land is easier to develop. It is usually flat, clear, and well-drained. Finally, and perhaps most importantly, forestland connectivity results are buoyed by large protected state and federal forest lands. While state and federal lands do not factor into land use change percentages because they cannot be developed (and hence would skew results), they are an important part of the green infrastructure network and impact overall connectivity. As a result, the eastern third of the county is almost perfectly contiguous, and the Cross Florida Greenway adds a connective corridor. Since patch metrics are area-weighted, the large acreages have a significant impact on fragmentation results.

The prominence of state and federal lands may also impact the county's motivation to preserve high quality natural areas. Since 1988, Marion County has used Pennies for Parks bonds to fund parkland and recreation facilities. In 2004, the county added a transfer of development rights program for agricultural lands. But Marion has taken few moves to protect ecologically valuable lands. This may be because the large area of high quality state and federally protected forestland reduces the motivation for the county to create its own programs. The loss of 45% of unprotected forestland during the study period supports the hypothesis. And while the county's tree protection regulations are good, they occur only as part of the development review process and are about mitigating disturbance rather than overall protection of forest resources.

COMPARATIVE RESULTS

The objective of this study is to examine the impact of county green infrastructure planning. It assesses the degree to which counties that employed many green infrastructure planning strategies and programs (Leon) during the 2000 to 2010 study period were more successful in retaining, protecting, and connecting green infrastructure than those that employed fewer (Alachua and Marion). The three counties had varying green infrastructure planning success. In general, Leon County, which employed 63% of Green Infrastructure Planning Framework strategies, was most successful in retaining green infrastructure and connectivity over time and Marion County with 29% was least successful. But there were two inconsistencies. Alachua County (55%) performed as well as Leon in protecting high quality lands and Marion performed as well as Alachua in retaining the connections between green spaces over time. This section outlines the main qualities of the three programs and details their comparative success in each of the three study areas.

Planning

The major programmatic differences among the three counties were in the area of growth management and landscape-scale planning. During the study period, both Leon and Alachua County had urban growth boundaries. Leon County plans with the City of Tallahassee, so the county's Urban Services Area was mostly within that municipality, where densities were the greatest. Alachua had two growth boundaries, a larger Urban Services Area to reduce sprawl and an Urban Cluster to increase density. The Urban Services Area left room for sprawl within it, but – based upon the land cover change map – still created a clustered rather than a sprawling development pattern. Both Leon and

Alachua were effective in preventing the spread of urban services and development into rural areas. Their urban growth boundaries contained around 90% of growth during the study period. Marion did not have an urban growth boundary and experienced significant sprawl. The county directed growth toward an Urban Reserve Area Overlay district, which encouraged leapfrog development and drew urban services into the countryside.

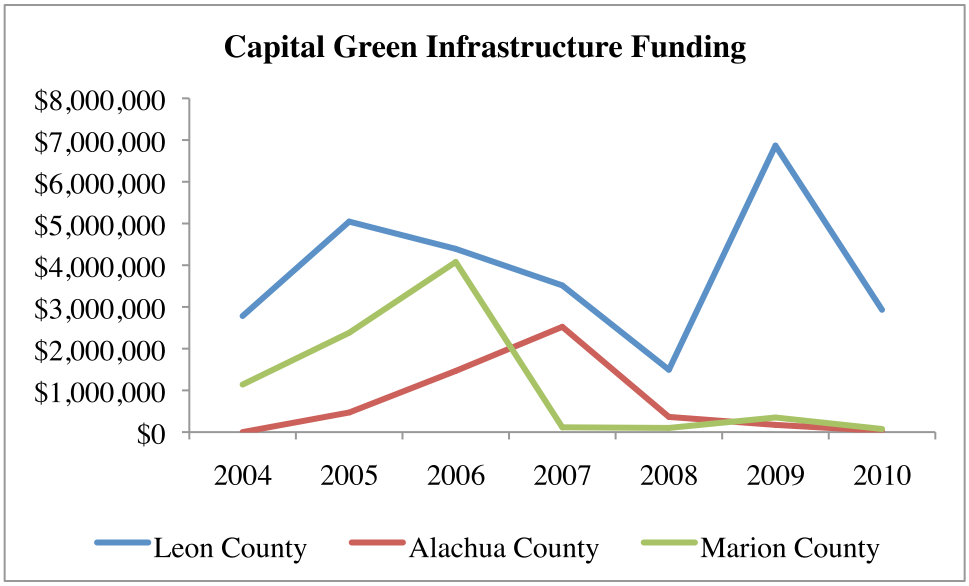
None of the three counties had strong rural zoning during the study period. Leon County's Rural zone allowed development at one dwelling unit per ten acres, as did Marion's. Alachua County's rural zoning was one dwelling unit per five acres. All three counties were impacted by the strength of development interests - and the Harris Act - that limited zoning possibilities. Alachua County's experience is representative. Clustering provisions – which did not impact overall density - held up the comprehensive plan for four years. Cluster strategies were a prominent part of land development regulations in the three counties, but were rarely used on a large scale. Marion is the only county with more three clustered developments, and those developments – hamlets – encouraged sprawl. Nearly 40 hamlet developments – with a maximum density of one dwelling unit per five acres - spread throughout rural Marion County after 1999. Leon and Alachua County also made use of restrictive overlay districts and conservation and preservation areas during the study period.

Another significant difference among the counties is the scale of green space planning. The T-LC greenways program and 2004 Greenways Master Plan included a countywide analysis of green infrastructure quality and critical connections. T-LC planners created both a conceptual map of important green space hubs and links and a more specific prioritization of greenway segments that could be fed into the county's land preservation program, Blueprint 2020. Alachua County has a strong land preservation program, but not the county-scale planning and analysis necessary for purposeful conservation. Marion County has even less landscape scale green space planning and no countywide land preservation program. While the county's transfer of development rights program has great potential for preserving a key agriculture district, it cannot go beyond its focus area to create a broader green infrastructure network.

Funding and Land Preservation

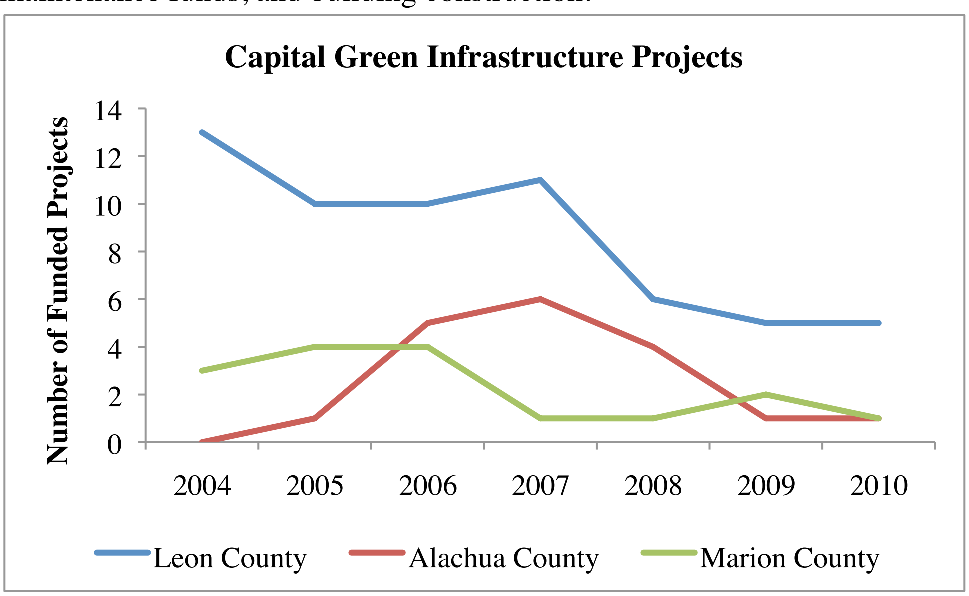
The three counties have had different levels of green space capital expenditures. Between FY 2004 and FY 2010, Leon spent an annual average of $3.7 million on parks, greenways, and preserves. Alachua and Marion averaged around $1 million a year. Both counties also experienced a decrease in funding – and planning staff – in the second half of the study period. Funding for green space in Leon County was higher during the study period, and rebounded quickly after the 2008 low.

Figure 5-16. Capital green infrastructure funding from FY2004 to FY2010 in Leon, Alachua, and Marion Counties (by author). Excludes park facility improvements and building construction.



Examining the number of funded projects shows the decline of green space funding more clearly (Figure 5-17). While Leon County rebounded with $6.8 million dollars in spending in 2009, the number of projects continued to decline. Only Marion experienced an increase, albeit of one project.

Figure 5-17. Capital green infrastructure projects from FY2004 to FY2010 in Leon, Alachua, and Marion Counties (by author). Excludes park facility improvements, maintenance funds, and building construction.



Leon County's capital budgets also included a larger number of projects than the other two counties. Discounting capital budgets, Leon and Alachua had similar green infrastructure funding, particularly for land preservation. Leon and Alachua have county land preservation programs, Blueprint 2000 and Alachua County Forever, respectively. Each was launched in the early part of the study period and is funded by a dedicated tax. Marion County has a transfer of development rights program, but no dedicated land preservation funding source. The preservation funds allow the counties not only to protect lands directly, but also to leverage investments from other agencies and organizations, such as the state. Between 2000 and 2010, Leon County and partners received $16 million in Florida Forever Funds, while organizations in Alachua County received twice as much, $30.5 million. Marion received no Florida Forever grants.

Partners are also an important part of land preservation success. Marion County had no active land trusts during the study period, while Alachua and Leon had several. Between 2000 and 2010, Florida Forever funded 11 different projects in Alachua County. The Alachua Conservation Trust was involved in 6, either as the only applicant, or in partnership with the county. In Leon, the most active land trust was Tall Timbers Land Conservancy. Tall Timbers has preserved 30,000 acres in Leon County, ten times more than the county government (Table 5-13).

Marion County has 276,000 acres of National Forest within its bounds, and Leon County has over 100,000. The federal lands bolstered protected area numbers in the two counties. Alachua County's land preservation program was most active, with 18,200 acres preserved to Leon's 2,700 and Marion's 3,200.

Table 5-13. Preserved and government-owned resource land in Leon, Alachua, and Marion County in 2010.

Owner/Manager	**Leon**	**Alachua**	**Marion**
County	2,683	18,218	3,198
Land Trust	29,349	1,207	0
National Non-Profit	0	839	0
Water Management District	576	61,066	28,886
State	13,393	39,141	71,158
Federal	107,000	0	276,000
TOTAL	**153,001**	**120,471**	**379,242**

Quantity

Land use change is linked not only to planning strategies, but also to population growth. To compare land use change across counties, it is necessary to account for differences in the magnitude of population change. Doing so changes land use values from raw numbers to comparable land use efficiency figures. For example, during the study period, 5% of agricultural land in Leon County was converted to other uses. The value is high because Leon had a relatively small amount of farmland within its jurisdiction. The 5% is only 910 acres, or .03 acres per new resident (Table 5-14). Leon County, the high level green infrastructure planning county, had the highest degree of resource efficiency during the study period. In addition to the .03 acres per capita for agricultural land, the county lost only .10 acres of forested land per individual added to the population. Alachua County was a close second in efficiency with .09 acres of agricultural land lost per new resident and .16 acres of forested land lost. Marion County development was the least efficient of the three. The county had the greatest loss of green space per individual added to the population. The county grew by 74,400 people between 2000 and 2010. To accommodate the growth, the county developed 16,500 acres of agricultural land (.22 acres per capita) and 26,900 acres of forested land (.36 acres per capita).

Table 5-14. Forested and agricultural land developed between 2000 and 2010 in Leon, Alachua, and Marion County, Florida, by acreage and per capita added to the population.

	Leon (High)	**Alachua (Moderate)**	**Marion (Low)**
Population Added	36,000	29,400	74,400
Increase in Developed Area	22%	22%	34%
Agriculture Developed (Acres)	910	2,500	16,500
Agriculture Developed (Per Capita Added)	**.03 ac**	**.09 ac**	**.22 ac**
Forested Land Developed (Acres)	3,450	4,700	26,900
Forested Land Developed (Per Capita Added)	**.10 ac**	**.16 ac**	**0.36 ac**

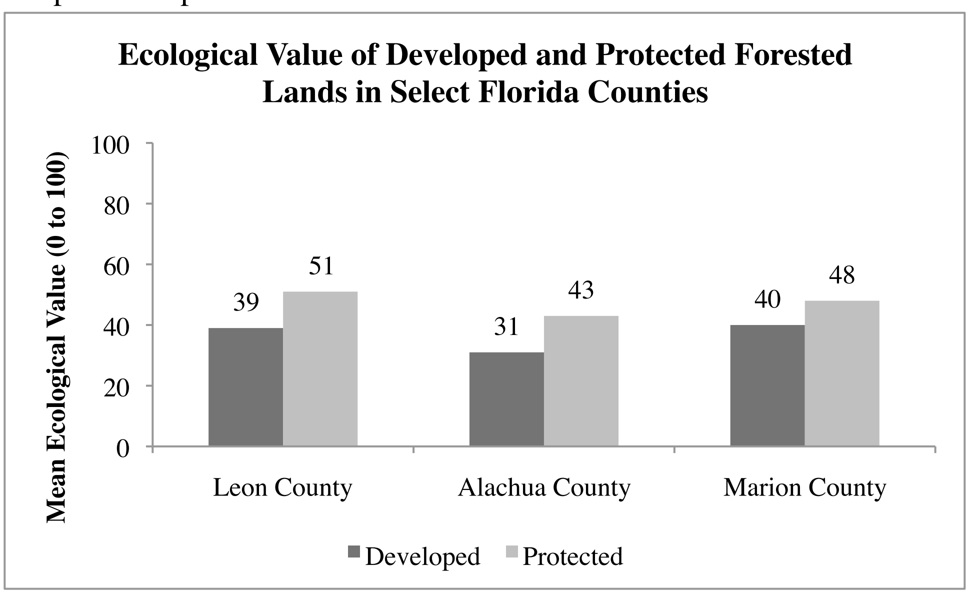
Quality

Leon, Alachua, and Marion have different average ecological values. The mean ecological quality of land in Leon and Marion Counties during the study period was 43 and 44 (out of 100), respectively. Alachua County was about ten points lower at 34. The difference related most strongly to the high quality of mature state and federal protected areas. The two higher value counties – Leon and Marion – had abundant state and federal parks and conservation lands while Alachua had fewer.

One objective of green infrastructure planning is to retain high quality green space by guiding development toward marginal and previously developed or degraded areas. Counties that are successful in green infrastructure planning should exhibit a large difference between the ecological value of protected land and the ecological value of developed land. Since the average ecological value of the three counties examined here is different, inter-county comparisons of the average value of developed or protected land are not meaningful. The ratio of developed area value to protected area value is more informative. In addition, because state and federal lands are unevenly distributed in the three-county sample, they are not included in the ecological value averages described below.

Leon and Alachua County had a comparable level of success in directing development toward marginal forested lands, despite differences in their level of green infrastructure planning (Figure 5-18). But the difference in ecological quality for the two (12) was only four points greater than for Marion County (8). Some of the similarity may be due to the rough equivalency of the counties' habitat and tree protection regulations. While the regulations – which apply during subdivision and development review – do not change land use patterns, they can move development to higher or lower quality areas within a property. In this way, they have an aggregate impact on the quality of lands that remain when a region is developed. However, Marion County was less successful than the other two in either preserving high quality lands or in steering development to lower quality areas. The county's high overall environmental quality and lack of strongly directed growth indicates that the latter is more likely.

Figure 5-18. Mean ecological value of forested land developed between 2000 and 2010 and protected prior to 2010.



County land preservation programs in Florida typically focus upon parcels with high ecological and water resource protection values, rather than agricultural values. In addition, farming was not an important economic driver in Leon or Alachua Counties during the study period. Because of this, there was not enough farmland preserved in those counties to make a useful comparison with the value of farmland that was developed. Marion County does have an important agricultural industry and preserved farmland through its 2004 transfer of development rights program, but inter-county comparison is necessary for the value to be instructive.

Connectivity
The third major facet of green infrastructure planning is connecting green spaces into a functional network. Counties that are successful in green infrastructure planning will retain the size, contiguity, and proximity of their green spaces over time.

During the study period, Leon County exhibited the greatest stability in connectivity and patch metrics. Forested areas in Leon County actually gained a small amount of connectedness during the study period (Table 5-15). The increase is likely due to new development that matured, or 'grew in,' during the study period. Marion County experienced a slight decrease in connectivity. Patches of forestland became slightly shorter and further apart. Fragmentation in Alachua County was the greatest. Patches of forested land in Alachua became significantly smaller and much more distant.

Table 5-15. Interpretation of change in landscape metrics for forested lands in Leon, Alachua, and Marion Counties between 2001 and 2009. MC = Minimal Change; Darker Color = Greater Change. For full results see previous tables.

	Forest		
	Leon	**Alachua**	**Marion**
Area-weighted Mean Patch Length/Contiguity (GYRATE_AM)	MC	Decrease in patch length/contiguity	(Slight) Decrease in patch length/contiguity
Patch Shape Complexity (SHAPE_AM)	MC	MC	MC
Patch Aggregation (CLUMPY)	MC	MC	MC
Area-weighted Mean Distance to Nearest Like Patch (ENN_AM)	MC	MC	MC
Area-weighted Mean Patch Size and Proximity Metric (PROX_AM)	Patches become (slightly) larger and closer	Patches become much smaller and more distant	Patches become smaller and more distant

Leon County also experienced the least change in connectivity of agricultural land (Table 5-16). Fragmentation of agriculture by development made patches slightly smaller and further apart, but to a lesser extent than occurred in Alachua and Marion Counties. Patches of agricultural land in Alachua County became slightly longer during the study period – likely due to an increase in the irregularity of their shape – but also smaller, and slightly more distant. In addition, while Marion County had the strongest farming industry during the time period, its agricultural lands experienced the greatest degree of fragmentation. Agricultural patches in Marion County became significantly smaller, less contiguous, and farther apart.

Table 5-16. Interpretation of change in landscape metrics for agricultural lands in Leon, Alachua, and Marion Counties between 2001 and 2009. MC = Minimal Change; Darker Color = Greater Change. For full results see previous tables.

	Agriculture		
	Leon	**Alachua**	**Marion**
Area-weighted Mean Patch Length/Contiguity (GYRATE_AM)	MC	(Slight) Increase in patch length/contiguity	Decrease in patch length/contiguity
Patch Shape Complexity (SHAPE_AM)	MC	MC	MC
Patch Aggregation (CLUMPY)	MC	MC	MC
Area-weighted Mean Distance to Nearest Like Patch (ENN_AM)	Increase in distance to nearest like patch	(Slight) Increase in distance to nearest like patch	(Slight) Increase in distance to nearest like patch
Area-weighted Mean Patch Size and Proximity Metric (PROX_AM)	Patches become (slightly) smaller and more distant	Patches become smaller and more distant	Patches become smaller and more distant

HYPOTHESIS TESTING AND CONCLUSION

As described in Chapter 3, a strong relationship between the policies and strategies associated with green infrastructure planning and on-the-ground green space outcomes will disprove the null hypothesis and support the alternative hypothesis that green infrastructure planning leads to better green space outcomes. For the purposes of this study, a ‘strong relationship’ means an overall trend that counties employing a ‘high’ level of green infrastructure planning outperform counties employing a ‘low’ level of green infrastructure planning in the three areas of analysis: retaining green infrastructure over time, protecting high quality areas, and connecting green infrastructure into functional network). If this relationship is strong, the level of green infrastructure planning (high/moderate/low) should match the level of county success (high/moderate/least) in each of the three areas. Table 5-17 shows this relationship.

Table 5-17. County level of success in retaining, protecting, and connecting forested and agricultural land between 2000 and 2010. Areas that do not follow the H/M/L trend are shaded. N/A = Insufficient Data

	Forested Land			**Agricultural Land**		
	Leon (H)	**Alachua (M)**	**Marion (L)**	**Leon (H)**	**Alachua (M)**	**Marion (L)**
Retain	High	Moderate	Least	High	Moderate	Least
Protect (High Quality)	Moderate	Moderate	Least	N/A	N/A	N/A
Connect	High	Least	Moderate	High	Moderate	Least

Based upon this analysis, the relationship between level of county green infrastructure planning and on-the-ground green space outcomes is strongest in four areas. The first is at the highest level of green infrastructure planning, as shown in Leon County. Leon outperforms Alachua and Marion in retaining and connecting forested and agricultural lands. The second area in which the relationship is strong is agricultural land broadly. While agriculture is not an emphasis of natural resource planning in most Florida counties, farmland provides important ecosystem services and supports local economies. Leon County had a higher level of success in retaining interconnected farmland than Alachua, which had more success than Marion. This result is in spite of agriculture being a strong and valued industry in Marion County.

A third area in which the level of green infrastructure planning is connected to green space outcomes in Florida is in retaining green space over time. Leon County – the high-level green infrastructure planning county – exhibited more efficient land use during the study period than the other two. For each new resident to the county, Leon converted only .03 acres of agricultural land and .1 acres of forested land, slightly less Alachua and far less than Marion. The efficiency led the county to retain more green space in the face of population growth. Finally, there is also a relationship between the level of green space planning and ability of a county to retain green infrastructure connections. Leon County was more successful at retaining the connections between forested and agricultural lands over the study decade than Alachua and Marion. Connections between forested lands in Leon even increased slightly. In addition, Alachua - the moderate-level green infrastructure planning county - outperformed Marion – the low-level county – in retaining agricultural connections, but not for connections between forested lands. However, connections in Marion County were bolstered by large chunks of state and federal land, which were not present in Alachua. So the Marion/Alachua result may be less related to county planning activities and more to the underlying fragmentation potential of the landscape, based upon the way the metric is calculated.

The strength of these relationships support the alternative hypothesis rather than the null. The level of green infrastructure planning that a county employs appears to have an impact on that county's success in retaining green spaces and critical green infrastructure connections. It may also have an impact on the ability of a county to steer development away from ecologically valuable lands, but there is not enough data to test that hypothesis using these three counties. Still, results show that it *is* ‘good to be green’ in Florida. At the highest level, the benefits of employing many green infrastructure planning strategies are almost across the board. Leon County exhibits a high level of green infrastructure planning and leads the other two counties in retaining and connecting green spaces. But at the low-to-moderate level of green infrastructure planning, benefits relate more strongly to the connectivity of agricultural lands and ability of counties to retain green space, overall. Factors with a likely impact on these results are growth management strategies, land preservation partnerships, and the presence or absence of landscape-scale green space planning.

CHAPTER 6: GREEN INFRASTRUCTURE PLANNING IN BOULDER, ARAPAHOE, AND ADAMS COUNTY, COLORADO

INTRODUCTION

This chapter examines the green infrastructure planning programs and results of three counties in Colorado: Boulder County (high-level), Arapahoe County (moderate-level), and Adams County (low-level). The chapter begins with background on the programs and policies that comprise Colorado's green infrastructure planning framework. It then outlines each county's Green Infrastructure Planning Framework score, the plans, regulations, and policies that make up that score, and the results of each green infrastructure planning program. Key areas of assessment are:
1) Quantity: Loss of forested and agricultural land between 2000 and 2010,
2) Quality: Difference in ecological quality between protected and developed land, and
3) Connectivity: Change in connectivity and patch metrics from 2000 and 2010.

The analysis finishes with a comparative examination of the three counties. It concludes that counties that employ more green infrastructure planning policies and strategies are generally more effective at retaining green space and directing development away from high quality lands than those that employ fewer. Furthermore, counties with high and moderate levels of green infrastructure planning seem to be more effective at retaining connections between green spaces than those with low levels.

MAJOR STATE PROGRAMS

State policies and programs create a framework for local green infrastructure planning. In Colorado, there are three main categories of regulations and programs that impact local green space planning: state-level planning, land preservation, and natural resources.

State-Level Planning and Requirements

In general, Colorado does not have state-level planning or growth management standards. But the state does support, and in some cases require, local planning. The Colorado Code of Regulations tasks county planning commissions with creating a master plan (comprehensive plan) to guide the physical development of unincorporated areas of the county. In 2001, to speed up the process, the legislature passed a bill mandating that communities above certain population and growth rate thresholds adopt a master plan within two years. The same regulation requires that the adopted plan include a tourism and recreation element - the only mandatory component (Colorado Department of Local Affairs 2001). The remaining contents are left up to the local government. The Colorado Department of Local Affairs reviews comprehensive plans and provides comments, but cannot require changes. And since there is no state-level comprehensive plan, local plans are not reviewed for consistency with overarching statewide goals. In addition, local plans are wholly advisory, and not required to be consistent with local regulations, such as zoning ordinances or subdivision regulations. Capital improvements also do not need to follow the local plan. The Department of Local Affairs provides guidance for communities interested in creating comprehensive plans, including planning rationale, suggested elements, and contracting with consultants. The state provides similar guidance for land use codes, although the model land use code for counties was not released until 2008 (Duerksen, Hobbs et al. n.d.).

Colorado is a home rule state and many local governments already have significant regulatory and taxing authority. But the state has taken several actions to enhance or underscore those powers. In 2001, the state granted municipalities and counties the ability to levy impact fees to help ensure that new development is self-supporting. In addition, since 1972, the state has mandated that counties adopt subdivision regulations (the action is optional for municipalities) and that property owners subdividing their land into parcels smaller than 35 acres undergo a county subdivision review process. Divisions of land that result in parcels greater than 35 acres are not considered ‘subdivisions’ under the 1972 Bill (Colorado Department of Local Affairs 2001).

Growth management is an important component of green infrastructure planning. Compact development results in less sprawl and minimizes fragmentation of rural resources. Colorado does not have state-level growth management, but regional organizations are active. A 2009 study by the Lincoln Institute of Land Policy characterized Colorado’s growth management strategy as ‘regional and voluntary’ rather than state-level and mandatory. For example, the Denver Regional Council of Governments (DRCOG) is the regional planning commission for the Denver metro region, the most populated area of the state. In 1992, the organization created its first regional vision and, in 2000, the Mile High Compact, a voluntary agreement through which signatory counties and municipalities agree to manage growth by adhering to principles outlines in the regional vision. The majority of local governments within the DRCOG boundary signed on within a few years (DRCOG 2013).

Land Preservation

In 1992, Colorado residents voted to use a majority of lottery funds for parks, natural areas, and open space. Forty percent of proceeds go into the Conservation Trust fund to be distributed to counties, municipalities, and open space districts for open space projects. An additional 10% goes to the Colorado Division of Parks & Wildlife for state park projects. The majority of the remainder – up to a set maximum - goes to Great Outdoors Colorado (GOCO), which distributes funds through two annual competitive grant cycles and further investments in the Colorado Division of Parks & Wildlife. Local governments, land trusts, the Colorado Division of Parks & Wildlife are eligible for three types of GOCO grants: open space, planning, and non-motorized trails. Open Space Grants fund protection of greenways, stream corridors, community separators, agricultural lands, wildlife habitat, scenic viewsheds, and urban parks, particularly those that are unique or have special conservation values. Planning Grants fund planning activities that forward GOCO’s goals of trail access and connectivity, enhancing existing recreation areas, planning for local park acquisition, site planning for park development, and master planning to include open space elements. GOCO also administers Conservation Excellence grants which are intended to increase organizations’ capacity for land conservation planning by funding conservation planning, staff training, program assessment, and expansion of services in underserved regions (Great Outdoors Colorado

2010). To date, GOCO has invested $715 million in lottery proceeds in 3,500 projects over all 64 counties, including permanently protecting 837,000 acres of open space and building or restoring 720 miles of trail (Great Outdoors Colorado 2011).

Since 1981, Colorado has had a statewide land trust, Colorado Open Lands. Over the past thirty years, Colorado Open Lands has preserved 378,000 acres of open space with natural resource values. The majority of the land under easement (72%) is agricultural, and helps to protect the state's working landscape heritage (Colorado Open Lands 2013). Colorado also has a Coalition of Land Trusts which provides support, information, and a venue for collaboration for the substantial land trust community of Colorado. Around 35 land trusts are registered with the group, including national organizations such as The Conservation Fund and smaller local groups. Some of the groups are highly active. For example, the Colorado Cattlemen's Agricultural Land Trust, one of the largest, has preserved more than 400,000 acres (Colorado Cattlemen's Agricultural Land Trust 2013).

Natural Resources

In 1974, Colorado adopted the '1041 powers,' which grant local governments additional ability to regulate certain types of development and activities that have the potential for significant impacts. The state allows local governments to regulate "areas of state interest," including geological hazard areas, flood hazard areas, historical and archaeological resource areas, significant wildlife area habitats, and shorelands of major publicly-owned reservoirs, and "activities of state interest" such as, site selection and development of new communities, transportation facilities, and utilities and major extensions domestic water and sewage treatment systems (Colorado Department of Local Affairs 2001).

Under defined circumstances, a local government can designate an area or activity within its jurisdiction to be a matter of statewide interest. Doing so allows the county or municipality to request assistance from the state in developing the regulations. Once an area is designated to be of statewide interest, the local government must establish development guidelines that, at a minimum, meet standards set forth in the statute itself. The local guidelines become a permitting process for each type of area of activity. Once standards are established, landowners wishing to develop in the designated area or undertake the identified activity must first show their action will meet the guidelines. While, for Colorado, the 1041 powers are far-reaching, courts have upheld them in the face of several challenges (Duerksen, Hobbs et al. n.d.). Two counties in this study use 1041 rules to review the potential impact of new communities: Boulder and Arapahoe.

Significant wetland areas are often designated as areas of state interest, but Colorado also protects them directly through the Colorado Wetland Partnership. Colorado Department of Natural Resources launched the voluntary, incentive-based program in 1997 administer non-regulatory efforts to protect and restore wetlands. The Program provided funds for wetland education, inventories, restoration, and acquisition, statewide (Environmental Law Institute 2008). To date, the state's voluntary wetland programs have preserved or enhanced over 200 miles of streams and 220,000 acres of wetlands and adjacent habitat (Colorado Department of Natural Resources 2012).

COLORADO COUNTIES: BOULDER, ADAMS, AND ARAPAHOE

Case selection methods described in Chapter 3 were used to identify the three counties in Colorado that best fit within the period of the study (i.e. have aligning planning dates and horizons) and are most comparable in other ways: Boulder County, a high-level nationally-recognized green infrastructure planning county, Arapahoe, a moderate-level county, and Adams, a low-level county for green infrastructure planning. All three are growing counties near the Front Range, a part of the Rocky Mountains that forms the western boundary of the "Urban Corridor," in which the vast majority of the state's population resides. Adams and Arapahoe are adjacent to one another and within the Denver Metropolitan Statistical Area (MSA). Boulder is just north of the official MSA boundary. Between 2000 and 2010, Boulder was also the slowest growing. With a population increase of 8.4%, Boulder County was the only one of the three to grow slower than the U.S. average (9.7%) and the state of Colorado as a whole (16.9%). Arapahoe's growth (17.2%) was comparable to the state's growth rate, while Adams outpaced it (21.4%).

The biggest difference among the three counties is size. Adams County is the largest at 1,200 square miles. Nearly 200 square miles are incorporated into the county's 12 municipalities, leaving 1,000 square miles within county jurisdiction. Arapahoe is 800 square miles, but has only 150 square miles of cities and towns for a county jurisdiction of 656 square miles. Although Boulder has fewer major incorporated municipalities than Adams and Arapahoe, it has the smallest jurisdiction of the three. Discounting land that is incorporated into municipalities, Boulder has 666 square miles within its boundaries. However, a significant portion – about 300 square miles – is part of Roosevelt National Forest and not directly controlled by the county. The heavily forested western portion of the county features steep slopes that are not suitable for development. Adams and Arapahoe are distant enough from the Front Range to have little topographic variation.

In addition, Colorado has few comprehensive planning requirements, which means that the capacity of local planning departments is highly divergent. Boulder had the largest program of the three counties with a planning staff of 50, followed by Arapahoe – where planning is a division rather than a department - with 24 and Adams with 17. The differences in parks and open space departments were even greater. Boulder's open space department had a staff of 100, but the value was inflated by being combined with parks and including recreation and maintenance personnel. In comparison, Adam's Parks & Community Resources Department had 24 while Arapahoe's Open Space Division, which did not include parks, had 9. Funding differences also play a role in green infrastructure planning and will be outlined in later sections.

According to Greg Ingram of the Lincoln Institute of Land Policy, "despite the lack of a statewide policy, Colorado acts like a smart growth state" (Ingram 2009, 206). The reason, he notes, is local and regional action. While the statement overstates planning in rural areas of the state, it is true of many localities along the populous Front Range. The quality makes the Front Range of Colorado an interesting study area for county-level green infrastructure planning and each of the three counties discussed in this chapter is within that region. This section describes the strategies and programs that comprise each county's green infrastructure planning program, outlines green infrastructure framework results, and describes land use change between 2000 and 2010.

HIGH GREEN INFRASTRUCTURE PLANNING: BOULDER COUNTY

Boulder County is a leader in green infrastructure planning in Colorado. The county has a highly prolific open space preservation program bolstered by a variety of policies and programs that encourage landowners to donate easements. The county also protects sensitive and high quality resources through growth management, including strong rural zoning and intergovernmental agreements that restrict the sprawl of development into rural resource areas.

Demographics, Economy, and Environment

In 2010, Boulder County's population was 295,000, an increase of 8.4% over the 2000 population. The growth is modest when compared to the state of Colorado (16.9%). The county has ten incorporated areas, but only two have a population greater than 50,000: the City of Boulder at 97,000 and Longmont with 86,000. Boulder County is directly northwest of the Denver MSA, and while not considered a part of that agglomeration, development from Denver extends into the county and connects to Boulder to form the Denver-Boulder-Greeley Combined Statistical Area.

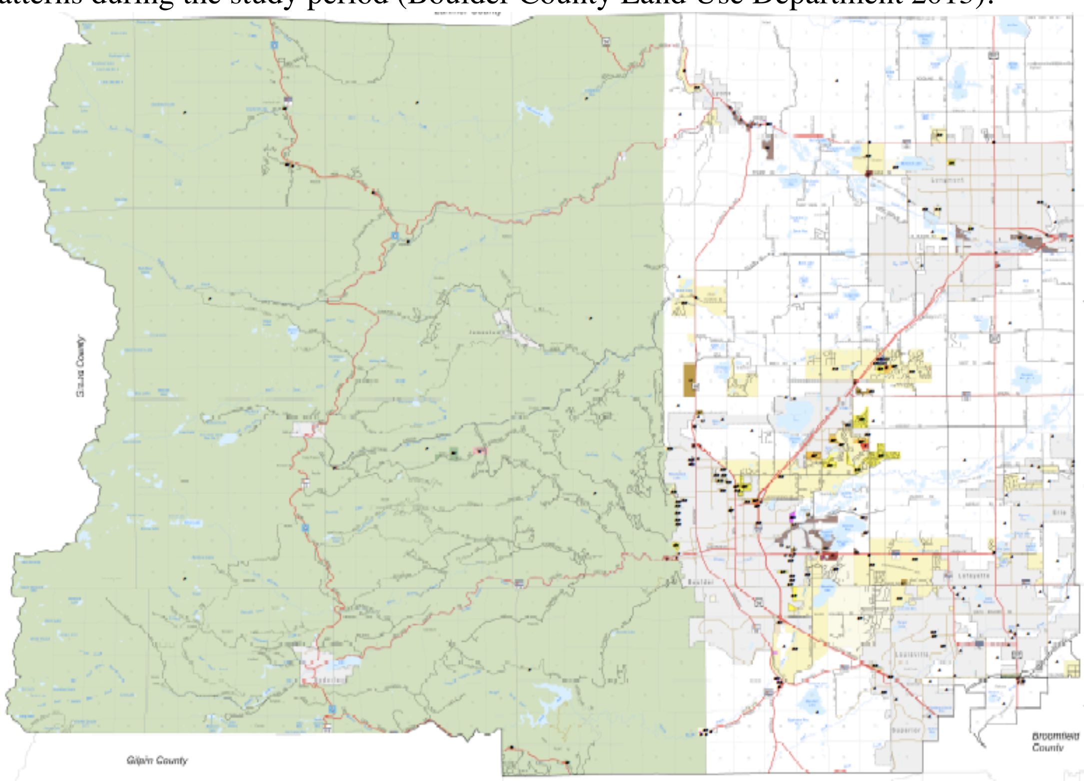
The largest industries in Boulder are technology, research, education, and the sciences. Boulder is known for its attractive natural environment and access to parks and trails. The surroundings have proven attractive to technology companies such as IBM (4,800 employees) and Sun Microsystems (3,200), and numerous of smaller organizations. But, mid-decade, the largest single employer was the University of Colorado at Boulder – a flagship of the state system - with 7,500 workers. Related to presence of the university and tech industries, the population of Boulder County is highly educated. In 2010, around 58% of the population had at least a bachelor's degree, compared to 36% for the state, as a whole. A full quarter of the population also had a graduate or professional degree (US Census 2010). Boulder is also one of the more liberal counties in Colorado. Residents consistently elect Democratic candidates to the three-member County Board of Commissioners and support liberal candidates in state and national elections.

The county provides a variety of local and regional buses to serve commuters and meet other transportation needs, but the majority of commuters do so via private vehicle. However, the population driving to work alone decreased from 71% in 2000 to 66% in 2010. The change was due an increase in population working from home, rather than increased transportation choice. The percentage of the population working from home nearly doubled between 2000 and 2010, from 6% to 11%, three times higher than surrounding counties (US Census 2000, 2010). The outcome may be due to an increasing popularity of work-from-home arrangements in the technology field since the county itself does not provide any particular incentives.

Boulder County was impacted by the recession of the late 2000s, but to a lesser extent than many other counties in the state and residents remained relatively affluent. Despite economic pressures, between 2000 and 2010, median home value increased 15% to $353,000, twice the state's median home value. During the same time, median income fell by 9% to $64,000, but remained well above the state's median of $47,000. As in most of the country, unemployment did increase, but modestly, less than surrounding counties - from 2.4% in 2000 to 7% in 2010.

Boulder County is sharply divided along a north-south axis into the forested western region and the eastern plains (Figure 6-1). The western section is mountainous and difficult to develop while the plains are principally flat, residential and agricultural, and where the vast majority of development occurs.

Figure 6-1. Zoning Map of Boulder County, CO. Light Green = Forestry; White = Agriculture, Grey = Incorporated Municipality, Light Yellow = Low-Density Residential Development. Map shows 2013 zoning, but is representative of underlying land use patterns during the study period (Boulder County Land Use Department 2013).



The flatter eastern half of the county is comprised of two major population centers (Boulder and Longmont), surrounded by agricultural lands and small towns. But while farming is locally important, the agricultural industry is not a major economic driver. According to the 2007 Census of Agriculture, the market value of agricultural products sold in Boulder County in one year is $34 million, a small fraction of Colorado's $6 billion. The number of farms in the county is relatively high (746 acres), but the average farm size is small, only 185 acres (United State Department of Agriculture 2009).

Boulder is better known for its picturesque peaks and extensive forest resources. The US Forest Service, Bureau of Land Management, and National Park Service own and manage nearly 200,000 acres of the mountainous western half of the county. The US Forest Service alone has 161,000, mostly in Roosevelt National Forest (118,000 acres) and Indian Peaks Wilderness (36,000). The state owns far less, only 2,100 acres, much of it state trust land. The county is also active in land preservation, and by 2000 had protected nearly 57,000 acres of forested and agricultural land, 60% of which was open for public use (Boulder County 2013).

Green Infrastructure Planning in Boulder County

In Boulder County, there are two major departments responsible for green infrastructure planning: Land Use and Parks & Open Space. The Land Use Department manages comprehensive planning, zoning, and issuing building and land development permits. The department has a staff of around 50, more than 20 of which are planners or spatial analysis staff. The Parks & Open Space Department serves a variety of land acquisition and resource management functions, including managing the Conservation Trust Fund, Open Space Capital Trust Fund, and resource land acquisition. Parks & Open Space is also in charge of managing county-owned land and lands for which the county holds an easement. Discounting seasonal positions, the Parks & Open Space has a staff of 100, 8 with planning and spatial analysis job titles (Boulder County Comprehensive Annual Reports 2007 – 2010, Boulder County Annual Budget 2012).

For the 2000 to 2010 time period, Boulder County receives a score of 87, indicating that the county employed 62% of the strategies, policies, and programs included in the Green Infrastructure Planning Framework (Table 6-1). Compared to the other two Colorado Counties, the score indicates a high-level of green infrastructure planning. The county's strengths were in enacting land use planning strategies that support green infrastructure, protecting green infrastructure through cooperation, and supporting a variety of landscapes and services. Boulder lags behind in plans and policies oriented toward creating linkages and fostering connectivity and in mitigating damaged or degraded green infrastructure. The following sections provide an overview of planning in Boulder County and describe the policies and strategies through which Boulder County furthered each principle of green infrastructure planning between the years of 2000 and 2010. For a complete Green Infrastructure Planning Assessment Framework for Boulder County, see Appendix 6-A.

Table 6-1. Boulder County Green Infrastructure Planning Framework Results Summary

Green Infrastructure Principle	Framework Score (Out of 20)
Create linkages and foster connectivity	**7**
Value areas of ecological quality and local importance	**12**
Support a variety of landscapes and ecosystem services	**15**
Restore and mitigate damage to green infrastructure	**7**
Manage green infrastructure to support ecosystem services	**12**
Enact land use planning strategies to protect and retain all scales of GI	**18**
Protect and support GI through a collaborative and cooperative process	**16**
TOTAL (Out of 140)	87
PERCENTAGE	**62%**

Boulder County is known for its natural environment. The county adopted its first comprehensive plan in 1978 in response to concerns that development was occurring in patterns that could negatively impact natural resources. The latest edition of the comprehensive plan is dated 1999, although the county has adopted several more recent amendments, including a sustainability element in 2007. The plan's objectives, broadly, are to channel growth to incorporated municipalities, protect agricultural lands, and prioritize the environment and natural resources in land use decisions (Boulder County 2013). Major Boulder County strategies include intergovernmental agreements and land preservation.

Development in the eastern section of the county, called the 'plains planning area,' is bounded by Community Service Areas (CSAs). A CSA is the area around an incorporated municipality in which that city expects to accommodate future growth and expand urban services. The boundary is jointly adopted by the county and municipality and considered a legally binding plan for county lands adjacent to each municipality. CSAs are a form of urban growth or urban service boundary. Boulder County designates land within CSAs for growth, with the long-term objective of municipal annexation, and slates land outside of CSAs for agricultural and natural resource protection, low density development, and other rural land uses. Municipalities in Colorado have virtually unchecked power to annex unincorporated lands, even lands that are distant from existing municipal boundaries. The power has the potential to undermine county growth management efforts. But legally binding intergovernmental agreements (IGAs) like CSAs resolve the issue and lead to more cooperative - and enforceable – land use planning (de Raismes, Hoyt et al. 2000). The state IGA bill allowing enhanced cooperation in land use regulation passed in 1989, and by 1999, the county had eight municipal CSAs. Most IGAs last 15 to 20 years and must then be revisited (Boulder County 1999).

Open space planning and acquisition is a particular emphasis of Boulder County. The county's 1968 Parks & Open Space Advisory Board was among the first in the country focusing on that topic. Boulder's open space program and Parks & Open Space Department (POS) began in earnest in the mid-1970s, when POS began receiving state trust lands and subdivision dedications, and conducted the county's first open space land purchases. Through 1993, funds came from state lottery funds and property taxes, but soon after residents passed a 0.25% sales tax to further fund open space and voted for two different bonds initiatives based upon the growing revenue (1994 and 1996) (Boulder County 1996). By 2000, the county had acquired around 60,000 acres and 80 miles of trails (Boulder County 2011). Around 25,000 acres was agricultural land that the county leased to qualified operators and a further 25,000 acres was designated as 'natural area' (Boulder County 2013). Boulder County used several mechanisms to preserve natural and agricultural open space, most prominently subdivision dedications, planned unit developments, transfers of development rights, and purchases or donations of land and development rights (Boulder County 1996). Conservation easements were a particular emphasis. The county's incentive programs were successful enough that Boulder County rarely purchased conservation lands during the study period (Boulder County Parks & Open Space 2012). In 2012, the county held over 900 easements – including those jointly held with other organizations – on 36,000 acres, or about 37% of the county's open space holdings (Boulder County Parks & Open Space 2012).

On a site scale, the county also used the state 1041 regulations to protect important resources in the development process. Boulder designates "site selection and development of new communities" as an activity of special state interest under Colorado's 1041 rules (Boulder County Code 8-308). The designation allows Boulder to require additional review of proposed development, with guidance from the state. The review is similar to an Environmental Impact Assessment and includes an inventory of natural and cultural resources and description of potential impacts, in addition to an assessment of the stress that new development would place on existing infrastructure and facilities. The stringency of review depends on the level of probable impact, as determined by the planning during pre-application conferences. Proposals with no impact require little review, those with some impact require Minor Permit Review, and those with significant impact require Major Permit Review (Boulder County Code 8).

Create Linkages and Foster Connectivity

Connectivity was a consideration in Boulder County green infrastructure planning between 2000 and 2010, but not a major emphasis. One reason may be the success of Boulder's existing network of protected green space. The forested western half of the Boulder County has large hubs of federal, state, and locally protected green space. The land is in government ownership, relatively connected, and mountainous enough to have a low threat of development. Since connectivity is most important for natural resource lands, the county was already highly successful prior to the study period.

The 1999 Comprehensive Plan differentiated between 'fine filter' conservation - the protection of individual sites such as individual wetlands or habitat areas – and 'coarse filter' conservation – landscape scale strategies. The county also mapped landscape-scale resources in the Plan's Environmental Conservation Areas Map, which included not only hubs of green infrastructure, but stream and overland habitat connectors. Boulder's 'course-filter' objectives were to protect the largest, richest natural areas, surround them with buffers, and connect them with natural corridors. The Comprehensive Plan also emphasized the importance of riparian corridors for their wildlife habitat and connective characteristics (Boulder County 1999). The county did not identify or prioritize critical green space connectors and while the comprehensive plan included a map of the county's prodigious protected open space, the map was busy and unclear.

Boulder County supported connectivity most strongly through land preservation. In assessing potential open space, the Parks and Open Space Department gave each parcel a score, based upon its conservation merits. Attributes such as 'part of a habitat connector,' 'adjacent to existing protected lands,' and/or 'provided a critical trail or open space linkage' were among the highest rated in the county score sheet. Properties that did not have these attributes received negative points in the assessment and were less likely to be accepted when proposed for donation (Boulder County Parks & Open Space 2012).

The county also supported linkages by considering green space configuration in the subdivision and land development process. County code required that development be clustered within subdivisions to maximize connectivity within open space areas and that park dedications link to existing open spaces, trails, and recreation areas (Boulder County Code 7-1303). The 1999 Comprehensive Plan also noted that the county should acquire lands or right-of-way easements to connect public lands wherever possible (Boulder County 1999).

Value Areas of Ecological Quality and Local Importance
Boulder County integrated a variety of natural and cultural resources information into their long-term planning efforts. The 1999 Comprehensive Plan identified and mapped prominent or important landscape features, called Natural Landmarks, and Natural Areas, areas with unique natural beauty and significance and set out the criteria for designating each. At the beginning of the study period in 2000, county maps included 25 Natural Landmarks and 8 Natural Areas. The comprehensive plan also described site-based resources like critical wildlife habitats, rare plant sites, plant communities of special concern, and wetlands, and included them in an Environmental Resources Map. A larger scale Environmental Conservation Areas map showed landscape-level green infrastructure (Boulder County 1999).

Boulder County's main strategies for protecting areas of ecological quality and local importance were land preservation, development review, and subdivision regulations. As previously discussed, private donation of conservation easements was a major mechanism for natural and agricultural land protection in Boulder County. One county strategy for ensuring protection of lands with ecological quality and local importance was assessment and prioritization of potential open space. In deciding which easements to accept, the county emphasized several quality-oriented criteria, such as: 1) whether the property is part of an important corridor, Natural Area, Natural Landmark, viewshed, or Environmental Conservation Area, 2) whether the land contains valuable forest species or characteristics, 3) whether property's soils of local, state, or national significance, and 4) whether the property contains or supports rare species, habitat, or breeding areas. Other attributes that enhance or diminish conservation merits, such as acreage, condition, and adjacency to other preserved lands were also factors (Boulder County Parks & Open Space 2012).

The county also protected high quality cultural and natural areas through development review. As part of the subdivision and land development process, the Boulder County Land Use Code required developers to submit a 'development report' addressing the impact of a proposed subdivision on cultural and environmental resources. Rules required applicants to use field surveys and experts, to identify the short and long term impacts of development on local flora and fauna and design mitigation plans. The Parks and Open Space Department also reviewed applications for potential impacts on open space and environmental resources (Boulder County Land Use Code 2-201, 2-203). In addition, at the site scale, the county disallowed development on areas of a parcel with cultural resources, agricultural soils of state, local, or national significance, or natural ecosystems and wildlife communities, unless there were no other areas of a parcel that could be 'reasonably developed' and impacts upon the areas were avoided or mitigated (Boulder County Land Use Code 4-806). Site review also ensured that development did not impact Natural Areas or Natural Landmarks, and their surrounding 250-foot protective buffers.

The county provided additional protection for natural and locally important resources under Colorado's '1041 powers.' Under the rules, development proposals for land located in Natural Resource Areas of statewide importance, in Historical and Archeological Resource Areas of statewide importance, or related to the 'site selection and development of new communities' were subject to additional review. County code required that proposals for land in Natural Resource Areas include a survey of habitat of affected species, a plan for construction and operations, and an analysis of the impacts of the proposed development on wildlife in the designated habitat areas. The Code included similar requirements for proposals in Historical and Archeological Resource Areas (Boulder County Land Use Code 8-507). New communities were also subject to review. The county's 1041 regulations – standardized throughout the state - outlined the general considerations to be used in determining the impact of proposed developments. The rules were comprehensive and described the areas of review for each of the categories listed above (Figure 6-2). To receive a permit, applicants were required to adequately mitigate any identified impacts.

Figure 6-2. Excerpt from Boulder County 1041 Standards for approval of all permit applications (Boulder County Code 8-511).

> *f. The determination of effects of the proposed activity on terrestrial or aquatic life may include but is not limited to the following considerations:*
>
> *i. Changes that result in loss of oxygen for aquatic life.*
> *ii. Changes in flushing flows.*
> *iii. Changes in species composition or density.*
> *iv. Changes in number of threatened or endangered species.*
> *v. Changes to habitat and critical habitat, including calving grounds, mating grounds, nesting grounds, summer or winter range, migration routes, or any other habitat features necessary for the protection and propagation of any terrestrial animals.*
> *vi. Changes to habitat and critical habitat, including streambed and banks, spawning grounds, riffle and side pool areas, flushing flows, nutrient accumulation and cycling, water temperature, depth and circulation, stratification and any other conditions necessary for the protection and propagation of aquatic species.*
> *vii. Changes to the aquatic and terrestrial food webs.*

Boulder County has placed a particular emphasis on wildlife and wildlife habitat. In addition to the aforementioned 'areas of state interest' rules, County Code required that development applications for areas such as Natural Landmarks, Natural Areas, Riparian Corridors, or other areas mapped as Environmental Resources in the Comprehensive Plan or designated by the Park and Open Space Department include a wildlife impact report, prepared by a county-approved wildlife expert. The required report contains an inventory of Species of Special State Concern (SSSC), an assessment of the property's status as habitat for SSSCs, an assessment of the development's impact on SSSCs, a review of the potential measures for mitigating or alleviating the impacts, and a recommendation as to whether development can go ahead without a negative impact on SSSCs. The county could deny applications that staff determined to have negative impacts upon SSSCs or require mitigation measures such as relocating species and donating a conservation easement for important habitat (Boulder County Land Use Code 7-1700). The Colorado Division of Wildlife also evaluated applications for impacts on important wildlife and associated habitat (Boulder County Land Use Code 3-204).

Another way that the county protected green space and reduced overall environmental impacts, particularly early in the study period, was through Non-Urban Planned Unit Developments (NUPUDs) and Non-Contiguous NUPUDs (NCNUPUDs). NUPUDs are planned unit developments that take place outside of CSAs and are intended to provide economic benefit to agricultural landowners while keeping farmlands in farming. County code required that most applicants for NUPUDs have at least 320 acres, 75% of which was located in an area designated for agricultural, environmental, or open space preservation in the county comprehensive plan. NUPUDS were particularly useful for retaining large contiguous blocks green space since they also required clustering of development on 25% of the site - 15% where land is of particular agricultural or environmental significance – and donation a conservation easement to permanently protect remaining land (de Raismes, Hoyt et al. 2000). (Boulder County Parks & Open Space 2012). NCNUPUDs are similar to NUPUDs, but allow for density transfers from a sending to a receiving area. NCNUPUDs also had stronger environmental protection requirements. At least 90% of land proposed for protection under a NCNUPUD had to be significant agricultural land and the majority – by area – was required to contain environmental or open space values and be proposed as open space in the Comprehensive Plan. In the western forested section of the county, sending areas were required to include at least 175 contiguous acres, and in other areas at least 35, although as with NUPUDs, no more than 25% could be used for development (Boulder County Land Use Code 6-500).

Between 1979 and 1996, 146 landowners completed the NUPUD process, protecting over 11,000 acres of agricultural land, although not all that land remained in agricultural production. The strategy became progressively less popular as the number of large, divisible, properties in the county declined. In 2000, the Land Use Department registered 23 NUPUDs and in 2001 it counted 11. But between 2004 and 2010 the county recorded only 1 (Boulder County 1996) (Boulder County Budget Summary 2003 – 2010). Today, there are very few properties large enough to become NUPUDs, and the policy is not often used (Boulder County Parks & Open Space 2012).

Support a Variety of Landscapes and Ecosystem Services
Boulder County emphasized several types of green infrastructure. In addition to agriculture and wildlife habitat, the county highlighted the importance of cultural resources such as historic or archaeological sites, prominent natural features such as Natural Landmarks and scenic vistas, and lands that separate communities and bound CSAs. Natural Landmarks are a particularly unique feature of Boulder County Land Use Planning and the first type of natural resource identified in the 1999 Comprehensive Plan. Natural Landmarks are important for their visual prominence and use in distinguishing between communities and establishing a sense of place.

The county used two main strategies for supporting green spaces with cultural resources, scenic features, and community buffering capacities: conservation easements, and development review. In the score sheet used to prioritize conservation easements proposed for donation by landowners, the county gave points to properties that have urban shaping capabilities, Natural Landmarks, scenic views or rural character, or contain historical or archaeological resources. Of these, Natural Landmark areas received the most points (Boulder County Parks & Open Space 2012). The same categories are also subjects of inquiry in the subdivision and land development review process. County code requires that subdivision or land development proposals describe how changes would impact any scenic vistas, cultural resources, or Natural Landmarks. These features are also among the natural attributes that qualify land for an NUPUD or NCNUPUD (Bounder County Land Use Code 6-400).

Restore and mitigate damage to green infrastructure
Boulder County's work in restoring and mitigating damage to green infrastructure occurred mainly through the development review process and on county-managed open space. To receive a development permit under 1041 regulations, applicants were required to mitigate any impacts discovered through the review process. Wildlife, rare and critical species, riparian areas, and wetlands were the focuses of the county's specific restoration and mitigation rules. The county required that development proposals in areas that could impact wildlife habitat and rare or critical species include reports detailing appropriate mitigation procedures, such as site restoration, species relocation, and/or a conservation easement. Wetlands and riparian areas were also emphases. Where impacts upon riparian areas were unavoidable, the county required 'appropriate mitigation' such as reintroducing of native species, eliminating exotic species, and restoring degraded plant communities. Where impacts upon wetlands were unavoidable, the county required that wetlands communities areas be restored, enhanced, and/or constructed and monitored to ensure the mitigation measures were successful (Boulder County 1999).

The county also restored degraded portions of county open space to increase biodiversity and enhance or create habitat. Staff and volunteers in the Plant Ecology program restored a variety of areas such as wetlands, riparian areas, grasslands, trails, and old roadbeds that had been disturbed, overused, or overgrazed. Ecological restoration strategies included erosion control activities and replanting with native plants or seed (Boulder County 2013)

Manage green infrastructure to support ecosystem services
Boulder County's green space management efforts between 2000 and 2010 were largely oriented toward open spaces, wildlife, and native vegetation. The Parks & Open Space Department maintained management plans for all county open spaces and encouraged landowners selling or donating conservation easements to create a management plan at the time the land changed hands. Once land was sold or donated to the county, the Parks and Open Space Department took charge of maintaining and updating the management plans (Boulder County Parks & Open Space 2012). Ecosystem function was a major emphasis of county protected area management. The 1999 Comprehensive Plan set policy that the county should create management plans that consider regional ecosystems and environmental flows and follow good stewardship practices and other techniques to protect and preserve natural and cultural resources. The Plan also noted the importance of minimizing disturbance of large parklands to allow for natural function. County policy held that that, with the exception of certain types of regional parks (e.g. the County Fairgrounds), the county would provide minimal maintenance and development on parkland and that recreation would only be allowed on county lands where it was consistent with a management plan and would not negatively impact natural or cultural resources (Boulder County 1999).

County Code also required that development proposals for areas that could potentially impact specific environmental resources include a management plan for the resource. The 1999 Comprehensive Plan provided guidance that management plans for riparian areas should mimic natural processes, minimize human impacts, and include long-term monitoring (Boulder County 1999). The county also required that development reports addressing potential impacts upon wildlife habitat or rare or critical species include site-specific management and monitoring plans.

Wildlife habitat was a particular emphasis of open space planning and management in Boulder County. County biologists created an annual report detailing their wildlife management activities. The reports describe a variety of management and monitoring activities undertaken in the county including surveying and mapping species on county open space, species relocation, and population studies (Boulder County 2013). The 1999 Comprehensive plan also suggested a broad 'critical wildlife habitat management program.' The outlined plan included buffer zones to insulate wildlife habitat, mitigation of incompatible land uses, and retention of existing compatible land uses (Boulder County 1999, ER-8). While the degree to which these suggestions were implemented directly is unclear, the principles were integrated into the development review requirements for changes that could impact wildlife habitat, which are among the most stringent in the Land Use Code.

Boulder County also worked to protect and manage forests and native plant species. While the county did not create a cohesive forest management strategy until the end of the study period, the Forest Division did manage around 30,000 acres of forested lands. To maintain healthy forest ecosystems the Division conducted forest inventories and assessments and designed management actions to maintain and improve wildlife habitat, reduce wildfire danger, and generally, 'preserve the aesthetic and ecological value of the forest' (Boulder County 2013). The County's Plant Ecology program also managed the natural environment of county open space. Plant Ecology staff and volunteers inventoried open space for significant and unique native plant communities, designed management plans to protect them, and carried out management actions such as removal of weeds and other non-native species (Boulder County 2013).

Enact land use planning strategies to protect and retain all scales of GI
Boulder County's major land use planning strategies have included CSAs, zoning, subdivision regulations, and transfers of development rights. The county's overall strategy was to contain development within existing municipalities and protect agricultural and natural resources in more rural areas through zoning and programs that provide economic support while encouraging landowners to donate conservation easements. As previously described, community service areas (CSAs) are legally binding growth and planning areas, negotiated between Boulder County and incorporated municipalities. Land outside of an incorporated municipality but within the surrounding CSA is considered growth area, land to which urban services will eventually be extended. Under most circumstances, only land within a CSA is considered for development. Areas outside of CSAs are intended to remain largely rural, and support agriculture, natural resource, and limited low-density residential development.

As with most urban service areas, CSAs require support from policies outside the boundary to effectively direct growth. In Boulder County, most of this support is in the form of rural zoning and subdivision regulations. To protect rural and agricultural lands, in 1985, Boulder County rezoned 35,000 acres. The change reduced the allowed density outside of Community Service Areas from one dwelling unit per five acres to one per 35 acres. The 35 acre value was selected to match Colorado's 1972 Subdivision Bill - often called Bill 35 – that held that divisions of land resulting in parcels greater than 35 acres are not 'subdivisions' and therefore are not subject to subdivision review. To minimize the economic hardship of the downzoning – and further protect large blocks of agricultural land - the county introduced the previously discussed NUPUD at the same time.

Zoning has remained relatively unchanged since that time. The county had three major rural zones, Forestry, Agriculture, and Rural Residential. With the exception of a few small, incorporated municipalities, the entire western half of Boulder County was zoned Forestry. The majority of the eastern half was zoned Agriculture. If within a CSA and served by sewer and water, land zoned Forestry or Agriculture could be developed at a density of one dwelling unit per 35 acres. Another prominent zoning district was Rural Residential. If within a serviced CSA, Rural Residential areas could be developed at a density of one dwelling unit per acre.

The county also had one relevant overlay zone, the Natural Resource Protection Overlay District. The Overlay covered areas that had not been fully developed, but were platted prior to 1978 and not reviewed for impacts on habitat, wetlands, and wildlife corridors. The county required landowners wishing to develop in this area to undergo additional environmental review and take actions necessary to mitigate potential impacts (Boulder County Code 4-300).

NUPUD rules allowed landowners in Boulder County to receive density bonuses for clustering development and protecting resource areas, but they could also develop at greater densities through the transfer of development rights (TDR) program. Like the NUPUD rules, the TDR program allowed landowners to benefit from twice the statutory density - two dwelling units per 35 acres rather than one. But while NUPUDs used bonuses on-site, the TDR program allowed landowners to transfer or sell them to developers of receiving sites in more desirable locations. Landowners were eligible for two TDRs per 35 acres, if they agreed donate their land's development rights to the county. One or both TDRs could be transferred to other sites. The location of receiving areas was relatively open. To use TDRs, county code required only that landowners apply for approval to develop the receiving area as a TDR-Planned Unit Development and show the area has adequate services for the new population. The general rule was also that 75% of the development credits should come from the same area as the development site, particularly if the county and city had agreed upon a CSA (Boulder County Parks & Open Space 2012). The location of TDR sending sites was more specific, designated on the Boulder County TDR Sending Sites map, or identified in intra-governmental agreements, such as CSAs (Boulder County 1999) (Boulder County Code 6-700). However, according to county open space records, the program has not been popular.

Through 2000, 8 TDR sending sites had been protected, totaling 493 acres. During the study period that number dropped to 4 and a protected area of only 122 acres.

In the 1999 Comprehensive Plan, Boulder County also designated land east of the Forestry zoning district and outside CSAs as the Plains Planning Area (PPA). Most was within the Agricultural zoning district. Under the 1999 Comprehensive Plan, the PPA was to remain rural, with no urban services extended to the area and a gross density of not greater than one dwelling unit per 35 acres (per the 1985 rezoning). Tools such as NUPUD and TDR (sending area) could be used in the area, but only for areas with "significant agricultural land and sensitive or important ecosystems" (Boulder County 1999, PPA-5). Parts of the PPA could serve as a receiving area, but only if the proposed receiving location was within a CSA and had adequate infrastructure (Boulder County 1999). While more advisory than other strategies, the PPA was another way that Boulder County restricted development outside of municipalities and underscored the desired development pattern for the county.

Protect and support GI through a collaborative and cooperative process

In planning for green infrastructure, Boulder County collaborated with the State of Colorado, local governments, regional planning authorities, and local citizens. Within the county, the Land Use Department coordinated with Parks & Open Space in comprehensive green space planning and review of development applications with potential impacts on natural and cultural resources. The county also worked with cities on protecting and managing open spaces near their boundaries, particularly through Intergovernmental Agreements (IGAs). Through CSAs, counties and municipalities agree where growth and annexation will occur. Some IGAs also have an open space preservation component where counties, municipalities, and other government agencies collaborate to protect land in certain important areas. While land under an IGA is initially protected statutorily, it is often made permanent with conservation easements (Boulder County Parks & Open Space 2012).

Boulder also participated in 130 joint open space projects with municipalities and other partners (Table 6-2) (Boulder County 1999). Between 2000 and 2010, the most frequent collaborator was Boulder County, but several other municipalities were partners in preservation efforts, both in fee and through easements (Boulder County 2013).

Table 6-2. Boulder County partners in conservation projects between 2000 and 2010. Table by author. (Boulder County 2013).

Conservation Partners (2000 to 2010)	Number of Properties
City of Boulder	50
City of Longmont	19
City of Lafayette	11
City of Louisville	8
Town of Ward	6
Two or More Municipalities	5
Gunbarrel Improvement District	4
Estes Valley Land Trust	2
Town of Mead	2
Town of Superior	2
Partner Unlisted	21

The County also used state and regional funding and expertise. State agencies provided mapping and natural resource expertise that the county used in green infrastructure planning and management and Great Outdoors Colorado (GOCO) lottery proceeds provided financial support for the county's open space vision. Through GOCO, Boulder County and partners have received \$14.6 million in grants, \$50.5 million directly through the Conservation Trust Fund, and \$5.6 million in spending on state parks (Colorado Lottery 2013).

Boulder also collaborated with nonprofit organizations during the study period. Boulder County is within the planning area of the Denver Regional County of Governments (DRCOG). DRCOG is a regional planning body, and the local MPO. Boulder County makes data on open spaces available to the public through the organization's periodic regional parks and open space survey. There are also a few land trusts active in the Boulder County region, but they are not prolific and not mentioned in county planning documents. The county has worked with only one, Estes Valley Land Trust. Boulder is the backup easement holder for two of the organization's preserved agricultural properties, a total of 135 acres.

The citizens of Boulder County were among the most important players in county green infrastructure planning. The county collaborated with numerous local citizens to coordinate conservation easement donations and environmental management and restoration efforts. In developing open space and management plans, the county also solicited comments from interested individuals, organizations, and landowners. In addition, Boulder County citizens have been highly supportive of the county's green space protection efforts and repeatedly voted for taxes and bonds. Residents passed the first 0.25% Open Space sales and use tax in 1993 and voted to increase it three times. Revenue was dedicated to repaying voter-supported open space bonds issued in 1994, 1996/1998, 2005, 2009, and 2011 (Boulder County 2011).

Funding
Boulder County categorizes green infrastructure spending as ‘land use and conservation’ and divides it into three major categories based upon source: land acquisition, Conservation Trust Fund, and 2005 Open Space Bonds. Between FY2003 and FY2010, the county spent an average of $11.7 million per year in the three categories, with a low of $4.7 million in 2009 and a high of $30 million in 2006. Funding peaked in the center of the study period with the greatest expenditures in 2006, 2007, and 2008, the three years in which the county used the 2005 Open Space Bonds ($25, $17, and $7 million, respectively.) Land acquisition spending was the steadiest with $3.8 million budgeted each year between FY2004 and FY2010. The county did not report the specific projects supported by the funds (Boulder County Budget Brief 2003 – 2011).

The Conservation Trust Fund is supported by revenue from the State Lottery, which is disbursed to counties on a per capita basis. The funds support the acquisition and development of parks and trails. The 2005 Open Space Bonds were the latest in a series of open space bonds serviced by dedicated sales and use tax revenue. As previously mentioned, in 1993, Boulder County residents approved a 0.25% sales and use tax to expand the open space program. Residents also voted to increase the tax an additional .10% in 2002, an additional .10% in 2005, and a further .15% in 2011, although the latter increase is outside the study period. The proceeds were used to service the issuance of several open space bonds, two during the study period, in 2005 and 2009 (Boulder County 2011). The operations and maintenance of the open space program were funded by a separate property tax (Boulder County 1999).

In addition, landowners donating conservation easements in Boulder County during the study period were eligible to receive tax benefits, but only if a did not receive fair market value for the easement. Easements donated as part of a land use or land development process, such as NUPUD, TDR, or subdivision open space dedication, were not eligible for tax benefits (Boulder County Parks & Open Space 2012).

Green Infrastructure Network Change in Boulder County

Quantity
Based upon land cover classification of Global Land Survey images from 2001 and 2009, Boulder County lost 1 percent of its unpreserved agricultural base, but no natural land cover, while increasing developed area by 2% (Table 6-2). However, in Colorado, where grassland and prairie are common natural land covers, land use in counties with considerable grassland and prairie is more fluid than in counties where the dominant natural land cover is forest. Agricultural lands that are left fallow return quickly to prairie and grasslands are easily tilled and planted. Consequently, there may be significant movement between agricultural and natural land uses over a decade. Land use changes can happen multiple times on the same parcel over the course of a decade. Table 6-2 shows the area of natural and agricultural land in Boulder County between 2000 and 2010, but shifts between natural and agricultural land uses obscure the amount of each that was converted to non-resource uses such a residential or commercial development. In

all, 409 acres of land that was agricultural and 246 acres of land that was forest or grassland in 2010 were converted to developed land uses by 2010. These account for 0.5% of agricultural land and 0.1% of natural land. However, these values may also be impacted by shifts between natural and agricultural land covers. The clearest outcome is that, between 2000 and 2010, 654 acres of Boulder County were converted from green infrastructure to developed uses. The new development accounts for 0.2% of privately-owned land in the county and indicates a 2% increase in developed area (as shown in table 6-3).

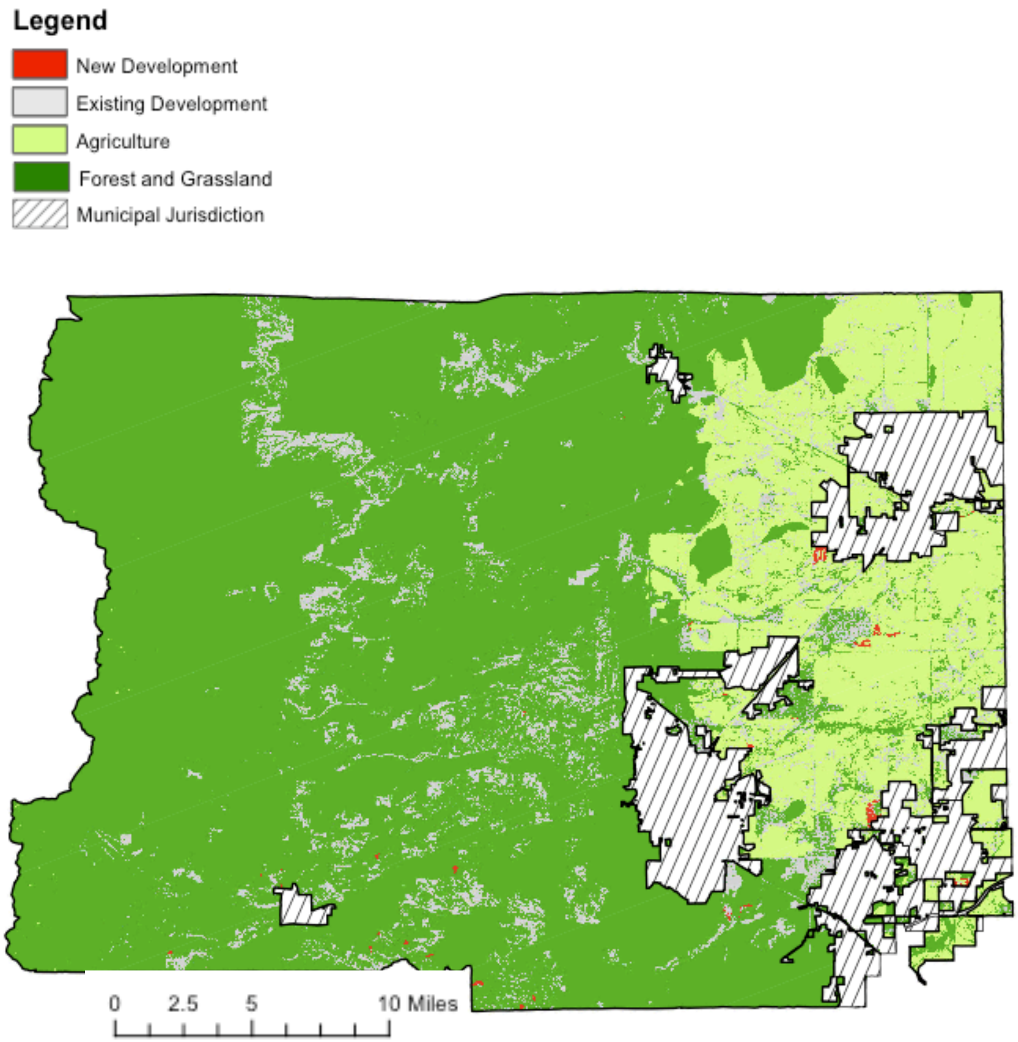
Table 6-3. Land Use Change in Boulder County, 2001 to 2009* (by author). Natural includes both forest and grassland.

	2001 (acres)	**2009 (acres)**	**Change (%)**
Water	7,861	7,861	**0**
Agriculture	79,996	79,544	**-1**
Natural	158,271	157,838	**0**
Developed Area	53,160	54,045	**2**

*Considers only privately-owned unprotected lands under county jurisdiction.

Between 2001 and 2009, development occurred principally in the eastern section of the county, where the majority of existing development was concentrated (Figure 6-2). But pockets of land conversion spread relatively widely within that section. Limited development also occurred in along the central portion of the southern border.

Figure 6-3. Natural land, farmland, and developed area in Boulder County in 2009. 'New Development' is development that occurred since 2001 (by author.)



Next to the US Forest Service, the largest conservation landowner is Boulder County. In 2000, the county owned 38,300 acres in fee and protected an additional 18,600 acres with conservation easements (Table 6-4). Between 2000 and 2010, the county increased its open space holdings by 51% to 58,000 acres and conservation easements by 79% to 33,300.

Table 6-4. Boulder County conservation land by type of preservation. Table by Author. (Boulder County 2013)

Type of Conservation Land	Through 1999		2000 to 2010		Total Acreage
	Number of Properties	Acreage	Number of Properties	Acreage	
County Open Space (Owned in-fee)	319	34,152	686	16,051	**50,203**
County Open Space Partnership (Owned in-fee with partner*)	28	4,162	43	3,552	**7,714**
County Conservation Easement	416	18,170	430	11,486	**29,656**
County Conservation Easement Partnership**	12	446	87	3,187	**3,633**
TOTAL	775	56,930	1,246	34,276	**91,206**

* Partner may jointly own land or hold a conservation easement on land owned in-fee by the county.
** Partner may jointly hold the conservation easement or own conserved land in-fee.

The greatest conservation increase over the study period was in conservation easements. The county was particularly successful in protecting land through partnerships with municipalities. But the relative use of different conservation easement mechanisms also changed over time. Through 2000, the most prolific easement tool was the Non-Urban Planned Unit Development (NUPUD) (Table 6-5). The NUPUD a type of development allowed landowners to obtain additional density if they preserved between 75% and 90% of their land with a conservation easement. Between 1985 and 1999, the county approved 183 NUPUDs protecting nearly 9,000 acres, an average protected area of 48 acres. Since 1999, only 14 NUPUDs were completed, mostly in 2000 and 2001. The average protected area also declined, to 19 acres. As previously mentioned, the county attributes the drop to a reduction in parcels large enough to take advantage of the strategy. The other dramatic change was an increase in regulatory conservation easements, easements donated to the county through the land use review and approval process. Despite the dip from 28 to 23, the rate of regulatory easements probably increased, as did the average easement size. Prior to 2000 the average regulatory conservation easement was 13 acres, and between 2000 and 2010 it was 50. As the size of remaining undeveloped parcels declined throughout Boulder County the overall easement size also fell, from 44 acres prior to 1999 to 27 acres between 2000 and 2010. Notably, declines in the average size of new conservation easements - and new protected lands more broadly - are not indicative of a decrease in the effectiveness in Boulder County's program. They are signs of success. Most large parcels in the county are already preserved. In addition, during the study period, the decline in easement size - and in land preservation through PUD, NUPUD, and TDR - was balanced by a doubling of other, more direct, easement acquisition strategies.

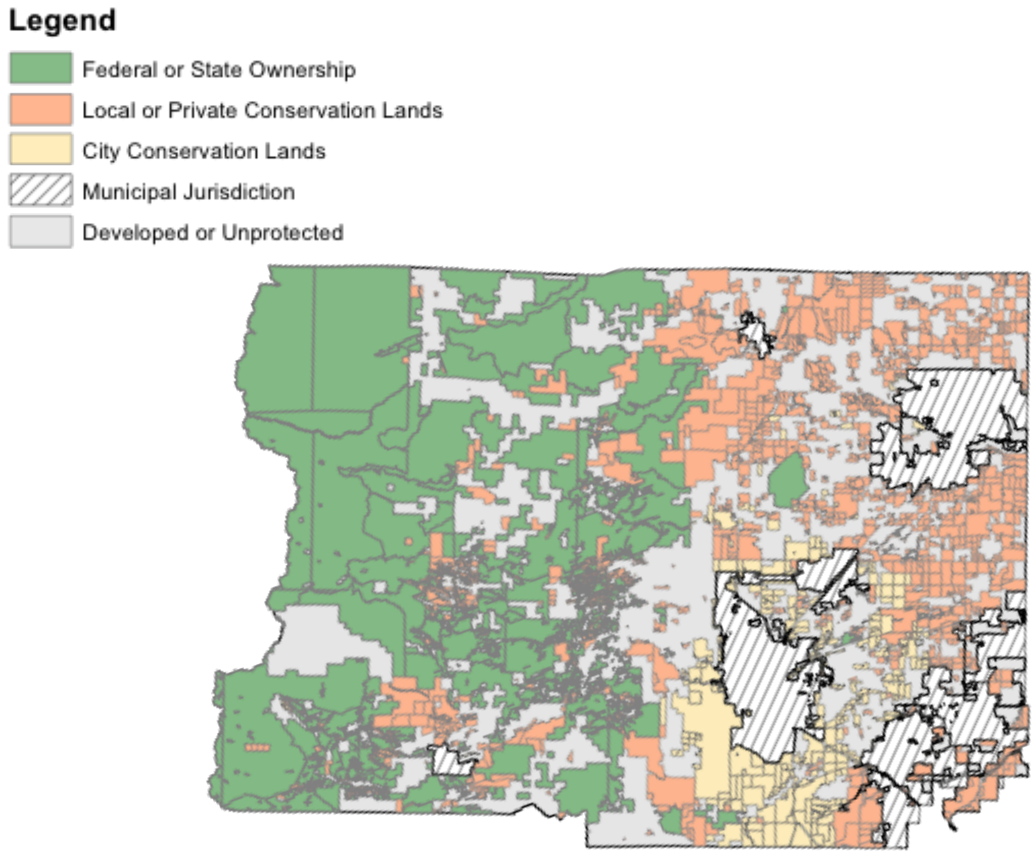
Table 6-5. Boulder County conservation easements by mechanism. Table by Author. (Boulder County 2013)

Type of Conservation Easement	Through 1999		2000 to 2010	
	Protected Areas	Acreage	Protected Areas	Acreage
Through a PUD	14	289	2	11
Through an NUPUD	183	8,897	14	266
TDR Sending Site	8	493	4	122
Regulatory*	28	362	23	1,153
Other (Direct Purchase or Donation)	183	8,129	387	9,934
TOTAL	**416**	**18,170**	**430**	**11,486**

* County was granted a conservation easement by the landowner, generally as part of the county land use process.

Protected land in Boulder County is well-distributed. Federal and state lands dominate the mountainous western half and local and city preservation occurs principally in the flatter, more populated eastern areas (Figure 6-3). The number of protected lands, and the clustered configuration, means that most preserved properties are well-connected to the broader network. Boulder County properties also help to fill gaps between state and federal lands, connecting them and increasing the functional size of the major mountain green space hubs.

Figure 6-4. Protected lands in Boulder County, Colorado in 2010, by ownership. Properties protected through county or joint city/county efforts are shown as 'Local or Private Conservation' (by Author).



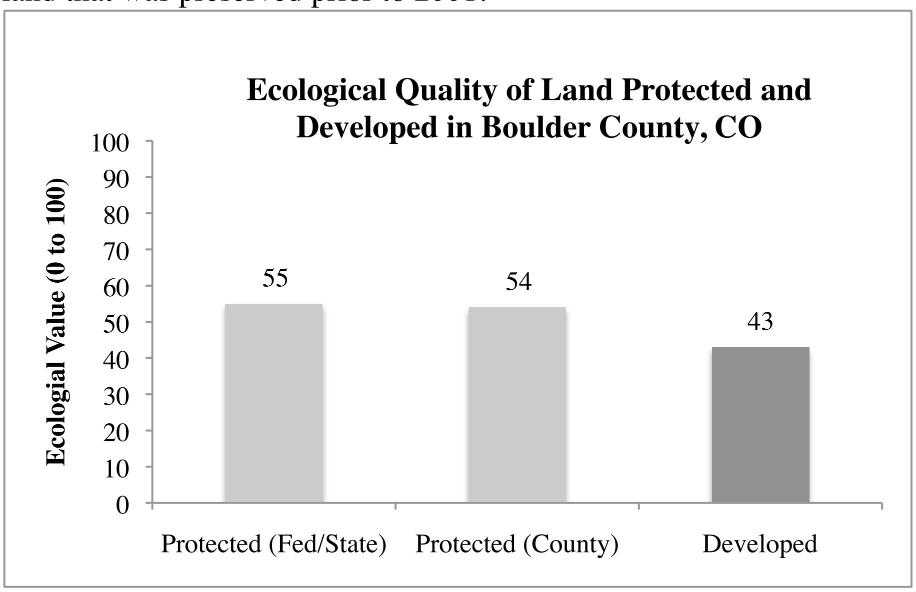
Quality

An important objective of green infrastructure planning is to protect sensitive and high quality resources by a) preserving them or b) directing development to other areas. A county's success in these areas can be measured by the ecological value of protected and developed lands. Developed areas should have a relatively low ecological quality while protected land should have a high ecological value. Since land cover in much of Colorado is relatively fluid (i.e. land changes from natural grassland to agricultural uses and back again quickly), it is difficult to separate natural and agricultural lands for the purposes of comparing quality and the two types must be considered together. Additionally, Boulder County has far more state and federal land than Arapahoe and Adams, and much is it is mature forestland in the mountainous western half of the county, which is inherently high quality. Arapahoe and Adams have nothing comparable; the vast majority of the counties are agricultural plains. Due to the inequity, overall quality comparisons include only local preservation areas, with state and federal lands shown for context.

Important features for calculating the ecological value of lands in Colorado include sensitive resources such as wetlands, species habitat, interior forest, and streams, and other features with ecological implications such as proximity to development and roadways. Together the information forms a single layer that indicates the relative ecological importance of each 30mx30m block of land in Boulder, Arapahoe, and Adams County on a scale of 0 (least ecological value) to 100 (most ecological value).

Between 2000 and 2010, Boulder County was moderately successful in directing development to ecologically marginal areas. In 2009, the area-weighted mean ecological value of county protected lands in the county was 54 and the value was similar for lands owned by state or federal agencies. The mean ecological value of land developed between 2001 and 2009 was significantly lower, at 43 (Figure 6-4).

Figure 6-5. Area-weighted mean ecological quality of land developed in Boulder County between 2001 and 2009. Federal/State and county protected area quality averages include land that was preserved prior to 2001.



Connectivity
A third objective of green infrastructure planning is to retain lands that form a network of large, interconnected, green space. A county's success in this area is indicated by stability in the connectivity and patch attributes of green infrastructure over time. Increasing connectivity is not usually feasible, but local governments can retain existing connections by preserving critical linkages and planning development in a way that does not fragment the network.

Landscape ecology metrics provide information on the spatial configuration of landscapes. A patch is an area of continuous landscape, such as farmland or forested area. Metrics noted here discuss the average patch shape for each type of green infrastructure, as well as connectivity and proximity.

Between 2001 and 2009, the connectivity of Boulder County's forest network was stable. Patches of forested land remained around the same size and retained their connectedness (Table 6-6). Results for farmland show some loss of connectivity. As shown through the Area-Weighted Mean Patch Length/Contiguity and Area-weighted Mean Patch Size and Proximity Metrics, patches of agricultural land became slightly shorter, smaller, and further apart.

Table 6-6. Patch Shape and Contiguity Metrics for Boulder County Natural and Agricultural land in 2001 and 2009 (by author).

	Natural Land			Agricultural Land		
	2001	**2009**	**Change Notes**	**2001**	**2009**	**Change Notes**
Area-weighted Mean Patch Length/ Contiguity (GYRATE_AM)	15,170m	15,166m	Minimal Change	4,073m	4,031m	(Slight) Decrease in patch length
Patch Shape Complexity (SHAPE_AM)	33	33	Minimal Change	21	21	Minimal Change
Patch Aggregation (CLUMPY)	0.93	0.93	Minimal Change	0.91	0.91	Minimal Change
Area-weighted Mean Distance to Nearest Like Patch (ENN_AM)	60m	60m	Minimal Change	61m	61m	Minimal Change
Area-weighted Mean Patch Size and Proximity Metric (PROX_AM)	3,949	3,938	Minimal Change	10,637	10,708	Patches become (slightly) smaller and more distant

Overall

Between 2000 and 2010, the Boulder County Land Use Department and Parks & Open Space Department conducted a high level of green infrastructure planning. The county's activities covered 62 percent of the policies and strategies included in the Green Infrastructure Planning Assessment Framework. The county's highly successful open space program and resident support for open space acquisition and management contributed to the score. Boulder County also had strong growth management. The county used community service areas to bound growth, and rural zoning and land preservation to support the CSA boundaries and minimize sprawl into rural areas. Provisions such as NUPUD and NCNUPUD, which allowed development in ways that would help keep land in farming but limit disturbance, led to significant permanent conservation and also contributed to the score, as did the TDR program. The county's main weaknesses were the lack of mapped green infrastructure hubs and links and the absence of a parks and/or open space plan. Without a clear landscape scale green space plan or strategy, open space planning is largely reactive and it is difficult to ensure that preservation is creating a configuration of green infrastructure that is most supportive of ecosystem services.

The county's green infrastructure network remained remarkably stable over the study period. Only 650 acres were converted from natural resource to developed land uses. Prior to development, most of the land was agricultural. The county was also moderately successful in directing development away from high quality natural areas and towards more marginal lands. The average ecological quality of land developed during the study period was 12 points lower than the average for protected lands. Finally, and unsurprisingly given the large block of forested land in western Boulder County, there was no change in the connectivity of forested lands during the study period. But there was a small decrease in connectivity of agricultural lands. Patches of farmland became slightly smaller and further apart.

MODERATE GREEN INFRASTRUCTURE PLANNING: ARAPAHOE

During the study period, Arapahoe County had a clear growth management strategy, focused land preservation, and good local and regional collaboration. The county also used the state 1041 rules for new communities to strengthen development review and protect natural and agricultural resources. But the county lacked a broader open space strategy and actions that support connectivity.

Demographics, Economy, and Environment

In 2010, Arapahoe County had a population of 572,000, an increase of 17.2% over 2000. As Adams County's southern neighbor, Arapahoe is part of the greater Denver Area. The heavily urban and suburban western portion of the county includes several Denver suburbs and satellite cities. Aurora, along the Adams-Arapahoe border, is the largest but the county includes 12 smaller municipalities, as well. Only one – Centennial (100,000) – had a 2010 population greater than 50,000 (US Census 2000, 2010).

The major industries in Arapahoe are education, health, management, and the sciences. Mid-decade, the top employers were Qwest Communications (telecommunications), King Soopers (a grocery chain), and Lockheed Martin. Only bus service is available in the county and the vast majority of commuters (78%) drive to work alone, the highest percentage of the study counties.

Arapahoe was impacted by the mid-decade recession. Unemployment increased from 2.4% to 8.8% between 2000 and 2010, a change roughly in keeping with the state, as a whole. But household income fell by 15%, among the greatest declines in the region. Despite the economic constraints, median home value increased by 7% to $232,000, greater than the median for Colorado ($167,000).

In Arapahoe County, agriculture is locally important, but not a major economic driver. According to the 2007 Census of Agriculture, the market value of agricultural products sold in Arapahoe in one year was only $29 million, a small fraction of Colorado's $6 billion and the lowest of the three study counties. While the county has a moderate number of farms (627), they are small. The average farm size in Arapahoe in 2007 was 489 acres, half the state average of 853 acres (United State Department of Agriculture 2009). In addition, the eastern two-thirds of Arapahoe is dotted is State Trust lands, the majority of which are leased to private individuals for agricultural uses. The State Trust Board holds 28 traditional state trust lands in Arapahoe, at an average of 640 acres each.

The largest hub of green space in Arapahoe County is Lowry Range. At 26,000 acres, it is one of the more unique parcels held by the State Trust Board. It is only 20 miles southeast of Metro Denver – directly east of Arapahoe's major municipalities – and, according to the State Land Board, "one of the largest contiguous parcels under single ownership by a major metropolitan area in the country" (Colorado Department of Natural Resources 2012, 1). Like other State Trust lands, Lowry is leased for a variety of uses, such as recreation, grazing, and mineral development (ibid). The second largest hub of green space in Arapahoe County is Cherry Creek Reservoir and State Park, at more than 7,600 acres. Together with the far smaller Chatfield State Park, and Department of Defense Lands, the state and federal governments own nearly 7,800 acres of non-state trust land in Arapahoe County, much of it park and recreation land.

Green Infrastructure Planning in Arapahoe County

Two divisions of the Department of Public Works & Development were the main organizations responsible for green infrastructure planning in unincorporated areas of Arapahoe County during the study period. The Planning & Zoning Division, undertook traditional planning tasks, such as zoning, development review, and drafting and maintaining the comprehensive plan. Planning & Zoning staff numbers contracted during the study period, from 24 in 2007 to 19 in 2009. The other major group involved green space planning, the Open Space Division, saw an increase in staff, from 4 in 2006 to 9 by 2009. The Open Space Division tackled open space planning, acquisition, and maintenance, in addition to managing the sales and use tax funded Open Spaces Program (Arapahoe County Budget 2006 – 2010).

For the 2000 to 2010 time period, Arapahoe County receives a score of 65, indicating that the county employed 46% of the strategies, policies, and programs included in the Green Infrastructure Planning Framework (Table 6-7). The score reveals a moderate-level of green infrastructure planning. Arapahoe's strengths are in using land use planning strategies to protect and retain green infrastructure, protecting green infrastructure through a cooperative process, and valuing areas of ecological quality and local importance. Weaknesses are in fostering connectivity, supporting a variety of landscapes and ecosystem services, and in restoring and managing green infrastructure over the long term. The following sections provide an overview of planning in Arapahoe County and describe the policies and strategies through which Arapahoe County furthered each principle of green infrastructure planning between the years of 2000 and 2010. For a complete Green Infrastructure Planning Assessment Framework for Arapahoe County, see Appendix 6-A.

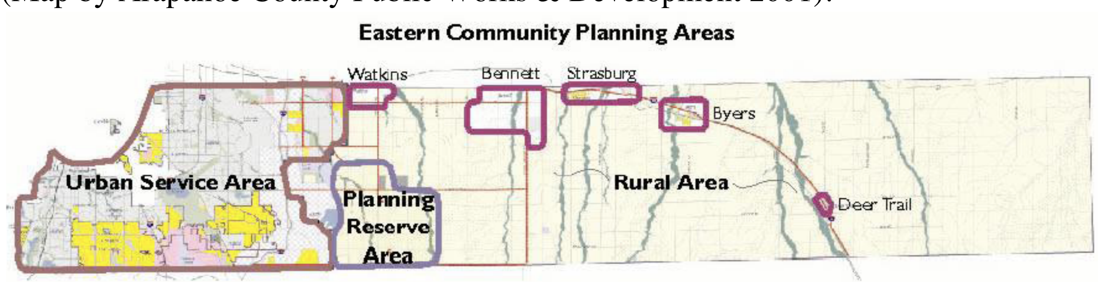
Table 6-7. Arapahoe County Green Infrastructure Planning Framework Results Summary.

Green Infrastructure Principle	Framework Score (Out of 20)
Create linkages and foster connectivity	**5**
Value areas of ecological quality and local importance	**11**
Support a variety of landscapes and ecosystem services	**9**
Restore and mitigate damage to green infrastructure	**5**
Manage green infrastructure to support ecosystem services	**9**
Enact land use planning strategies to protect and retain all scales of GI	**14**
Protect and support GI through a collaborative and cooperative process	**12**
TOTAL (Out of 140)	66
PERCENTAGE	**46%**

Arapahoe was the first county in Colorado, one of the original 17 colonies in the Louisiana Purchase. It adopted its first comprehensive plan in 1970, in response to intense growth in the western section of the county. Early plans focused on the western section of the county, largely ignoring the needs of central and eastern communities.

The 2001 Comprehensive Plan was the main long-range planning document during the study period. It outlined six Comprehensive Plan Principles to guide the county's development. Several of the principles had green infrastructure implications. For example, the first principle stated, "Arapahoe County will have a compact development pattern that encourages growth to locate within well-defined growth areas, and balances development and conservation of the natural environment" (Arapahoe County 2001, 22). The Plan divided the county into three planning areas, the Urban Service Area, the Eastern Communities, and the Rural Area (Figure 6-6). It also identified the Planning Reserve Area, land owned and administered by the State Land Board that would be planned – largely for conservation – outside of a 20-year time frame. Most of the Planning Reserve Area was within the Lowry Bombing Range and currently leased for grazing, recreation, and mineral extraction.

Figure 6-6. Main planning areas in the 2001 Arapahoe County Comprehensive Plan. (Map by Arapahoe County Public Works & Development 2001).



Growth management was a major objective of Arapahoe County's 2001 Comprehensive Plan. The county's general strategy was to direct growth to the Urban Service Area (USA) and encourage unincorporated communities within the USA to annex into incorporated towns. Under the plan, the USA would be planned for urban densities with associated services. The strategy also established growth areas around several unincorporated 'Eastern Communities.' The 2001 Plan did not encourage growth in those areas, but noted that it is occurring and should be carefully planned in ways that do not disrupt their rural town character. Rural lands outside of the USA and Eastern Community Planning Area boundaries were to be left rural to preserve agricultural and natural resources (Arapahoe County 2001).

Two further features of planning in Arapahoe County impact green infrastructure: the 1041 rules and the Open Space Program. Since 2004, Arapahoe County has designated "site selection and development of new communities" as an activity of special state interest under Colorado's 1041 rules. As in Boulder, the 1041 regulations meant that new development was subject to special review and 1041 permitting. Review under the 1041 rules was extensive, and required applicants to submit inventories, impact analyses, and mitigation strategies for impacts on natural, cultural, and agricultural resources. Review also addressed growth, finances, and consistency with the comprehensive plan (Arapahoe County 2006).

A final facet of Arapahoe County's green infrastructure planning strategy was the Open Space Program. In 2003, residents voted for a 0.25% Open Space Sales and Use Tax. Proceeds funded open space acquisition, upgrading, and maintenance. Half of the total tax collected was shared back to the county's 12 cities and towns and an additional 12% was allocated to municipalities and special districts through a competitive grant program. Remaining proceeds, minus administrative and maintenance allocations, funded open space and trails in the unincorporated county. In the end, 28% of the revenue funded acquisition and development of open space and trails in Arapahoe County. This structure had two particular distinctions. First, it contained the largest Open Space Share Back program in Colorado (50%), and second, it provided significant funds for open space acquisition in unincorporated areas (Arapahoe County 2010). During the study period, the program protected 15,752 acres of Arapahoe County open space (Arapahoe County 2010). While the county had a relatively informal land preservation prioritization procedure for its 28%, it did use criteria to distribute the 12% allotted to competitive grants. Unlike shareback funds, which were allocated to municipalities, grant funds were often used in incorporated areas of the county by special districts.

Create Linkages and Foster Connectivity
Arapahoe County planning documents include numerous references to connectivity. The first policy in the Open Space, Parks and Trails element of the 2001 comprehensive plan was to create a, "connected countywide system of open space, and public parks and trails" (Arapahoe County 2001, 107). The policy also notes the importance of establishing a regional, interconnected open space system, and identifying and protecting wildlife corridors (ibid). The 2001 Plan briefly mentions that development has been

fragmenting wildlife habitat, natural resources, and agricultural lands. But, while the plan did discuss connections, it did not provide an open space plan or strategy for creating the needed linkages. Nor did the county use a hub and corridor framework for green infrastructure.

Arapahoe County supported connectivity mainly through subdivision and land development regulations, including design standards. Design standards required that, if possible, natural features connect to similar areas on adjacent lands and that:

Open space areas are encouraged to be organized so as to create an integrated system that connects with the following types of lands located within or adjacent to the development, dedicated park lands, dedicated school sites, other dedicated open spaces, portions of the regional trail and open space system, and activity centers (Arapahoe Land Development Code 15-106.01).

The county also promoted connectivity through the Open Space Program. Funds allocated to Arapahoe County were often directed to properties that were well connected to the open space network or adjacent to existing protected areas. But the Open Space Division was also responsible for distributing the 12% of Open Space Sales and Use Tax funds allocated to the competitive grant program. Funded organizations included municipalities, but also a variety of special districts in unincorporated parts of the county. The county requested that applicants for all types of grants – trail, acquisition, site improvement – identify how the project would improve connectivity to trails, natural resources, and/or community resources (Arapahoe County 2013).

Areas of Ecological Quality and Local Importance
Arapahoe County integrated a variety of natural and cultural resources information into their long-term planning efforts. The main planning document, the 2001 Comprehensive Plan described key natural communities such prairie grasslands and forested riparian areas and mapped existing open spaces, riparian areas, and waterways (Arapahoe County 2001).

Arapahoe protected high quality and important resources through 1041 Permit Review, agricultural zoning and cluster developments, the Floodplain and Open Districts, and the Open Space Program. Like Boulder, development in Arapahoe is subject to 1041 Permit Review. All applications must include an Environmental Impact Analysis, including maps, inventories, descriptions, and impacts related to vegetation, viewsheds, forest canopies, waterways, riparian areas, wetlands, terrestrial and aquatic plants and animals, soils, natural hazards, and historic or archaeological resources. Applications must also show percentages of open space, park areas, and trails. In order to be approved, the applicant was required to show the development was in conformity with comprehensive plans, protected natural resources and existing environmental conditions, and would not interfere with wildlife habitat archaeological, historic or unique resources unless the impacts were mitigated.

The county also protected natural and agricultural resources through zoning. The main agricultural zoning district, A-E had a minimum lot size of 35 acres. As the 2001 Plan notes, the district would be more protective with a lower density, but it is the smallest size that can require review under state regulations. In 2006, the county attempted to mitigate some of the impacts of development in the A-E district - and sister zone A-1 (1 dwelling unit per 19 acres) – by adding provisions encouraging clustered development. The rural cluster rules provide density bonuses for development clustered on 40% or less of a property (Arapahoe Land Development Code 13-1100). While the clustering could mitigate some of the impacts of developing on large agricultural parcels, their existence does facilitate, if not encourage, development in the most agricultural district of the county.

The county also used Open and Floodplain zones to protect natural resources. The Open district was used primarily for open space buffers and outdoor recreation areas (Arapahoe Land Development Code 9-300). The Floodplain district covered the 100-year floodplain and prohibited permanent structures within the limits of the zone (Arapahoe Land Development Code 9-400).

The county also protected important resources through the Open Space Program. While the allocation process for the county's 28% share of open space funds was relatively informal – based upon comprehensive plan goals and landowner willingness – planners did use an evaluation matrix to rate potential open space lands' natural resource quality from D to AAA (Deffner 2013, personal comm.). In allocating grant funds to other organizations, the county asked applicants to identify the prospective site's historic values, native ecosystems, and their quality and management needs. The application also requested that applicants describe natural resources on site, such as wildlife, vegetation, and scenic and water resources. Only properties achieving above a certain score were eligible for funding (Arapahoe County 2013).

Support a Variety of Landscapes and Ecosystem Services

Arapahoe County emphasized waterways, floodways, and agricultural areas, but also noted the importance of protecting wildlife, wetlands, views and ridgelines, historic, cultural, and archaeological resources. The county protects these areas principally through the 1041 rules, subdivision regulations and design standards, and the Open Space Program. The 1041 rules were most protective. They required applicants for development to submit an inventory of natural, agricultural, and cultural resources, identify possible impacts, and suggest mitigation strategies (Figure 6-7) (Arapahoe County 2006). In requiring applicants to consider impacts upon agricultural resources, Arapahoe's 1041 regulations go beyond that of many other counties, including Boulder.

Figure 6-7. Excerpt from Arapahoe County 1041 Permit Review standards. General Considerations for terrestrial & aquatic life and agricultural activities (Arapahoe County 2006, Appendix A).

A.12. The determination of effects of the proposed activity on terrestrial or aquatic life may include but is not limited to the following considerations:
a. Changes that result in loss of oxygen for aquatic life.
b. Changes in flushing flows.
c. Changes in species composition or density.
d. Changes in number of threatened or endangered species.
e. Changes to habitat and critical habitat, including calving grounds, mating grounds, nesting grounds, summer or winter range, migration routes, or any other habitat features necessary for the protection and propagation of any terrestrial animals.
f. Changes to habitat and critical habitat, including streambed and banks, spawning grounds, riffle and side pool areas, flushing flows, nutrient accumulation and cycling, water temperature, depth and circulation, stratification and any other conditions necessary for the protection and propagation of aquatic species.
g. Changes to the aquatic and terrestrial food webs.

…

A.16. The determination of effects of the proposed activity on agricultural activities may include but is not limited to the following considerations:
a. Changes in quality and quantity of farming.
b. Changes in access to agricultural activities.
c. Changes to quality and quantity of ranching.
d. Changes to the quality and quantity of water for agricultural uses.

While 1041 rules protected natural and agricultural resources in developed areas, subdivision regulations and the Open Space Program identified ways to preserve natural and cultural resources in designated open space. In distributing grant funds, Arapahoe County gave extra points to sites with high quality native ecosystems, historic values, scenic areas, water resources, and/or important wildlife (Arapahoe County 2013). In addition, the county's rural cluster option encouraged landowners to group development on less than 40% of land, retaining the remainder for natural or agricultural uses. Under County Code, the conservation portion – at least 60% of the site – could contain riparian areas, wildlife corridors, historic structures, and archaeological sites (Arapahoe Land Development Code 13-1104). For areas within the USA, Development Design Principles stated that the most effective way to protect riparian areas, historic or archaeological sites, views, and other natural features is to work them into landscaped areas or dedicated open spaces (Arapahoe Land Development Code 15-105.09)

Restore and mitigate damage to green infrastructure
Arapahoe County outlined specific mitigation standards for development impacts trees, and more general requirements for other natural areas, principally through the 1041 rules. Under the Development Design Principles, tree masses and large individual trees had to be preserved, relocated, or replaced. Rules required that developers replace trees greater than 4 inches wide with trees the same size or with enough smaller trees to equal the width of removed specimens (Arapahoe Land Development code 15-102.01).
In addition, landowners submitting development plans for Permit Review under the 1041 rules, were required to include a monitoring and mitigation plan. Rules required that the plan describe how mitigation would be carried out and financed and the methods that would be used to identify the effectiveness of the mitigation strategy (Arapahoe County 2006).

Manage green infrastructure to support ecosystem services
During the study period, Arapahoe County managed green infrastructure principally through the Colorado State Extension Office and protected area plans. As it does in Adams County, Colorado State University Extension has an office in Arapahoe. The Extension Office provides public education and programs on implementing best management practices for agricultural and natural resources, including small acreage management (Colorado State University 2013).

Applicants for Open Space Program funding were required to submit evidence that a management agency had agreed to maintain the proposed site and that there was sufficient funding. In addition, while the county did not create plans for all county open spaces, the Open Space Division did create management and strategy documents for important hubs of green space. In 2007, the Division created a master plan for 17 Mile House Farm Park and a sub-area plan for the Lowry Range, with input from other stakeholders (Arapahoe County 2010). For 17 Mile House Farm Park, for example, management objectives were to maintain the important historic features and protect the natural resources and wildlife corridor.

Enact land use planning strategies to protect and retain all scales of GI
Arapahoe used a several land use planning strategies to retain green infrastructure, including rural zoning, and urban growth boundary/area, and protective subdivision and land development regulations. One of Arapahoe's strengths is the clear identification of growth areas. Just prior to the study period, Arapahoe adopted an urban services area to serve as boundary between the western growth area and rural areas beyond. The USA matched recommendations area by DRCOG and directed growth to the areas delineated by that organization (Arapahoe County 2001). The USA was not adjusted during the study period, and principally enforced through zoning and development review. The county also set growth boundaries around several growing Eastern Communities.

To limit development in rural areas, the county zoned the majority of land outside of the USA and Eastern Communities as Agricultural. The County Code included two restrictive types of agricultural districts, Agricultural Estate (A-E) and Agricultural-1 (A-

1). The A-E district was most restrictive and set a minimum lot size of 35 acres. The value matches the minimum density subject to review by local government under state regulations. The A-1 district was less restrictive, with a 19-acre minimum lot size. The county provided rezoning criteria for both, stating that rezoning should only occur if, "any residential development proposed within the district will have no significant, adverse impact on the continued operations of any adjacent agricultural use(s) and will comply with any applicable "right to farm" provisions in state statutes" (Arapahoe Land Development Code 4).

In addition to the more restrictive rural zoning districts, the county used three rural residential districts, allowing one dwelling unit per nine acres (Agricultural-2), one dwelling unit per 2.41 acres (Residential-Agricultural), and one dwelling unit per 1.6 (Residential-Estate). The zones were intended for transitions but also facilitated extension of development into rural areas. The county attempted to minimize their use to transitions by outlining rezoning criteria. Land could only be rezoned to A-2 if it was within an Eastern Community Planning Area and property could only be rezoned to R-A or R-E if it was part of a sub-area plan for Byers or Strasburg or immediately outside the edge of Arapahoe's Urban Service Areas. The main difference between R-A at 2.4 acres and R-E at 1.6 was urban services. R-E was required to have urban services at the time of development, while the slightly larger lot sizes of R-A were intended for developments that would not have central or community sewer and water (Arapahoe Land Development Code 5).

In 2006, the county added a rural cluster option to provide additional protection for rural resources in the A-1 and A-E districts. The rules allowed for increased density in return for natural and agricultural resource protection. County Code required that the conservation area account for no less than 60% of the development and be protected in perpetuity by a conservation easement or other comparable restriction. Through clustering, developments in A-1 districts could have a maximum overall density of 2.25 dwelling units per 35 acres and A-E could have 1.75 per 19 acres. Landowners could also earn further density bonuses, which were cumulative. Providing central (community) water and sewer or installing additional fire safety would earn an additional 20% increase in density and public trail dedications would earn 10% more density (Arapahoe Land Development Code 13-1100). However, the rural cluster rules proved unpopular. There has been only one application and it was rejected by the County Board of Commissioners. The proposed subdivision was close to an incorporated town, yet proposed on-site wells that were potentially problematic (Yeckes 2013, personal comm.). Under other types of subdivision development, open space dedication requirements were less. The county required that low-density PUDs allocate 10% and conventional subdivisions dedicated 6 acres per 1,000 residents (Arapahoe Land Development Code 14-100).

The county's 1041 rules may also have had an impact on land use over the study period. As previously mentioned, the development projects in Arapahoe County were subject to 1041 Permit Review. One area of review was growth. As part of the permit-granting process, the county considered whether the proposed development would "cause or contribute to urban sprawl or 'leapfrog' development" or "cause significant changes in the amount of impervious surface" (Arapahoe County 2006)

Protect and support GI through a collaborative and cooperative process
In planning for green infrastructure, Arapahoe County collaborated internally and with the State of Colorado, regional planning authorities, land trusts, and local citizens. The two county divisions with the greatest impact on green infrastructure planning, the Planning Division and the Open Space division, were within the same department and worked together to plan and protect green infrastructure.

Arapahoe County was involved in a variety of truly collaborative efforts during the study period. For example, the county worked with a variety of organizations to acquire and manage one of their first conservation easements, for the 12,578 acre Middle Bijou Creek property. The Colorado Cattlemen's Agricultural Land Trust holds and monitors the easement on the site, which is the largest easement ever funded in the United States by the Natural Resources Conservation Service through their Farm and Ranchland Protection Program. Funding for the property came from all levels of government and a private organization: Arapahoe County Open Space, the Natural Resources Conservation Service, Great Outdoors Colorado, and the Trust for Public Land (Arapahoe County 2011). The county also served as organizer and participant in a number of regional projects with long lists of collaborators, including the South Platte Working Group, Cherry Creek Basin Working Group, High Line Canal Greenway, City of Glendale Infinity Park. The county also convened groups to create plans for 17 Mile House Farm Park and the Lowry Range (Arapahoe County 2010).

Arapahoe also benefited from state and regional funding and expertise. State agencies provided a variety of natural resources and natural heritage information and served as additional reviewers through the 1041 rules. The Great Outdoors Colorado (GOCO) lottery proceeds also supported open space acquisition in the county. Through GOCO, Arapahoe County and municipalities received \$11 million in grants, \$90 million directly through the Conservation Trust Fund, and \$3 million in spending on state parks (Colorado Lottery 2013). Typically, the county spent GOCO funds on capital projects rather than land acquisition. Arapahoe County was also within the DRCOG, and adopted their recommendations for growth areas and the USA in addition to providing open space information through the organization's parks and open space survey (Arapahoe County 2001).

Funding
The Arapahoe County Capital Improvement Programs divided green space spending into two categories: Conservation Trust Fund and Open Space Sales and Use Tax Fund. The Conservation Trust Fund is supported by revenue from the State Lottery that is disbursed to counties on a per capita basis. The fund supports the acquisition and development of parks and trails. Between 2004 and 2010, the county spent Conservation Trust Fund dollars principally on the Arapahoe County Fairgrounds construction project rather than

land acquisition and natural resources management. Expenditures through the Open Space Sales and Use Tax increased steadily between 2004 and 2010 from $6.2 million to $18.5 million. But not all proceeds were spent in the county. For example, according to the annual budgets, between 2006 and 2010 Arapahoe spent an average of $540,000 per year on true open space and trails projects, with a high of $1.5 million on four projects in 2010 (Arapahoe County Adopted Budget 2006 – 2010).

In 2003, Arapahoe voters approved a 0.25% sales and use tax to fund the preservation of urban and rural open space. Half of the total tax collected was shared back to the county's 12 cities and towns and an additional 12% was allocated to municipalities and special districts through a competitive grant program. Remaining proceeds, minus administrative and maintenance allocations, funded open space and trails in the unincorporated county. In the end, 28% of Open Space Sales and Use Tax revenue funded acquisition and development of open space and trails in Arapahoe County, in addition to a number of projects funded through the competitive grant program. The Open Space Program was administered by the county Open Space Division, but an independent group, the Open Space and Trails Advisory Board was responsible for reviewing proposed projects distributing funds (Arapahoe County 2010).

Green Infrastructure Network Change in Arapahoe County

Quantity

Between 2001 and 2009, developed area in Arapahoe County increased by 6,600 acres, or 28%. (Table 6-8. The county's net loss of agricultural land was significant (20%), but loss of natural land was minimal. However, while the overall statistics show the area of natural and agricultural land in Arapahoe County in 2000 and 2010, they include shifts between natural and agricultural land and obscure the amount of each that was permanently converted to non-resource uses. In all, 4,672 acres of land that was agricultural and 1,957 acres of land that was forest or grassland in 2010 were converted to developed land uses by 2010. These account for 13% of agricultural land and 1% of natural land. Together, 2.7% of county land was converted from green infrastructure to developed land, for a 28% increase in developed land uses.

Table 6-8. Land Use Change in Arapahoe County, 2001 to 2009* (by author). Natural includes both grassland and limited forest.

	2001 (acres)	**2009 (acres)**	**Change (%)**
Water	85	85	**0**
Agriculture	36,122	28,828	**-20**
Natural	182,143	182,808	**0 (+)**
Developed Area	24,087	30,717	**28**

*Considers only privately-owned unprotected lands under county jurisdiction.

Over the study period, development in Arapahoe occurred mainly in the western section of the county where it was in close proximity to the urbanized Denver region (Figure 6-

8). Several pockets of new residential development also expanded lightly developed sections in the central portion of Arapahoe County.

Figure 6-8 Natural land, farmland, and developed area in Arapahoe County in 2009. ‘New Development’ is development that occurred since 2001 (by author.)

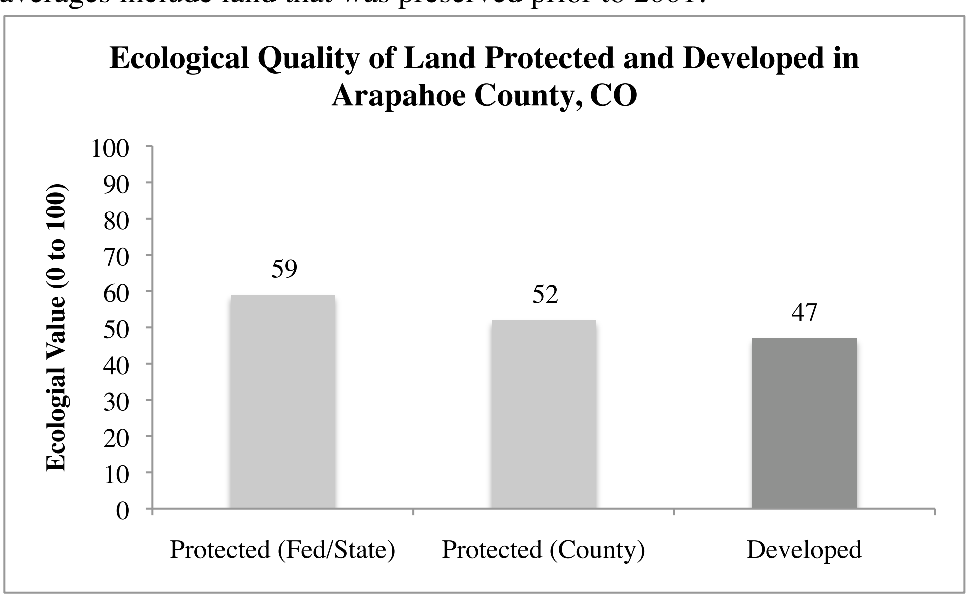
Prior to 2000, the county focused on providing parkland in populated western areas of the county. Unincorporated Arapahoe County had around 400 acres of protected open space, mostly within the 236-acre Arapahoe County Fairgrounds and Regional Park. After the 2001 Comprehensive Plan, the county reoriented conservation efforts toward larger parcels in the agricultural central region. The county also launched the Open Space Program in 2003, which accelerated land preservation. By 2010, the county’s Open Space Program had protected 17,600 acres of land (Arapahoe County 2010). Included in the total is 4,000 acres of parkland and 13,000 acres of conservation easements, all in the central region of the county. Arapahoe County won the Colorado Lottery Starburst Award for one of the easements, the 12,500-acre Middle Bijou Creek Ranch. The Starburst Award is given to organizations for their excellent use of lottery proceeds to support conservation of Colorado’s natural resources (Arapahoe County 2008). Just over half of the easement is located in Arapahoe County, with the remaining acreage in Elbert County, Arapahoe’s southern neighbor. Middle Bijou Creek is the stair-step shaped property in the south-center of Figure 6-9.

Maps of Arapahoe County conservation lands clearly show the results of focusing efforts on the southern central portion of the county. While state trust lands are scattered throughout the center and east of the county and federal and other types of state lands are concentrated in the populated west, county lands show more focus. Two clusters of contiguous preserved agricultural lands dominate the south-central portion of the county (Figure 6-9). Both clusters contain major waterways and provide riparian area protection in addition to agricultural preservation.

Figure 6-9. Federal, state, local, and privately-owned protected areas in Arapahoe County, Colorado in 2010 (by Author).

Quality
The area-weighted mean ecological quality of land developed in Arapahoe County between 2001 and 2009 was 47, lower than the average for county protected lands, 52 (Figure 6-10). The difference indicates that Arapahoe County was somewhat successful in directing development toward marginal areas and away from valuable lands. State and Federal protected lands have a higher average ecological value than county lands – likely because they include more mature vegetation and less working farmland. State and Federal land averages yield an even greater difference between the ecological value of protected and developed lands.

Figure 6-10. Area-weighted mean ecological quality of land developed in Arapahoe County between 2001 and 2009. State/Federal and County protected area quality averages include land that was preserved prior to 2001.



Connectivity
Between 2001 and 2009, the fragmentation of agricultural land in Arapahoe increased significantly. Patches became shorter, smaller, and further apart (Table 6-9). Over the same time period, the connectivity of natural land improved. While increases in the Area-weighted Mean Patch Length/Contiguity usually indicate an increase in complexity as patches are fragmented from large geometric shapes to irregular shapes, the Area-weighted Mean Patch Size and Proximity Metric results corroborate the overall growth of natural land patches. The latter measure also shows that parcels became larger and closer over the study period. The counterintuitive result was likely caused by agricultural lands reverting to prairie. Despite a 28% growth in developed area and loss of nearly 2,000 acres of grassland, the county had slightly more grassland in 2009 than in 2001.

Table 6-9. Patch Shape and Contiguity Metrics for Arapahoe County Natural and Agricultural land in 2001 and 2009 (by author).

	Natural Land			Agricultural Land		
	2001	**2009**	**Change Notes**	**2001**	**2009**	**Change Notes**
Area-weighted Mean Patch Length/ Contiguity (GYRATE_AM)	5,284m	5,421m	Increase in patch length	5,098m	4,749m	Decrease in patch length
Patch Shape Complexity (SHAPE_AM)	31	30	Minimal Change	26	23	Minimal Change
Patch Aggregation (CLUMPY)	0.84	0.84	Minimal Change	0.87	0.88	Minimal Change
Area-weighted Mean Distance to Nearest Like Patch (ENN_AM)	62m	62m	Minimal Change	61m	61m	Minimal Change
Area-weighted Mean Patch Size and Proximity Metric (PROX_AM)	14,818	16,136	Patches become larger and closer	13,903	12,870	Patches become smaller and more distant

Overall
Between 2000 and 2010, the Arapahoe County Planning and Open Space Divisions conducted a moderate level of green infrastructure planning. The county's activities covered 47 percent of the policies and strategies included in the Green Infrastructure Planning Assessment Framework, a moderate level for Colorado. The county's clear growth management strategy and excellent local and regional collaboration contributed to the score. Based upon recommendations from DRCOG, the county designated a growth boundary (the USA) for the highly populated western end of the county and smaller service areas for several Eastern Communities. The USA was supported by rural

agricultural zoning and strong subdivision and land development regulation and review. Arapahoe County also designated “site selection and development of new communities” as an activity of state interest under the 1041 rules. The designation led to strict review of land development proposals for impacts on natural and agricultural resources. But, while the county’s growth management strategy was strong, Arapahoe did have several weaknesses, most critically the lack of a countywide open space concept. Without a cohesive open space strategy, land protection and preservation does not build to protecting key resources and systems. While the county was successful in grouping easements into two large blocks, they have little connection with state or federal lands and are not part of a strategy that will create a connected network of green space. The prioritization methods for land preservation were also relatively informal. The county rated potential conservation lands AAA through D based upon their conservation metrics, but conducted no other formal assessments. Without such information, it is difficult to ensure that conservation dollars are spent efficiently.

Arapahoe’s green infrastructure network was impacted by development over the study period. Over 6,000 acres of agricultural and natural grasslands was converted from developed land uses, 2.7% of the county’s land area. But the county was moderately successful in directing development toward marginal areas. The area-weighted mean ecological quality of land developed during the study period was 47, while the average ecological quality of protected land in the county was 59. So the average quality of protected lands was higher than that of developed lands. However, during the study period, the fragmentation of green infrastructure increased. Agricultural lands, in particular, became shorter, smaller, and further apart. Results for natural grasslands show the opposite, and increase in connectivity. Despite a 28% increase in developed area and loss of nearly 2,000 acres of grassland, the county had slightly more grassland in 2009 than in 2001. The counterintuitive result was likely caused by agricultural lands reverting to prairie, or simply left fallow for a season or two.

LOW GREEN INFRASTRUCTURE PLANNING: ADAMS COUNTY

Between 2000 and 2010, Adams County’s green infrastructure planning was promising at the site level, but not well connected to countywide strategies. The county protected important natural resources through development review, design regulations, and a resource-based transfer of development rights program, but lacked countywide open space planning and supportive growth management.

Demographics, Economy, and Environment

Adams County is part of the booming Denver MSA. Between 2000 and 2010, the population of the county grew by 21.4% to 442,000, one of the fastest growth rates in the region. The western portion is highly urbanized and the location of the county’s more populous municipalities. Three cities, Westminster, Thornton, and Aurora, have a population greater than 50,000. The largest, Aurora - with a population of 325,000 - is one of the principle cities of the Denver MSA, and third most populated city in the state. It is located along the border between Adams and Arapahoe.

Education, health and retail are the largest industries in Adams County. The most significant single employers are the Children's Hospital of Colorado with 4,400 jobs and University of Colorado Hospital with an additional 4,400. The United Parcel Service and Avaya, a telecommunications company, also employ 2,300 and 1,000, respectively. While Adams is part of the Denver MSA, the city's light rail system does not extend into the county and buses are the only transit available to residents. Adams County residents have the longest commute time of the three study counties, an average of 29 minutes in 2010.

Between 2000 and 2010, unemployment in Adams County jumped from 2.8% to 10.3%, higher than the rate for the state (9%). During the same time period, median home value stagnated, increasing only 1% to $192,000. But the value did remain above the state median home value of $167,000. In 2000, the median household income was $60,000, among the lowest in the region, but it declined only 8% between 2000 and 2010, so it was also one of the most stable. At the conclusion of the decade, household income was $55,000, higher than the state average (US Census 2000, 2010).

Agriculture is the dominant land use in Adams County. Farmland and rangeland cover three-quarters of the county, by land area. Adams is second only to the much larger Weld County in agricultural acreage. The central section of the county is dominated by wheat production and the eastern reaches by rangeland, both of which are fed by an extensive system of canals. Agriculture is an economically important industry in Adams County and the soils are among the best in Colorado (Adams County 2004). According to the 2007 Census of Agriculture, the market value of agricultural products sold in Adams County in one year is $153 million, 2.5% of Colorado's $6 billion. At 784 acres, the average farm size is around the state average. Only a smaller percentage of farmland (2.4%) is irrigated (United State Department of Agriculture 2009). In addition, the eastern two-thirds of the county is dotted with 48 State Trust Lands, with an average of 500 acres each. The vast majority are leased to private individuals for agricultural uses, with management oversight by the state.

Most protected green space in Adams County is state or federal. Large resource hubs include Rocky Mountain Arsenal National Wildlife Refuge at 17,900 acres, Barr Lake State Park with 1,350, and nearly 1,000 acres of wildlife management area owned and managed by the Colorado Division of Wildlife. All are located in the west of the county, in close proximity to populated areas (Adams County 2004).

Green Infrastructure Planning in Adams County

In Adams County, the Department of Planning and Development is responsible for traditional planning responsibilities such development review and long term planning, including drafting and updating the county's comprehensive plan. During the study period, the Department had a staff of 16 to 17 to carry out these activities. The Parks & Community Resources Department (PCR) also had a significant role in green infrastructure planning. With a staff 24 to 26, PCR managed the planning, acquisition, and maintenance of county parks, trails, and open space. PCR was also responsible for administering the county's various open space fund, such as the open space sales tax fund, the conservation trust fund, and the open space projects fund.

For planning during the 2000 to 2010 time period, Adams County receives a score of 55, representing 40% of the policies and strategies in the Green Infrastructure Planning Framework (Table 6-10). For Colorado, 40% is a moderate to low-level of green infrastructure planning. The county's strength was in valuing areas of ecological quality and local importance. The county employed fewer strategies oriented toward restoring and managing green infrastructure and creating linkages and fostering connectivity. The following sections provide an overview of planning in Adams County and describe the policies and strategies through which Adams County furthered each principle of green infrastructure planning between the years of 2000 and 2010. For a complete Green Infrastructure Planning Assessment Framework for Adams County, see Appendix 6-A.

Table 6-10. Adams County Green Infrastructure Planning Framework Results Summary

Green Infrastructure Principle	**Framework Score (Out of 20)**
Create linkages and foster connectivity	**5**
Value areas of ecological quality and local importance	**12**
Support a variety of landscapes and ecosystem services	**9**
Restore and mitigate damage to green infrastructure	**4**
Manage green infrastructure to support ecosystem services	**8**
Enact land use planning strategies to protect and retain all scales of GI	**9**
Protect and support GI through a collaborative and cooperative process	**9**
TOTAL (Out of 140)	55
PERCENTAGE	**40%**

Agriculture is the dominant land use in Adams County; it accounts for three-quarters of the county's land area. But over the past thirty years, the Denver Metropolitan Area has grown rapidly and pushed further into western Adams County. By 2000, growth from the west heavily impacted natural, cultural, and agricultural resources. Resident concerns about the loss of their natural environment prompted the county to create its first Open Space Plan, in 1998.

The 1998 Open Space Plan outlined important natural and agricultural resources, and created and carried out an evaluation process to prioritize parcels for conservation. But the Open Space Plan was less a plan than an analysis. It laid out broad priority regions for preservation but did not discuss, outline, or propose a cohesive open space network for the county. The analysis was based upon physical and natural resource characteristics, public use potential, community buffering potential, and opportunities and threats associated with each individual parcel in the county. The result of the analysis was a preservation strategy consisting of three components: agricultural preservation, environmental resource conservation, and trails. For agriculture and environmental resources, the plan ranked county lands from priority 1 (critical & high priority) to priority 4/5 (moderate to low priority) and identified the characteristics, rationale, and location of land in each category. Despite the variety of implementation mechanisms that were not carried out during the study period, such as Ag Districts, and encouraging clustering, the Plan did identify the need for a county purchase of development rights program (Adams County 1998).

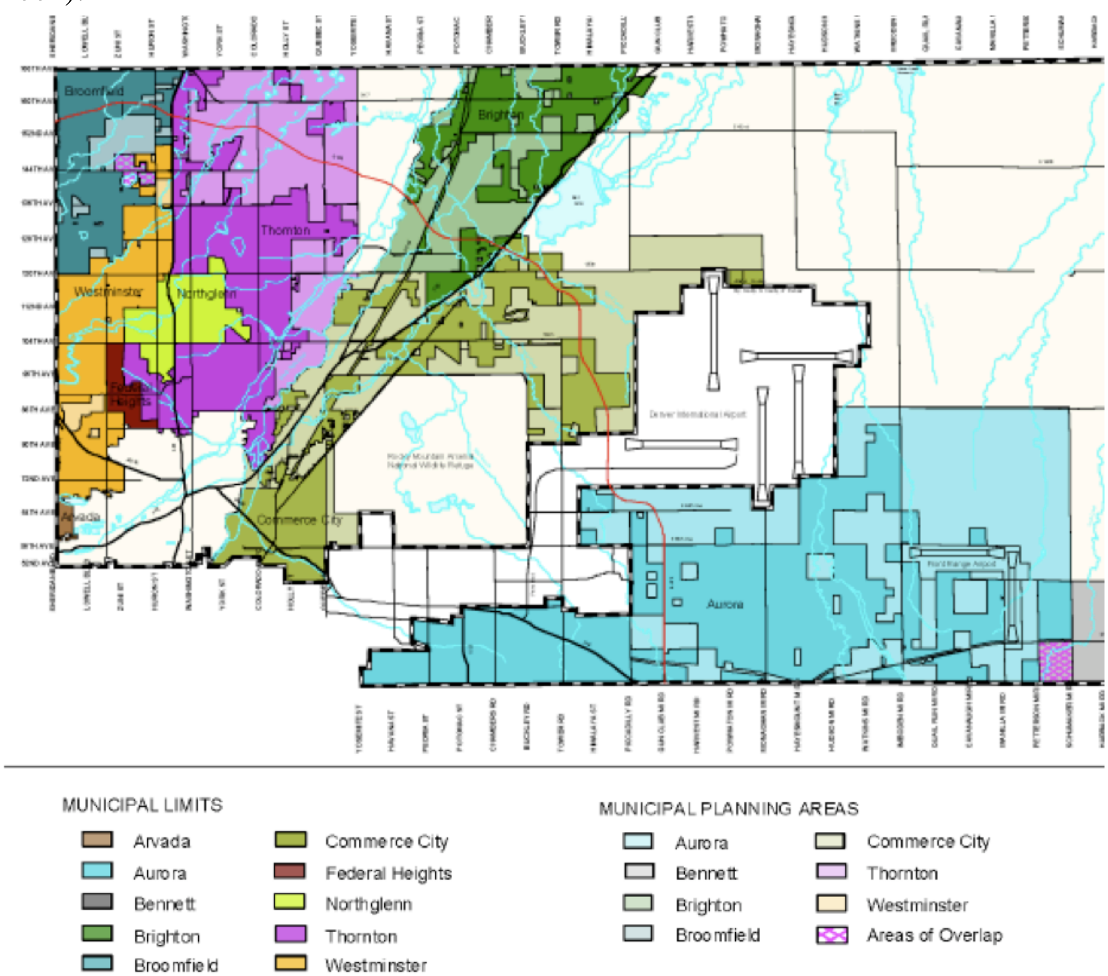
The year after the Open Space Plan was released, Adams County residents approved a 0.20% Open Space Sales Tax (now 0.25%) that provided the first dedicated county funding for agricultural preservation, environmental resources conservation, and trails (Adams County 2012). The tax led to a countywide open space program, managed by Adams County and an Open Space Advisory Board. The majority of funds (68%) were awarded to organizations within the county through a competitive grant program, 30% was went back to the jurisdiction that produced the funds (including unincorporated Adams County), and the remaining 2% covered administration (Adams County 2013). Each year during the study period, the Open Space Sales Tax program funded between 2 and 5 projects in unincorporated Adams County, ranging from 5 to 330 acres (Adams County 2013).

Just after the 1998 Open Space Plan, Adams County also adopted a completely new comprehensive plan, but new census numbers in 2000 made clear the need for an additional update. That update was completed in late 2003 (adopted in January 2004) and was the dominant planning document during the study period. Unlike the Open Space Plan, the 2004 comprehensive plan did not highlight the need for balance between conservation and development, although it did note that some of the most productive agricultural lands bordered population centers and that growing municipalities were encroaching on agricultural operations and increasing conflicts between residential and farming land uses (Adams County 2004, 12). The majority of the eleven goals of the 2004 comprehensive plan related to directing growth (e.g. establish municipal growth areas, establish standards for citing low-density development). But also among the goals were, "preserve the viability and character of existing agricultural areas, "establish community separators, and, "support and implement open space objectives" (Adams County 2004, 18).

The 2004 comprehensive plan included a variety of separate small area plans for key development areas. Several important resource areas were included, such as Barr Lake, the National Wildlife Refuge, South Platte River Corridor, and the rural eastern plains. The comprehensive and conservation-oriented 1998 Open Space Plan was also technically a section of the Comprehensive Plan, but the two were largely disconnected. The comprehensive plan did not mention the 1999 Open Space Sales Tax or outline the mechanisms through which the county might use the guidance provided by the Open Space Plan to better protect natural resources.

Adams County had two additional restrictions on municipal and unincorporated area growth during the study period. First, following the state growth area amendment of 1987, the majority of cities in western Adams County adopted self-certified urban growth boundaries, or municipal planning areas (MPAs). Since the growth boundaries were set by the municipalities themselves, there was some overlap between communities (Figure 6-11). The areas loosely bound growth and provided some predictability in servicing and annexation. Second, like most other counties in Colorado, Adams is not a sewer and water provider, so services in unincorporated areas were provided by other entities. In most growing areas of unincorporated Adams County, the service provider was the city in whose MPA the growth occurs. Generally, municipalities require annexation before they provide services. In most areas development cannot occur without urban services, so landowners wishing to develop within an MPA had to annex to a city before they could develop. These two rules pulled urban development toward incorporated municipalities, but did little to discourage the spread of low-density development in fringe areas outside of MPAs (Adams County 2004).

Figure 6-11. Western Adams County, showing incorporated municipalities and associated municipal planning areas. (Map by Adams County Planning & Development Department 2004).



Between 2000 and 2010, the population of unincorporated Adams County grew by 13.8%, faster than any incorporated area of the county (Adams County 2012). Since communities outside of MPAs cannot receive urban services, the growth was largely low-density. Estate residential development (1 dwelling unit per acre to 1 unit per 35 acres) proliferated. Under Colorado rules, landowners can divide property into lots larger than 35 acres with no review, and many of them did so. In 2004, to protect natural and agricultural resources, allow for higher density development in agricultural areas (greater than 1 dwelling unit per 35 acres), and to provide greater opportunities for landowners to develop their property, Adams adopted a Transfer of Development Rights Program. The county identified six receiving areas and four types of sending areas: 1) The Barr Lake and South Platte River area, 2) land in the Natural Resources Conservation Overlay, 3) Important Farmlands, and 4) land in the Airport Influence zone. Between 2004 and 2011, Adams preserved more than 5,000 acres through the program.

Create Linkages and Foster Connectivity

Connectivity was not a major emphasis of Adams County's green space planning during the study period. The county did not use a hub and link framework, and planning documents did not discuss fragmentation or the importance of creating a network of green space. But the 1998 Open Space Plan did note the importance of linkages in wildlife habitat and trail connections and the value of agglomerations of farmland and farm supporting industries (Adams County 1998).

Adams County took a piecemeal approach to connectivity. Subdivision regulations and design standards supported local rather than regional or countywide green space connections. For example, under County Code, land dedicated as regional parkland through the subdivision process was required to link to adjacent open space or resource areas (Adams County Development Standards and Regulations 5-05-05-02-02). In addition, requirements for open space residential PUDs held that, where possible, dedicated conservation areas should connect with adjacent open spaces, greenways, or farmland of the same type (Adams County Development Standards and Regulations 4-11-01-07). But while county subdivision regulations and design standards influenced how the natural resource networks in proposed subdivisions or developments connected to surrounding land uses, they had little impact on how the lands built to a larger network.

Adams County did explore potential countywide green space connections prior to the study period, with the 1998 landscape-scale evaluation strategy, a part of the Open Space Plan. The countywide assessment gave the greatest possible value to parcels with connectivity potential. Lands with characteristics such as 'adjacent to existing open lands or natural areas,' 'maintains connectivity,' 'creates an identified wildlife movement corridor,' and 'provides a trail connection' were marked as a 'high' level of importance (Adams County 1998). While results were not fully implemented or integrated into later planning documents, it was the most significant consideration of a countywide network of green infrastructure in Adams County.

The county also touched on broader scales of connectivity with assessment criteria for open space funding under the Open Space Sales Tax program. One evaluation criterion for applications submitted to the Open Space Advisory Board was the role of the proposed open space property in a regional or master plan. Properties important in regional open space visions received a greater number of points. Also included in the score was whether the property would link to adjacent parks, trails, or open space (Adams County 2013).

Value Areas of Ecological Quality and Local Importance

Adams County's planning documents listed major open space hubs and mapped important natural features such as streams, creek corridors, reservoirs, wildlife habitat, protected green spaces, and conservation overlays areas. They also highlighted the county's high quality soils and agricultural lands (Adams County 2004).

Between 2000 and 2010, Adams County protected high quality and locally important green infrastructure through overlay zones, development review, subdivision regulations, and open space prioritization. One of the county's strongest tools for protecting important resources was the Natural Resources Conservation Overlay (NRCO). The NRCO included wildlife areas, floodplains, riparian areas, and reservoir sites that feed wetlands and habitat areas. While the county did include the NRCO on land use maps, the boundary was representative. Under County Code, lands that staff identified as possibly within an NRCO were subject to a site-specific Resource Review. The county required that NRCO features identified through the Resource Review be protected in open space, with the acreage determined by a multiplier. The applicable multiplier varied by the resource in question; for example, 2 for wetlands and 1 for 100-year floodplains. The open space requirement was equal to the acreage of the natural feature times the applicable multiplier (i.e. a 1 acre wetland required 2 preserved acres). Remaining land could be developed at the original zoned density (Adams County 2004). The NRCO also served as a sending area for the TDR program.

Resource Review, a part of development the review process, also applied more broadly, to three other types of resources: individual protected resources, cultural resources, and agricultural resources. The individual protected resources section examined waterbodies, floodplains, and wetlands, and the NRCO section addressed wildlife habitat, migration routes, and any other applicable NRCO resources. The county required that each Resource Review include a map and inventory of the four applicable resource types, identification of how the proposed development meets outlined standards, description of development impacts, and – if applicable – a suggested mitigation plan. The acceptable design standards for development varied by resource type. For example, development near rivers required a 150 foot setback, wetlands 50 foot, cultural resources 100 foot, and streams and lakes between 50 and 150 feet. In addition, the county required subdivisions in agricultural areas to be low density and to provide limited clustering of development (Adams County Development Standards and Regulations 4-11-02-03).

In addition to the NRCO, the county had a second overlay zone, the Flood Control Overlay (FCO). The FCO limited land uses within the 100-year floodplain to protect life, property, and the characteristics of natural waterways. Development that could impact the FCO required a special floodplain use review and permit (Adams County Development Standards and Regulations 3-35).

One of the newer provisions of the county code protected important natural and agricultural areas through subdivision regulations, specifically conservation-oriented planned unit developments (PUDs). Under the optional open space residential PUD, landowners could group development on 50% to 70% of a parcel and protect the remaining land as open space. To enhance protection, the county required that no more than 25% of the conservation land be used for active recreation so that the majority could be dedicated to passive uses more oriented toward conservation. To guide the placement of conservation areas and optimally protect natural resources, the county also created a hierarchy of natural areas. Riparian and floodplains areas were most important, followed by agriculture, trails and greenways, significant tree stands, and mature ridgeline vegetation (Adams County Development Standards and Regulations 4-11-01).

Finally, prioritization criteria for open space programs - the County Open Space Sales Tax Program and TDR program - were also oriented toward important natural areas. The county and Open Space Advisory Board asked applicants to describe the natural resources or wildlife habitat on the proposed property and how the property relates to the needs of the community, which could be natural resources-related (Adams County 2013). The TDR program provided means – and incentive - to permanently protect the sensitive Barr Lake and South Platte River areas, lands within the NRCO, and 'important farmland' by transferring their development rights to other areas of the county. In addition, the Open Space Plan informally impacted land preservation strategies, as did the South Platte River Heritage Corridor Plan, which was created over the same time period. Together they "heavily focused" conservation efforts on important areas within the South Platte River corridor and land surrounding Barr Lake State Park (McDowell 2013, personal comm.)

Support a Variety of Landscapes and Ecosystem Services

In planning documents and implementing regulations, Adams County mainly emphasized farmland and water resources (e.g. through emphasis on the South Platte River corridor), but the county also noted the importance of protecting and maintaining community separators, protecting views, and preserving cultural and historical resources.

One of the eleven major goals of the Adams County's 2004 Comprehensive Plan was to 'establish community separators' (Adams County 2004, 18). The county's suggested strategy was to encourage municipalities to maintain open space buffers between themselves and other cities, mainly through supportive intergovernmental agreements. However, given that the majority of urbanizing western Adams County had already designated MPAs for future annexation, most of them connecting - if not overlapping - little land remained to fulfill the vision (Adams County 2012).

Adams protected scenic views more directly, particularly through development review and within open space residential PUDs. The Natural Resource Conservation Overlay also protected views, mainly where they occurred alongside other important resources.

While the county had no inventory of culturally or historically significant resources, and such resources were not mapped in planning documents, they played an important role in development review. Cultural Resources Preservation was one of the purposes of the county's Resource Review requirement. As part of the Resource Review, landowners developing more than five acres were required to survey cultural and history resources using Colorado State Historic Preservation Office rules. County Code also required that development be designed to minimize impacts on any discovered resources, for example through 100-foot setbacks, where necessary (Adams County Development Standards and Regulations 4-11-02-06).

Restore and mitigate damage to green infrastructure
Adams County had specific mitigation requirements for wetlands and more general mitigations for the NRCO and other resources. County Code required that landowners mitigate development impacts upon wetlands. On-site mitigation was required, wherever possible, at a ratio of 1.5 acres of new wetland for every 1-acre filled. Off-site mitigation, where necessary could occur at a ratio of 2.5:1, or 2.5 acres new for every 1 degraded. As part of Resource Review, County Code also required, generally, that the impacts of development on water resources, the NRCO, and cultural resources be appropriately mitigated (Adams County Development Standards and Regulations 4-11-02).

Manage green infrastructure to support ecosystem services
Adams County managed green infrastructure to support ecosystem services through county-owned open space management plans, the Colorado State Extension Office, and management plans for the maintenance of private open spaces created through the subdivision and PUD process.

The Adams County Parks & Community Resources Department created management plans for county-owned open space properties and major resource areas. Several were in effect during the study period, including the 1999 Adams County Regional Park Master Plan (updated in 2008) and 1999 South Platte River Heritage Corridor Plan. Both plans include an inventory and assessment of natural resources, identify environmental and public access and education goals, and outline a plan and management strategy for achieving them.

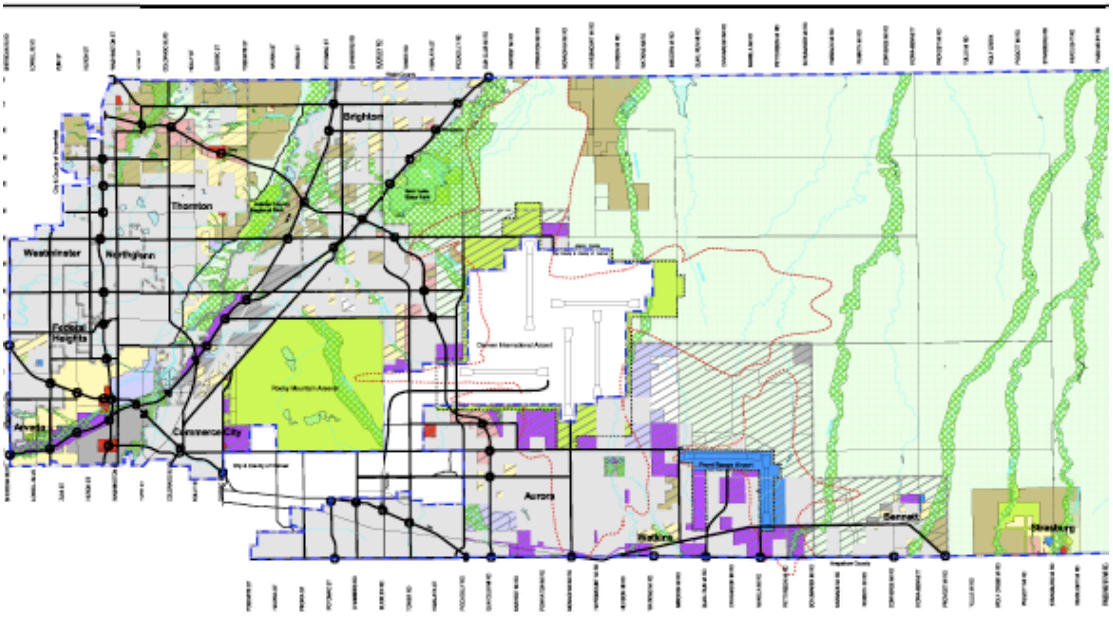
The county also provided public programs through the Colorado State University Cooperative Extension. Outreach focused on agricultural land management and reporting, land management strategies for small acreage landowners, weed management, and other issues relevant to rural areas (Colorado State University 2012).

County Code also required that land designated as conservation area, common open space, or agricultural land in a subdivision or PUD, be subject to an approved management plan. Landowners submitted the proposed plan as part of the subdivision and land development application process. The county required management plans to clearly identify management goals, properly protect wetlands and wildlife habitat, control noxious weeds, and use best management practices (Adams County Development Standards and Regulations 4-22).

Enact land use planning strategies to protect and retain all scales of GI
Adams County's major land use strategies were zoning, transfers of development rights, and subdivision regulations. The county also had a 'self-certified' urban growth boundary, which was added through a 1999 comprehensive plan amendment. The growth boundary was part of a regional effort led by the Denver Regional Council of Governments (DRCOG), but is only mentioned once in the 2004 comprehensive plan and not discussed in detail or mapped (Adams County 2004, 19). It seems to have had little impact on planning in the county. In addition, during the study period, the county had no major provisions for the clustering of development or a Right to Farm Ordinance, despite the increase in farm-resident conflicts.

Adams County Code included several zoning categories with implications for green infrastructure, principally Agricultural and Low-Density Residential Zones. The county's Agricultural zoning designation had three varieties, A-1, with a minimum lot size of 2.5 acres, A-2 with a minimum of 10 acres, and A-3 with a minimum of 35 acres (Adams County Development Standards and Regulations 3-07-02). The vast majority of central and eastern Adams County was zoned A-3 with a few pockets of A-1 in close proximity to developed areas and A-2 on the fringe of developed areas. The A-3 categorization was intended to preserve agricultural land uses, protect environmentally sensitive areas, and separate communities. A-1 and A-2, however, are essentially residential classifications. Another common zoning district was Residential Estate (R-E) (Figure 6-12). Land zoned R-E had a minimum lot size of 2.5 acres if served by well and septic and 1 acre if on public water or sewer (Adams County Development Standards and Regulations 3-11-07-01). Much of the county's fringe area sprawl takes place on land zoned R-E. As previously described, the county also used a Natural Resources Conservation Overlay to protect wildlife habitat and water resources (Adams County Development Standards and Regulations 3-37-02).

Figure 6-12. Adams County Future Land Use Map (2004). Pale Green = Agriculture, Bright Green = Natural Resource Conservation Overlay, Chartreuse = Parks & Open Space, Brown = Residential Estate, Crosshatch = Municipal Growth Areas, Grey = Incorporated (Map by Adams County Planning and Development Department 2004).



As previously mentioned, in 2004 the county also adopted a transfer of development rights (TDR) program. The program identified general sending and receiving areas. Sending areas had to be at least 35 acres and conferred development rights at different ratios. The Barr Lake and South Platte River area yielded development rights at a ratio of 25:1, the Natural Resources Conservation Overlay Zone at 15:1, Important Farmlands at 10:1 and the Airport Influence Zone at 5:1. The ratios acted as multipliers, based upon a base density of one dwelling unit per 35 acre. For example, a 350 acre parcel in Barr Lake could yield 10 dwelling units (1 per 35 acres), but if preserved, it conferred upon the developer 10 dwelling units times 25, or 250 potential residential dwelling units to use in a receiving area. The same size parcel in an area with important farmland would yield 100 residential dwelling units. The county required that receiving areas be at least 160 acres and use the planned unit development process (PUD) for development planning. Receiving areas were located in unincorporated areas of the county, predominately along major north-south or east-west roadways, but mostly outside of municipal planning area boundaries (Adams County 2004). Notably, since receiving areas were outside of MPAs, the strategy was only not entirely supportive of the county's stated growth management strategy of directing development toward municipalities.

Adams County also supported green space through parkland dedications as part of the subdivision process. County Code required developers of subdivisions with a density greater than 1 dwelling unit per 10 acres to dedicate 6 acres of neighborhood parkland per

1,000 residents and 4 acres for a regional park. Rules required that neighborhood parks be larger than 3 acres, but there were few other restrictions (Adams County Development Standards and Regulations 5-05-05). Roadways could even be included in the dedication for neighborhood, provided they were not already publicly-owned (Adams County 2012). Dedicated regional parks had more requirements. County Code required that regional parks cover at least 50 acres, preferably adjoining another regional park, and have clear natural resource values and links to other open paces.

As previously mentioned, the Adams County Code also supported green infrastructure through open space residential subdivisions, a type of planned unit development (PUD) where development could be concentrated on between 50% and 70% of a property and the land remaining protected as open space. But while the rules include provisions for orienting the open space portion for maximum conservation value, protection was not necessarily permanent. Under the County Code, common conservation land had to be zoned Conservation, and managed by a homeowners association, public agency, or district, but not put under conservation easement or otherwise protected in perpetuity (Adams County Development Standards and Regulations 4-11-01). In addition, the type of development was relatively new during the study period and not widely used.

Protect and support GI through a collaborative and cooperative process
In planning for green infrastructure, Adams County collaborated internally and with the State of Colorado, regional planning authorities, Colorado Open Lands, and local citizens. Within the county, the Planning & Development Department and Parks & Community Resources Department worked together to plan, protect, and manage natural resources, open space, and trails.

The county also benefited from state and regional funding and expertise. State agencies provided mapping and natural resource information that the county used in the Open Space Plan and development review process and Great Outdoors Colorado (GOCO) lottery proceeds supported green space acquisition. Through GOCO, Adams County and municipalities received $17.5 million in grants, $64 million directly through the Conservation Trust Fund, and $590,000 in spending on state parks (Colorado Lottery 2013). The county typically used GOCO funds for staff resources and capital projects, rather than land acquisition (McDowell 2013, personal comm.) The county also worked with Colorado State University to provide residents with cooperative extension services. In addition, Adams is also one of the principle counties of the Denver Regional County of Governments (DRCOG). The county made data on open spaces available to the public through the organization's periodic regional parks and open space survey.

Adams also worked with several organizations that hold easements on properties that the county owns. Colorado Open Lands, a land trust, holds five easements and the cities of Westminster and Commerce City hold six and one, respectively (McDowell 2013, personal comm.).

The citizens of Adams County were also important players in county green infrastructure planning. Resident concerns over open space loss and degradation encouraged the county to create the 1998 Open Space Plan. Soon after, residents approved an Open Space Sales Tax (1999) and returned to the poles to increase it in 2004. In all surveys completed during the study period, residents indicated that protecting parks and open space is important.

Funding
Adams County's Capital Improvement Programs divided green space spending into two categories: Conservation Trust Fund and Open Space Projects Fund. Between 2003 and 2004, the county spent an average of 6.7 million per year in the two categories, with a low of $2 million in 2007 and a high of $15 million in 2009. In most years, funding ranged from $5.5 to $7 million. The number of funded projects varied from year to year, with an annual average of 3. The vast majority were land acquisition, with a few trail projects. (Adams County Annual Budget 2004 – 2010).

The Conservation Trust Fund is supported by revenue from the State Lottery that is disbursed to counties on a per capita basis. The funds support the acquisition and development of parks and trails. The county created the Open Space Projects Fund in 2002 to consolidate the various other sources of county open space funding, including Adams County Open Space Sales Tax proceeds. The Open Space Sales Tax began in 1999, when Adams County voters approved the .20% tax to support active and passive recreation. In 2004, residents returned to poles and extended the tax to 0.25%. The majority of proceeds, 68%, were awarded to organizations within Adams County as part of a competitive grant program, 30% were returned to the jurisdiction within which the funds were generated, and the remaining 2% were allocated for administration. While the program was administered by the Adams County Parks & Community Resources Department, an independent citizen group – the Open Space Advisory Board – approved projects for funding (Adams County 2012).

Green Infrastructure Network Change in Adams County
Quantity
Between 2001 and 2009 – the satellite image dates – developed area in Adams County increased by 26%, adding 9,500 acres of residential, commercial and industrial area. Results also show the county lost 5% of its unprotected agricultural land, but gained natural land (Table 6-11). However, shifts between natural and agricultural land uses obscure the amount of each that was permanently converted to non-resource uses. In all, 6,567 acres of land that was agricultural and 2,960 acres of land that was forest or grassland in 2010 were converted to developed land uses by 2010. These account for 11% of agricultural land and 1% of natural land. Together, 2.9% of county land (9,500 acres) was converted from green infrastructure to developed land, for a 26% increase in developed land uses.

Table 6-11. Land Use Change in Adams County, 2001 to 2009* (by author). Natural includes both grassland and limited forest.

	2001 (acres)	2009 (acres)	Change (%)
Water	2,187	2,187	**0**
Agriculture	62,199	65,191	**5**
Natural	235,136	222,617	**-5**
Developed Area	37,157	46,684	**26**

*Considers only privately-owned unprotected lands under county jurisdiction.

The majority of new development in Adams County occurred in the northeastern and south central portions of the county (Figure 6-13). The south central section of the county had small, but growing communities. The far western and southwestern portions were part of the urbanized Denver area and the location of the vast majority of existing development in the county. Notably, the 'peninsula' cut from the center of the western side of the county is the Denver International Airport, and part of the City of Denver. The eastern reaches of the county were characterized by farms, ranches, and small rural communities and drew only limited development during the study period.

Figure 6-13. Natural land, farmland, and developed area in Adams County in 2009. 'New Development' is development that occurred since 2001 (by author.)

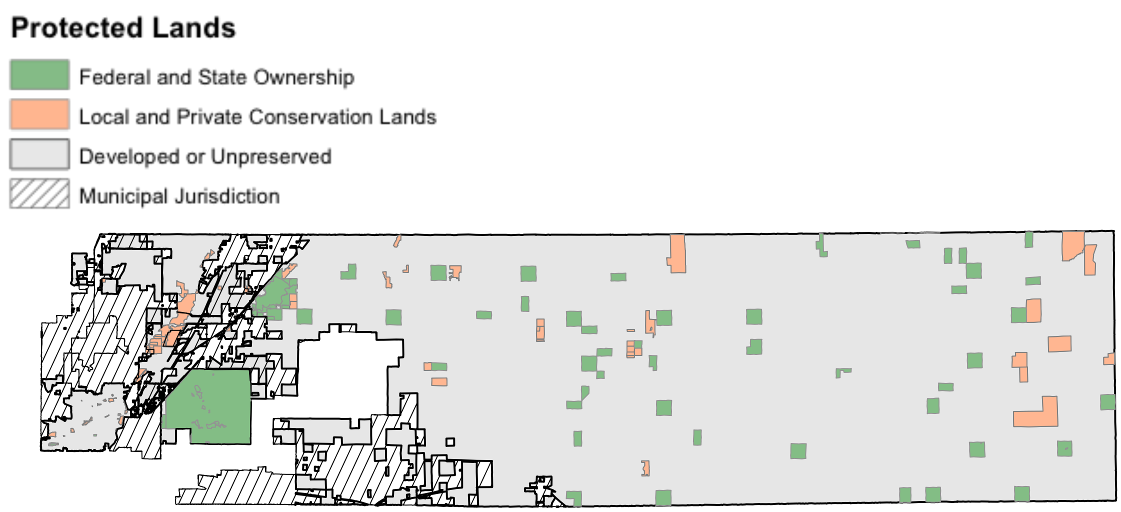
Prior to 2000, Adams County held one 53-acre conservation easement and owned 1,467 acres of open space and parkland (Table 6-12). Most of the open space was part of the county's Regional Park and Fairgrounds (1,150 acres). Between 2000 and 2010, the county added an additional 1,550 acres of public parkland and open space, but still lagged behind the Front Range and Northeast regions of Colorado in public parkland acres per capita. The Front Range had an average of 0.60 public acres per capita, while the Northeast region – which is similar to rural Adams County – had an average of 0.70.

Adams County, in 2010, had only 0.038 public acres per capita (Adams County Annual Budget 2010, Adams County 2012). Over the same decade, the county added 5,200 acres of conservation easements. About half the easements were acquired through traditional means – donated by or purchased from a property owner – and half were part of the county's TDR program.

Table 6-12. Land preservation in Adams County between 2000 and 2010. Table by Author. (McDowell 2013, personal comm.)

	Acreage		
	Prior to 2000	**In 2010**	**Difference**
Open Space or Parkland (In-Fee)	1,467	3,020	1,553
Purchase or Donation of Development Rights (Easement)	53	2,378	2,325
Transfer of Development Rights Program (Easement)	0	2,611	2,611
Other (Easement)	0	267	267
TOTAL	**1,520**	**8,276**	**6,756**

Figure 6-14. Federal, state, local, and privately-owned protected areas in Adams County, Colorado in 2010 (Map by Author).

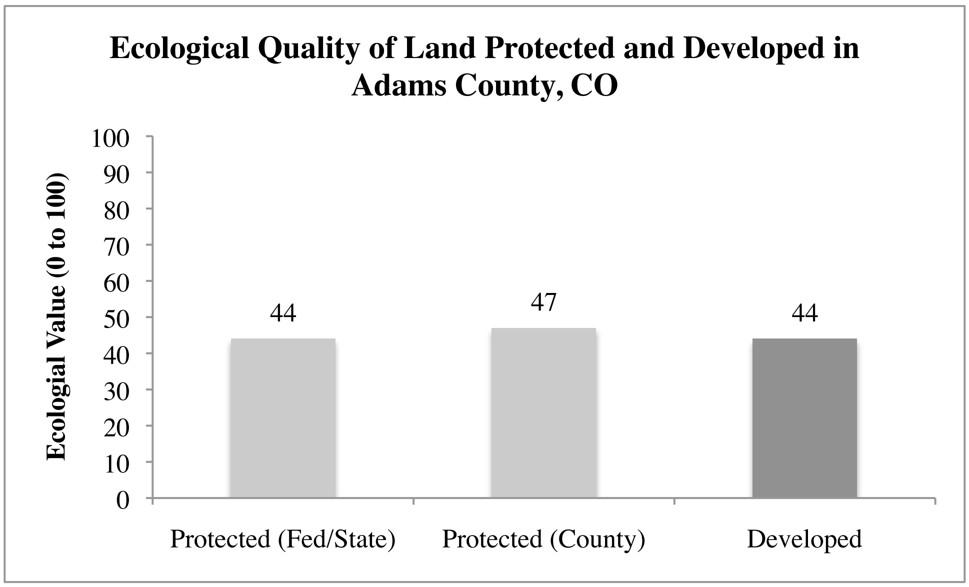


Local and private conservation lands are scattered throughout Adams County (Figure 6-14). While most properties are large, there are few connections between them. State Trust lands are also distributed throughout the eastern two-thirds of the county, creating a dispersed pattern of protected lands of all types. Conservation lands are more grouped in the western region of the county. The largest agglomeration of local and private conservation lands is also the most western, located along the South Platte River Corridor.

Quality

Between 2001 and 2009, the average value of agricultural and natural lands developed in Adams County was 44. The area-weighted mean ecological value of county protected lands was only slightly higher at 47 (Figure 6-15). The ecological value of state and federal lands was even lower. Together, the results show that county efforts to direct development had little impact.

Figure 6-15. Area-weighted mean ecological quality of land developed in Adams County between 2001 and 2009. State/Federal and county protected area quality averages include land that was preserved prior to 2001.



Connectivity

During the study period, the level of fragmentation of agricultural land in Adams County increased. Patches became slightly shorter, but also smaller and more distant from each other. Results for natural land are less straightforward (Table 6-13). Metrics show that patches of natural land became shorter, an indication of a loss of contiguity, but also that they became larger and closer together. The result is likely due to shifts between agricultural and natural land uses. Between 2001 and 2009, 13,700 acres changed from agricultural fields to natural grassland. The configuration of such changes impacts overall connectivity. The most likely explanation is that small sections of farmland – say in a certain region or owned by a certain landowner – regenerated. The new natural land patches were smaller than average but either in close proximity to each other or located in areas in which grassland was previously underrepresented, thus enhancing overall natural land connectivity.

Table 6-13. Patch Shape and Contiguity Metrics for Adams County Natural and Agricultural land in 2001 and 2009 (by author).

	Natural Land			Agricultural Land		
	2001	**2009**	**Change Notes**	**2001**	**2009**	**Change Notes**
Area-weighted Mean Patch Length/Contiguity (GYRATE_AM)	6,963m	5,845m	Decrease in patch length	13,654m	13,958m	(Slight) Decrease in patch length
Patch Shape Complexity (SHAPE_AM)	24	20	Minimal Change	44	41	Minimal Change
Patch Aggregation (CLUMPY)	0.87	0.87	Minimal Change	0.92	0.93	Minimal Change
Area-weighted Mean Distance to Nearest Like Patch (ENN_AM)	62m	62m	Minimal Change	62m	62m	Minimal Change
Area-weighted Mean Patch Size and Proximity Metric (PROX_AM)	5,455	15,531	Patches become larger and closer	15,815	15,009	Patches become smaller and more distant

Overall

Between 2000 and 2010, the Adams County Planning & Development Department and Parks & Community Resources Department conducted a low to moderate level of green infrastructure planning. The county's activities covered 40% of the policies and strategies included in the Green Infrastructure Planning Assessment Framework. The county's main strength was its strong protection of important natural resources through development review and design regulations. Resources Review applied to most developments and required an inventory of natural, cultural, and agricultural resources and mitigation of impacts and that development be planned to meet design standards delineated for each type of development. The county's transfer of development rights program was also a boon to green infrastructure. It provided flexibility but directed landowners toward protecting the most ecologically important lands with favorable preservation to development ratios. Through it, the county preserved 2,600 acres of agricultural land. The county's main weaknesses were growth management and countywide strategies. The proliferation of residential estate developments and lack of coordination with municipalities on growth areas encouraged development of farmland. In addition, while the county's support for connectivity and ecological quality was good, at a parcel level, there was little indication of broader countywide planning for green infrastructure. The 1998 Open Space Plan analysis provided a start, but the thinking was not carried forward into a conceptual or actual countywide network of green space hubs and links.

Adams County's green infrastructure network was significantly impacted by development over the study period. Nearly 10,000 acres of agricultural lands and natural grasslands were converted to developed land uses, 2.9% of the county's land area. The county was also unsuccessful at directing development toward marginal areas. The area-weighted mean ecological quality of lands developed during the time period was 44, about the same as the average ecological quality of protected areas. So the county either developed high quality green space or protected low-quality green space. Since developed land has a mean ecological quality equivalent to that of state and federal open spaces, which tend to be mature and well managed, the former is more likely. Finally, county green space became increasingly fragmented during the study period. Results are clearer for agricultural lands than natural lands. Patch shape and contiguity metrics indicate that patches of farmland became slightly shorter, but also smaller and further apart. Results for natural land changes are mixed, likely because of shifts between agricultural and grassland uses. But regardless of differences in the proximity of natural area patches to each other, the average grassland patch size shrank by more than 1,100 meters between 2000 and 2010.

COMPARATIVE RESULTS

The objective of this study is to examine the impact of county green infrastructure planning. It assesses the degree to which counties that employed many green infrastructure planning strategies and programs (Boulder) during the 2000 to 2010 study period were more successful in retaining, protecting, and connecting green infrastructure than those that employed fewer (Arapahoe and Adams). The three counties had varying degrees of green infrastructure planning success. In general, Boulder County, which employed 62% of Green Infrastructure Planning Framework strategies, was most successful in retaining green infrastructure and connectivity over time and Adams County with 40% was least successful. But there was one inconsistency. Adams County slightly out performed Arapahoe in retaining the connections between natural lands over time. This section outlines the main qualities of the three programs and details their comparative success in each of the three study areas.

Planning

The major programmatic differences between the three counties were in the areas of growth management, zoning and subdivision regulations, and support for green infrastructure connectivity. During the study period all three counties adopted the general strategy of directing development toward incorporated municipalities, or their planning areas, and protecting more distant rural lands. Boulder County supported the strategy through Community Service Areas, intergovernmental agreements with municipalities on lands that they would service and eventually annex. Arapahoe adopted a more conventional growth boundary called the Urban Service Area (USA), outside of which the county would not approve urban development. The majority of incorporated municipalities were west of the USA, but Arapahoe delineated separate growth and planning areas for the few Eastern Communities. Both Boulder and Arapahoe operated under the plan that the municipalities would eventually annex newly developed lands. Adams also adopted a growth boundary, and using the same era of DRCOG recommendations as Arapahoe, but the Adams County boundary appears to have had little impact. It is barely mentioned in the 2004 Comprehensive Plan and is not referenced in the County Code. In contrast, the USA is mentioned in most sections of the Arapahoe County code.

The three counties had similar base zoning, with the most restrictive agricultural zone allowing residential development at a density of 35 dwelling units per acre. The main differences were the ways in which that zone could be developed. Boulder County encouraged Non-Urban Planned Unit Developments (NUPUDs). NUPUD subdivision rules offered double the allowed density - two dwelling units per 35 acres and an additional dwelling unit per 17.5 acres – to landowners who clustered development on 25% of the parcel and donated a conservation easement. Arapahoe offered a rural cluster option. Under the rural cluster option, a landowner could receive cumulative bonus densities for providing various community services and trails, in addition to grouping development on no more than 40% of the site. Adams County had a similar development option, the open space residential subdivision, but the rules allowed for development on 50% to 70% of a site, too large an area to truly be considered clustered. In addition, the county did not require conservation areas to be protected in perpetuity under a conservation easement or equivalent restriction. However, the outcome of differences in this area were minimal, since use of NUPUDs in Boulder declined sharply over the time period, and clustered strategies were rarely, if ever, used in the other two counties.

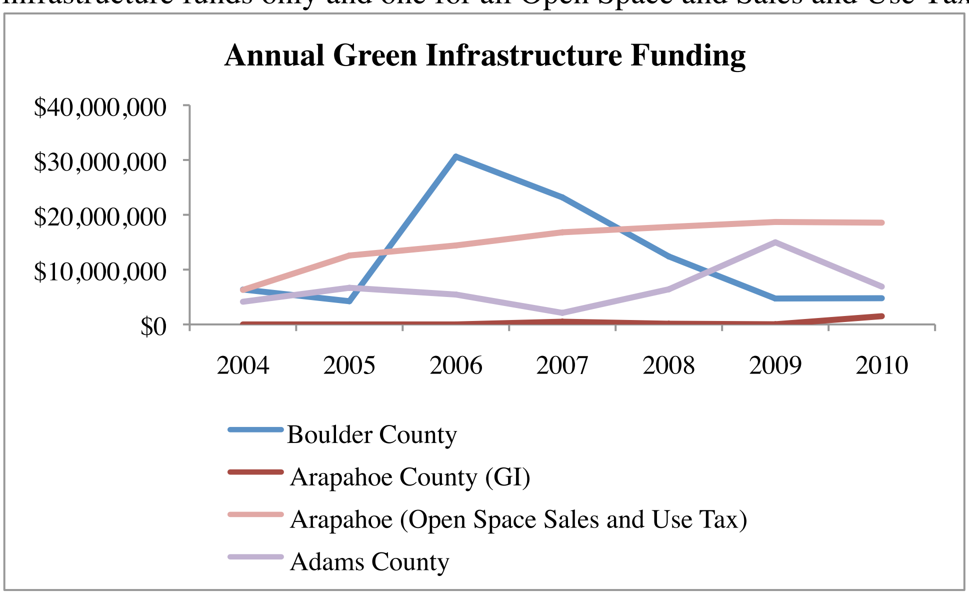
A final difference between the three was the level of countywide open space planning. Only Adams had an "Open Space Plan," but that plan did not include a strategy for creating a network of green space. It had a parcel-wise evaluation of conservation merits and information on focus-regions for different resources, but the information was used only informally. Open Space strategies were not incorporated into other planning documents such as the comprehensive plan. Boulder had the strongest framework for creating a network of conservation land, despite the lack of a formal plan. The county had land preservation prioritization criteria that strongly favored connections and adjacency. While Arapahoe considered adjacency in providing grants to other organizations, connectivity was not a formal consideration in allocating open space funds within the county. But despite the lack of formal connectivity-oriented prioritization criteria, Arapahoe County did have success in connecting county conservation lands into two large block of protected open space.

Funding and Land Preservation

The three counties had different levels of green space expenditures, but from similar sources. All three use a combination of funds from the state Conservation Trust Fund and local Open Space Sales and Use Tax proceeds. Boulder County received the greatest benefit from the latter source. Arapahoe and Adams had a tax of 0.25%. Boulder started at 0.25%, but climbed to 0.45% by 2005. Adams and Arapahoe also provided sharebacks and grant programs with the proceeds, while Boulder used the funds for debt service on open space bonds. Adams sent 30% of open space proceeds back to the jurisdictions that produced the funds (a "share-back"), and distributed an additional 68% through a competitive grant program. The county received a share-back and was eligible for the grant program, but received a relatively small amount of the revenue. Arapahoe focused less on grants and more on share-backs, sending 50% back to municipalities and allocating 12% through grants. The remaining 28% of funds belonged to the county. So Boulder County received most of the open space tax proceeds, Arapahoe was guaranteed 28%, and Adams was guaranteed however much it produced.

The counties also received differing amounts from the Conservation Trust Fund (CTF). CTF funds were distributed quarterly, on a per capita basis. For example, at the end of the study period, in December 2010, Boulder received $95,171 ($380,600 per year), Arapahoe received, $112,465 ($449,900 per year), and Adams received the most with $138,184 ($552,700 per year). Funds could be used for "acquisition, development, and maintenance of new conservation sites or for capital improvements or maintenance for recreational purposes on any public site" (Colorado Department of Local Affairs 2013, 1). Tabulations of green infrastructure spending in this study do not include on-site capital improvements or maintenance, unless the actions have natural resource or trail implications. For example, during the study period, Arapahoe County spent nearly all its CTF funds on building design and construction on the county fairgrounds property, so those funds were not counted as green infrastructure spending. Adams also used CTF funds for improvement rather than acquisition.

Figure 6-16. Annual Green Infrastructure Funding in Boulder, Arapahoe, and Adams County, Colorado. Figure includes only funds for green infrastructure (i.e. open space and trail acquisition, natural resources management, and trail development) for Boulder County and Adams County. Arapahoe County includes two measures, one for green infrastructure funds only and one for all Open Space and Sales and Use Tax expenditures.



Boulder County did not report individual projects, so it is difficult to compare funding levels, but an examination of Open Space Sales Tax, CTF funds, and annual budgets indicated that Boulder County's program receives the greatest funding (Figure 6-15). Allocations in Arapahoe and Adams are similar, with Adams spending fewer county funds on green infrastructure projects during the study period.

Boulder County also started with more preserved land and added more protected acreage during study period than the other two counties. The abundance of preserved land, particularly in the form of large hubs such as the 118,000-acre Roosevelt National Forest, supports local connectivity, quality, and biodiversity and reduces the impact of development on green spaces (Table 6-14a). Between 2000 and 2010, Boulder County built on its land preservation success and protected an additional 34,300 acres, alone and with partners (Table 6-14b). Arapahoe County protected 16,800 acres over the same time frame and Adams County lagged behind with 7,000 acres. Notably, both Arapahoe and Adams built easement programs from scratch. Each had fewer than 60 acres of conservation easements at the beginning of the study decade and ended it with thousands. All three counties added more easements than fee simple properties.

Table 6-14a. Preserved and government-owned resource land in Boulder, Arapahoe, and Adams County, Colorado in 2010.

Owner/Manager	**Boulder (H)**	**Arapahoe (M)**	**Adams (L)**
County	91,206	17,662	8,276
State Trust	723	41,858	24,115
State	2,087	4,143	2,342
Federal	198,175	3,635	17,896
TOTAL	**292,191**	**65,388**	**53,219**

Table 6-14b. Acres of land added to county protected area networks between 2000 and 2010.

County Preservation Type	**Boulder (H)**	**Arapahoe (M)**	**Adams (L)**
Conservation Easement	18,225	13,234	5,203
Fee Simple	16,051	3,591	1,553
TOTAL	**34,276**	**16,825**	**6,756**

Partners are also an important part of land preservation success. Boulder County worked with 10 different partners on fee and easement projects between 2000 and 2010, the majority of them multiple times. Arapahoe also forged partnerships and served as a convening organization for planning and management projects. The county's award winning Middle Bijou Creek project involved three public-sector partners and two land trusts, one of which held the easement. Adams did work with other organizations, but was less focused on partnerships than the other two counties.

Quantity

Land use change is linked not only to planning strategies, but also to population growth. To compare land use change across counties, it is necessary to account for differences in the magnitude of population change. Doing so changes land use values from raw numbers to comparable land use efficiency figures. Boulder County, the high level green infrastructure planning county, had the highest degree of land use efficiency, with .04

acres developed per new resident added (Table 6-14). While the population growth and increase in developed area were greatest in Arapahoe, its area developed per capital was smaller than that of Adams. In Arapahoe, .08 acres were converted per new resident, while in Adams the value was .12 acres.

Table 6-15. Forested and agricultural land developed between 2000 and 2010 in Boulder, Arapahoe, and Adams County, Colorado, by acreage and per capita added to the population.

	Boulder (High)	**Arapahoe (Moderate)**	**Adams (Low)**
Population Added	23,000	84,000	77,700
Land Developed (Acres)	886	6,629	9,527
Land Developed (As Percent of Private Land in County)	0.3%	2.7%	2.9%
Increase in Developed Area	2%	28%	26%
Land Developed (Per Capita Added)	**.04 ac**	**.08 ac**	**.12 ac**

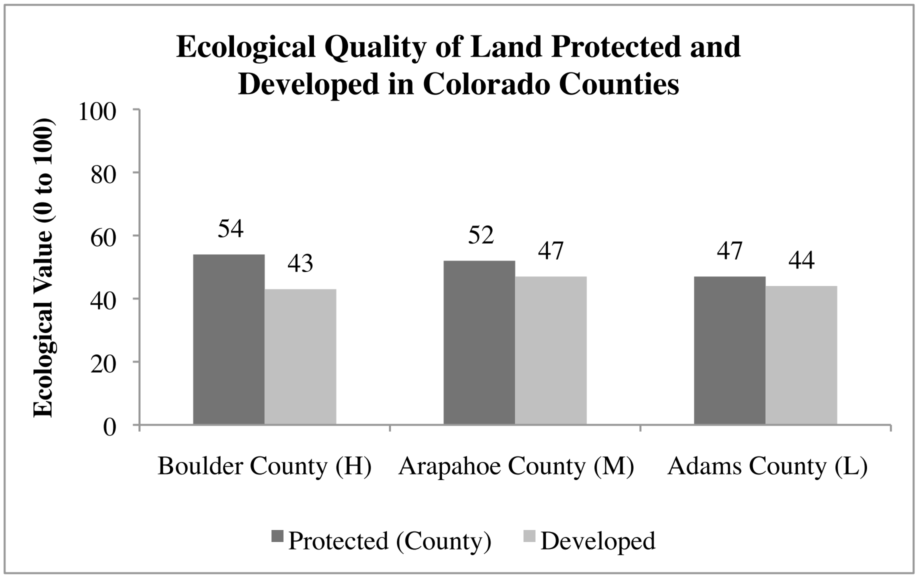
Notably, rates of land development per capita are low in Colorado partially because of the prominence of annexation. The three counties designated growth areas near municipalities with the understanding that new developments would be annexed. In most cases, the municipalities annexed new developments quickly. So, 'land developed (acres)' reflects only lands that remained within county jurisdiction, while 'population added' reflects individuals added in both municipal and county areas. But, the relative rate of land developed per capita is still useful.

Quality

One objective of green infrastructure planning is to retain high quality green space by guiding development toward marginal and previously developed or degraded areas. Counties that are successful in green infrastructure planning should exhibit a large difference between the ecological value of protected land and the ecological value of developed land. Since the average ecological value of the three counties examined here is different, inter-county comparisons of the average value of developed or protected land are not meaningful. The ratio of developed area value to protected area value is more informative. In addition, because there were so few county-owned protected areas in Adams in the early years of the study period, the ecological value averages include only state and federal lands.

Over the study period, Boulder, the high-level county, achieved the greatest success in directing development toward marginal areas. The difference between the mean ecological value of protected and developed areas in Boulder County was 11 (Figure 6-17). The difference was smaller for Arapahoe, at 5, and smallest for Adams, with only 3. Broadening the analysis to consider state and federal lands – rather than local – makes it clearer that Arapahoe outperformed Adams. The difference in average ecological quality between state/federal preservation lands and developed lands in Adams was zero, while in Arapahoe it was 12.

Figure 6-17. Area-weighted mean ecological quality of county land protected and developed between 2000 and 2009 in Boulder, Arapahoe, and Adams County, Colorado. County protected area quality averages include land that was preserved prior to 2001.



Connectivity
The third major facet of green infrastructure planning is connecting green spaces into a functional network. Counties that are successful in green infrastructure planning will retain the size, contiguity, and proximity of their green spaces over time.

During the study period, Boulder County exhibited the greatest stability in connectivity and patch metrics. The connectivity and proximity of forested and natural areas in Boulder County changed only minimally over the study period (Table 5-15). Several other metrics, however, are counterintuitive. While the county lost significant natural grassland during the study, patch metrics show that connectivity in Arapahoe increased. As previously noted, the result was probably caused by agricultural lands reverting to prairie. The explanation is supported by land use change metrics. Despite a loss of nearly 2,000 acres of 2001 grassland to development, the county had slightly more grassland in 2009 than in 2001. One of the Adams County metrics posts a similar result, and likely for the same reasons. However, the patches of natural grassland that were gained appear to have been smaller or more regular than those that were lost, because the result is an overall decrease in the length of grassland patches.

Table 6-16. Interpretation of change in landscape metrics for forested and grasslands lands in Boulder, Arapahoe, and Adams Counties between 2001 and 2009. MC = Minimal Change; Darker Color = Greater Change. For full results see previous tables.

	Natural		
	Boulder (H)	**Arapahoe (M)**	**Adams (L)**
Area-weighted Mean Patch Length/Contiguity (GYRATE_AM)	MC	Increase in patch length	Decrease in patch length
Patch Shape Complexity (SHAPE_AM)	MC	MC	MC
Patch Aggregation (CLUMPY)	MC	MC	MC
Area-weighted Mean Distance to Nearest Like Patch (ENN_AM)	MC	MC	MC
Area-weighted Mean Patch Size and Proximity Metric (PROX_AM)	MC	Patches become larger and closer	Patches become larger and closer

Agricultural connectivity data is less anomalous than grassland data. Again, Boulder County experienced the greatest stability in connectivity. Patches of farm and ranchland in Boulder County became only slightly smaller, shorter, and further apart (Table 6-16). In addition, Adams County outperformed Arapahoe, losing less connectivity over the study period.

Table 6-17. Interpretation of change in landscape metrics for agricultural lands in Boulder, Arapahoe, and Adams Counties between 2001 and 2009. MC = Minimal Change; Darker Color = Greater Change. For full results see previous tables.

	Agriculture		
	Boulder	**Arapahoe**	**Adams**
Area-weighted Mean Patch Length/Contiguity (GYRATE_AM)	(Slight) Decrease in patch length	Decrease in patch length	(Slight) Decrease in patch length
Patch Shape Complexity (SHAPE_AM)	MC	MC	MC
Patch Aggregation (CLUMPY)	MC	MC	MC
Area-weighted Mean Distance to Nearest Like Patch (ENN_AM)	MC	MC	MC
Area-weighted Mean Patch Size and Proximity Metric (PROX_AM)	Patches become (slightly) smaller and more distant	Patches become smaller and more distant	Patches become smaller and more distant

HYPOTHESIS TESTING AND CONCLUSION

As described in Chapter 3, a strong relationship between the policies and strategies associated with green infrastructure planning and on-the-ground green space outcomes will disprove the null hypothesis and support the alternative hypothesis that green infrastructure planning leads to better green space outcomes. For the purposes of this study, a 'strong relationship' means an overall trend that counties employing a 'high' level of green infrastructure planning outperform counties employing a 'low' level of green infrastructure planning in the three areas of analysis: retaining green infrastructure over time, protecting high quality areas, and connecting green infrastructure into functional network. If this relationship is strong, the level of green infrastructure planning (high/moderate/low) should match the level of county success (high/moderate/least) in each of the three areas. Table 6-17 shows this relationship.

Table 6-18. County level of success in retaining, protecting, and connecting forested and agricultural land between 2000 and 2010. Areas that do not follow the H/M/L trend are shaded. For 'Protect (High Quality),' a single result is displayed twice, for both Natural Land and for Agricultural Land.

	Natural Land			**Agricultural Land**		
	Boulder (H)	**Arapahoe (M)**	**Adams (L)**	**Boulder (H)**	**Arapahoe (M)**	**Adams (L)**
Retain	High	Moderate	Least	High	Moderate	Least
Protect (High Quality)	High	Moderate	Least	High	Moderate	Least
Connect	High	Moderate	Least	High	Least	Moderate

Based upon this analysis, the relationship between level of county green infrastructure planning and on-the-ground green space outcomes is strongest in four areas. The first is at the highest level of green infrastructure planning, as shown in Boulder County. Boulder outperforms Arapahoe and Adams in retaining, protecting, and connecting forested and agricultural lands. A second area is in protecting high quality green infrastructure – or rather, steering development toward low quality greenfields, rather than high quality. While it was difficult to separate natural and agricultural lands in Colorado, examining the land covers together shows that the higher-level green infrastructure planning counties were more successful than lower-level counties.

A third area in which the level of green infrastructure planning relates to green space outcomes in Colorado is in retaining green space over time. Boulder County – the high-level green infrastructure planning county – exhibited more efficient land use during the study period than the other two. For each new resident to the county, Boulder converted only .04 acres land, slightly less Arapahoe (.08) and far less than Adams (.12). The efficiency led the county to retain more green space in the face of population growth.

Finally, there is also a relationship between the level of green space planning and ability of a county to retain green infrastructure connections. Boulder County was more successful at retaining links between forested and agricultural lands over the study decade than Arapahoe and Adams. In addition, Arapahoe- the moderate-level green infrastructure planning county - outperformed Adams in retaining natural land connections, but not in retaining connections between agricultural lands. Arapahoe had stronger farmland preservation strategies than Adams, so the result is counterintuitive and requires further study. It may be related to fluctuations between grassland and agricultural land uses during the study period.

The strength of these relationships supports the alternative hypothesis rather than the null hypothesis. The level of green infrastructure planning that a county employs appears to have an impact on that county's success in retaining green spaces and critical green infrastructure connections. It also seems to affect the ability of a county to retain high quality lands and steer development toward less valuable areas. In short, results show that it *is* ‘good to be green’ in Colorado. At the highest level, the benefits of employing many green infrastructure planning strategies are almost across the board. Boulder County exhibits a high level of green infrastructure planning and leads the other two counties in retaining, protecting, and connecting green spaces. But at the low-to-moderate level of green infrastructure planning, benefits relate more strongly to protecting high quality natural and agricultural lands and the ability of counties to retain green space, overall. Factors with a likely impact on these results are growth management strategies, land preservation partnerships, and the history, strength, and activity of the preservation program itself.

CHAPTER 7: COMPARISON and CONCLUSIONS

This research assessed the process and outcomes of landscape-scale green infrastructure planning as a strategy to balance development with conservation. The study examined how nine county planning agencies carried out green infrastructure planning and the effectiveness of the actions in retaining and connecting green infrastructure over time. The study evaluated the effects of green infrastructure planning through nine case study counties, in Colorado, Florida, and Maryland, which were selected for their mature and well-documented greenspace programs. Results show that counties that incorporate many green infrastructure planning policies and strategies are more successful in retaining green space acreage, quality, and connections over time than those that use fewer. The facets of green infrastructure planning with the greatest potential impact on green space results are connectivity and growth management. Counties interested in supporting green space networks should focus on policies specifically designed to support connectivity – such as purchasing land and development rights to create large contiguous blocks of preserved land and requiring connections between open spaces in the subdivision and land development process – and strategies oriented toward bounding growth, such as urban growth boundaries and restrictive rural zoning.

APPROACH AND METHODS

This study tracked the results of green infrastructure planning over a ten-year time period. The main objective was to assess the differences in outcomes between county planning agencies that are highly involved in green infrastructure planning and those that are not. The study involved a green infrastructure pre-test (2000) and post-test (2010), and qualitative examination of three sets of three case studies, grouped by state and level of green infrastructure planning (strong, moderate, or weak). The work analyzed the plans, policies, and outcomes of counties with different levels of green infrastructure planning to determine the on-the-ground impact of green infrastructure strategies.

The key questions of the study were 1) Are county planning agencies that employ many green infrastructure planning strategies more effective at retaining green space, preserving ecologically significant lands, and creating more connected green infrastructure networks than those that employ fewer strategies? And, 2) If they are, what makes the difference?

The study tested two overarching hypotheses:

H_1: County planning agencies that employ many of the policies and strategies associated with green infrastructure planning will be more effective at retaining, protecting, and connecting green infrastructure over time than county planning agencies that employ fewer.

H_0: There will be no difference in on-the-ground green space outcomes between county planning agencies that apply many green infrastructure planning policies and strategies and those that employ few.

Testing was based upon the recognition that a strong relationship between the level of green infrastructure planning and green space success would disprove the null hypothesis and support the alternative hypothesis that green infrastructure planning leads to better green space outcomes

As detailed in Chapter 3, this study addressed research questions and hypotheses through five main steps:

I. Case selection, based a upon preliminary scan of counties in Colorado, Florida, and Maryland

Due to the quasi-experimental design of this research, results hinged upon the comparability of each set of three case studies. Three states – Colorado, Florida, and Maryland – were selected for their varying state-level frameworks, green infrastructure planning history, and standard of green space planning. A three-step process narrowed counties in each of the states down to three, one with a high-level of green infrastructure planning, one with a moderate-level, and one with a low-level. Those case study counties were: Boulder County (H), Arapahoe County (M), and Adams County (L) in Colorado; Leon County (H), Alachua County (M), and Marion County (L) in Florida, and Baltimore County (H), Anne Arundel County (M), and Charles County (L) in Maryland.

II. Development of an in-depth green infrastructure planning evaluation framework

The study created a Green Infrastructure Planning Evaluation Framework (Framework) to enable more detailed analysis of the relative emphasis of green infrastructure planning in each of the case counties. Development of the Framework began with a review of content analysis and plan evaluation literature that pointed toward a "principal-policy framework." The principle-policy framework defines an overarching planning goal (e.g. smart growth, sustainable development, green infrastructure planning) and policies and strategies that – if integrated into planning practice – would show support for the principles. The more policies and techniques that a given program includes, the more supportive it is of the overarching planning goal.

To populate the Framework with policies, strategies, and techniques that support the principles, the study reviewed a selection of ten green infrastructure plans written since 2002. The review resulted in between 9 and 17 strategies/policies for each of the seven green infrastructure planning principles, for a total of 88 policies and strategies.

III. Application of the green infrastructure planning evaluation framework to selected case counties

The Green Infrastructure Planning Evaluation Framework provided a platform for comparison of the case counties and a way to understand how the counties perform relative to national leaders in green infrastructure planning and the principles that define the strategy. To complete the Framework, a single evaluator reviewed the plans, programs, zoning ordinances, capital improvement programs (2004-2010), and subdivision and land development regulations for each of the nine green infrastructure planning programs. The review identified the extent to which each county implemented the 88 green infrastructure planning components identified in the Framework between 2000 and 2012.

IV. Follow-up Interviews with county planners and decision-makers

To further understand the nuances of major county green infrastructure planning strategies - and gain the additional information necessary to complete the Framework – a single interviewer also spoke with at least one planner in each county. Interviews were unstructured and tailored to the specific state or county, but focused on the importance of specific green infrastructure planning strategies, planning document data sources and accuracy, local politics and funding, and relationships with local/state/federal entities. Interview results were used to confirm Framework scores and to understand which policies and strategies had the greatest impact on green space outcomes.

V. Quantitative assessment of green infrastructure networks

The primary objective of green infrastructure planning is to protect and maintain green spaces that provide critical ecosystem services. The clearest indicator of county green infrastructure planning success then, is a locality's ability to retain or enhance green space characteristics that are supportive of such services, specifically a) retain green infrastructure, b) protect high quality green spaces, and c) maintain or increase network connectivity. The final section of the study examined green infrastructure changes over time in the three categories and used the results to evaluate the green space outcomes of each of the nine case counties.

Quantity

The research examined changes in the quantity of green infrastructure between 2000 and 2010 using remote sensing and GIS analysis of Global Land Survey (GLS) Data. It used three different vegetation indices (NDVI, WET, and NDBI) to classify 2000 and 2010 GLS data for each of the nine counties into simple land use/land cover maps. Comparisons between 2000 and 2010 maps for each county showed changes in natural and agricultural land between 2000 and 2010, including the most significant change - the conversion of natural land to development.

Quality

The quality of green infrastructure also impacts its ability to provide ecosystem services. One way for a county to protect high quality land is to use zoning, and/or subdivision and land development regulations to guide development away from critical ecosystem service areas and toward more marginal lands. Another way is to permanently preserve high quality areas. This study examined both by comparing the ecological quality of lands developed between 2000 and 2010 to that of protected lands in the same county. To make the comparison possible, the research created an ecological value matrix for each of the three counties, based upon methods used in Maryland's 2001 Green Infrastructure Assessment. The matrices showed the relative ecological value of each 30-meter by 30-meter cell in county maps, and could be averaged over developed lands and protected areas.

Connectivity
A robust green infrastructure network is interconnected, particularly within individual land use types, such as farmland or forestland. This study examined connectivity from the perspective of landscape ecology, which envisions landscapes as series of patches, hubs, and linkages. The work used a variety of metrics to measure the spatial arrangement of landscapes elements, particularly patches – contiguous areas – of forestland and farmland. To examine changes in patch size, shape, aggregation, and proximity to others of the same patch type over the ten-year study period, the research used FRAGSTATS, a raster-based spatial analysis program.

The following sections detail how results derived from the methods described above address the study's overarching research questions.

HOW DO COUNTIES CARRY OUT GREEN INFRASTRUCTURE PLANNING?

To understand how county planning agencies carry out green infrastructure planning (GIP), the study created and applied a principle-policy framework. As previously discussed, the Framework is comprised of seven core green infrastructure planning principles and 88 policies and strategies, derived from a scan of ten U.S. green infrastructure plans. The policies and strategies show how local governments support GIP principles and consequently how they carry out green infrastructure planning.

Some of the policies and strategies that populate the Framework are used more commonly than others. Of the 88 policies and strategies that comprise the Framework, 37 were used to some extent by at least eight of the nine case counties. GIP actions used by at least eight counties – also known as consensus strategies – are shown in Table 7-1. The principle with the greatest proportion of consensus strategies is number 7: Protect and support green infrastructure through a collaborative and cooperative process. There are nine actions in the Framework under that principle, and six of them are consensus strategies. Among the study counties, there is also relatively high agreement on principle number 5: Manage green infrastructure to support ecosystem services. Counties show less agreement on policies and strategies supporting the remaining five principles. There are two possible reasons for a lack of consensus on a principle. First, counties (or states) do not value the green space characteristic that underpins that principle (e.g. connectivity, ecological quality) and consequently are not motivated to undertake strategies related to that principle. Second, counties agree that the green space characteristic is important, but planning efforts to support the principle vary widely. Both are indicative of a high degree of variation in county approaches to green infrastructure planning.

Table 7-1. Frequency of use/adoption of GIP strategies and policies in nine counties in Colorado, Florida, and Maryland. Shows only policies and strategies used by 8 or 9 counties.

1) Create linkages and foster connectivity (11 total)	**No. of Counties**
In preservation, prioritizes land adjacent to existing public parks, open spaces, or preserved areas	9
Discusses fragmentation (in planning documents)	8
Maps network components (conceptually or actually)	8
In development review, includes connectivity of green space, parks, and/or open space dedications	8
2) Value areas of ecological quality and local importance (17)	
Identifies ecologically valuable features	9
Identifies major anchors of the green infrastructure network	9
In development review, requires natural resources assessment	9
Identifies culturally or historically important features	8
Maps ecological assets (i.e. wetlands, woodlands, farmland, rare plant and animal species)	8
In preservation, prioritizes large - economically and ecologically viable - tracts of land	8
In development review, includes rare or important environmental resources	8
Uses overlay or agricultural zones for prime soil or resource areas	8
3) Support a variety of landscapes and ecosystem services (11)	
Identifies cultural, working, recreational, and natural landscapes	9
Identifies a variety of ecosystem services/benefits	9
Capital improvements program balances funds for recreation and preservation	9
4) Restore and mitigate damage to green infrastructure (11)	
Requires mitigation of impacts on wetlands	9
Requires mitigation of impacts on other natural resources (e.g. forests, habitat)	9
5) Manage green infrastructure to support ecosystem services (14)	
Identifies environmentally sensitive areas (e.g. steep slopes, floodplains, wetlands, coastal areas)	9
Uses overlay zones to restrict development of environmentally sensitive areas	9
In development review, requires special treatment of environmentally sensitive areas	9
In development review, requires a forest/resource management plan	9
Develops resource management plans for county green infrastructure network anchors	9
Conducts environmental education programs to encourage sound stewardship of green infrastructure	9
Maps environmentally sensitive areas	8
Ensures physical and/or visual access to preserved areas, where appropriate	8
6) Enact land use planning strategies to protect and retain all scales of green infrastructure (15)	
Defines and maps growth areas	9
Requires that development projects leave a portion of buildable area as park/open space	9
Uses agriculture protection zones to limit development outside of growth areas	8
Plans grey infrastructure servicing to reinforce growth and conservation areas	8
Funds green infrastructure protection from continuous, dedicated sources (e.g. taxes, fees)	8
Invests significant county funds in green infrastructure (not just leveraging of state/federal funds)	8
7) Protect and support green infrastructure through a collaborative and cooperative	

process (9)	
Coordinates conservation efforts with other local jurisdictions	9
Works with local land trusts and other NGOs	9
Participates in optional state and federal programs	9
Leverages state and federal funds for green infrastructure	9
Outlines how the public is involved in the green infrastructure planning process	8
Shares green infrastructure and local ecological information with other organizations	8

DO AGENCIES THAT EMPLOY MANY GREEN INFRASTRUCTURE PLANNING STRATEGIES HAVE BETTER GREEN SPACE OUTCOMES?

In all three states, the level of green infrastructure planning that a county employs does appear to impact the success of that county in retaining green spaces and critical green infrastructure connections. It also relates to the ability of a county to retain high quality lands and steer development toward less valuable areas. In short, results show that it *is* 'good to be green' in Colorado, Florida, and Maryland.

In general, counties with a high-level of green infrastructure planning exhibit a high level of success in the three outcome categories - green space quantity, quality, and connectivity - and low-level counties show the least success, with moderate counties falling in the middle. Colorado has the strongest trend, with only one divergence in the high-moderate-low (H/M/L) ordering in the area of connectivity. Florida has the second greatest relationship between number of policies and strategies and green space outcomes with only two divergences, one in connectivity and one in quality. Finally, Maryland has three divergences from the H/M/L pattern, two related to the counties' ability to retain green space over time and one to quality.

But assessments of 'High,' 'Moderate,' and 'Least' success in green infrastructure outcomes apply only within each state. Due to differences in state policies and oversight, natural environments, and general planning trends, comparing the growth and quality values for counties in different states is not useful. But, examining the differences in trends from the three states in general, provides some information on green infrastructure planning outcomes and what may cause deviations from the H/M/L ordering in some states and not in others.

Quantity

The level of a county's green infrastructure planning clearly relates to its ability to retain green infrastructure over time in Colorado and Florida, and to a lesser extent in Maryland, as well. Only Baltimore County (H) and Anne Arundel County (M), Maryland do not follow the H/M/L ordering. The overall result is that planning does make a difference for moderate and slow-growing counties, particularly where green infrastructure programs are mature and robust.

Absent planning and growth management, a county's ability to retain green space is a function of population growth rate. A high growth rate means more green infrastructure is converted to developed land uses while a low growth rate means slower loss. Results from this study suggest that population growth rate is not the only factor, that green infrastructure planning also makes a difference in green space loss. For example, in Florida, Leon County (H) had a higher growth rate than Alachua County (M), but retained more forest and farmland over time and in Maryland, Anne Arundel (M) slightly outperformed Baltimore (H) in retaining overall green infrastructure over time, even though it had the higher growth rate of the two (Table 7-2). Colorado is the only state in which the population growth rate related strongly to the rate of green infrastructure conversion. But, the connection holds true only for the rate of growth, not the absolute number of population added or the increase in developed area. Arapahoe (M) added more population and a greater percent of developed area, and yet had more success in retaining combined green infrastructure than Adams (L), which grew less. Notably, for counties with growth rates double that of comparable localities (i.e. Charles County, Maryland, and Marion County, Florida) and low-levels of green infrastructure planning, planning appears to have had a minimal impact on developed area per capita.

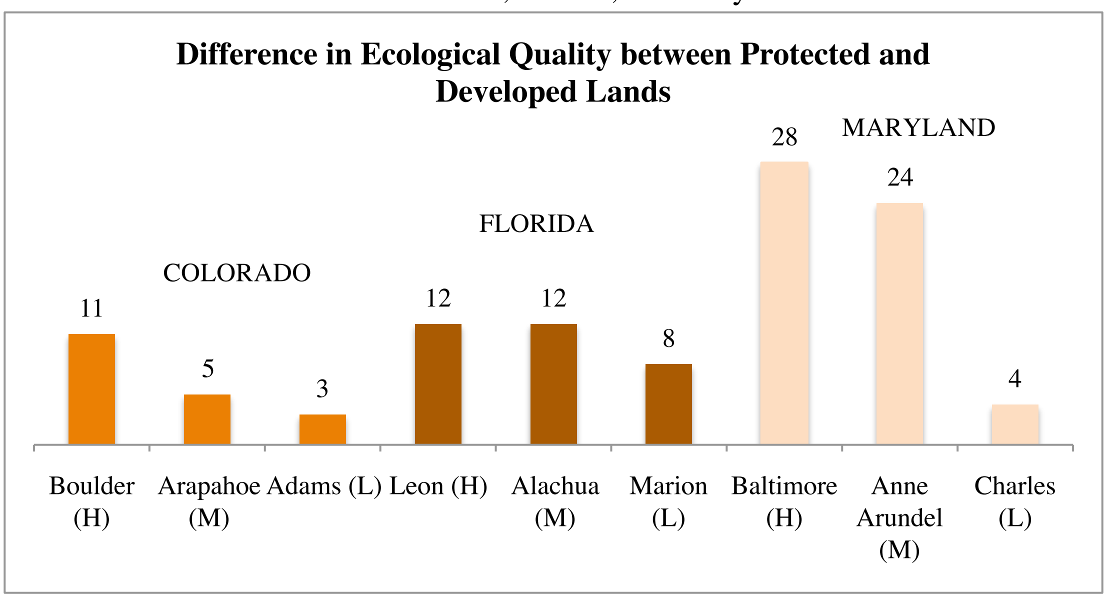
Table 7-2. Population and combined green infrastructure statistics for counties in Colorado, Florida, and Maryland between 2000 and 2010. Counties that do not follow the H/M/L ordering for overall land developed per capita are shaded.

	Colorado			**Florida**			**Maryland**		
	H	**M**	**L**	**H**	**M**	**L**	**H**	**M**	**L**
Population Added (‘000)	23	84	77.7	36	29.4	74.4	51	48	25
Growth Rate	8.4%	17.2%	21.4%	15%	13.5%	28%	6.7%	9.8%	21.6%
Increase in Developed Area	2%	28%	26%	22%	22%	34%	8%	7%	25%
Land Developed (Per Capita Added)	**.04 ac**	**.08 ac**	**.12 ac**	**.12 ac**	**.25 ac**	**.58 ac**	**.18 ac**	**.15 ac**	**.50 ac**

In general, the high-level green infrastructure planning counties included in this study have more mature planning programs and slower growing populations than the moderate and low-level counties. This is particularly true of Boulder County, Colorado (H) and Baltimore County, Maryland (H), which grew by 8.4% and 6.7% over the study decade and increased developed area by a modest 2% and 8%, respectively. Both counties are known for their planning and have not only stable populations, but strong – and prolific – land preservation programs and mature growth management regimes. For example, Baltimore (H) lost slightly more land area to development than Anne Arundel (M) over the study period, but unlike in Anne Arundel, developed lands were mostly within an urban services boundary. Leon County, Florida (H) has strong programs, as well, but it is not as mature and well-rounded as the other two. Consequently, the Leon experienced a more moderate level of growth and development that put it in the middle of the pack for its state.

Quality
The level of green infrastructure planning a county employs also relates to the difference in ecological value between protected lands and developed lands in that county. Counties have two options for retaining high quality lands over time, 1) permanently preserve lands with high ecological value, and 2) use zoning and subdivision and land development regulations to guide development toward low quality areas and away from important lands. For forested and natural lands, all three states generally follow the H/M/L ordering (Figure 7-1). But in Florida, while the ordering holds, there is little variation between high- and moderate-level counties. Leon (H) and Alachua (M) have the same – relatively high – level of success. But they do both outperform Marion County (L). The overall result is that green infrastructure planning helps to protect high quality green space over time, but the total acreage and quality of green space – protected or not – also has an impact.

Figure 7-1. Difference in areas-weighted mean ecological quality (a scale of 0 to 100) between forested lands that are protected and lands that were developed between 2000 and 2010 for nine counties in Colorado, Florida, and Maryland.



There are two major outcomes from this analysis. First, in all cases, there is *some* difference in the ecological quality between developed lands and protected areas. So all the counties examined in the study succeed in protecting higher quality lands than they developed, to some extent. No county overlooks green space quality enough to have a negative difference – which would mean developed lands were of higher quality than protected lands. The smallest difference is 3, for Adams County, Colorado, but the low value is in keeping with that of Arapahoe County. Both have significant agricultural land, which is highly managed and less variable in quality than natural land.

Second, the extent of high quality natural area in a county – particularly forestland – impacts overall ecological value, which inflates differences between protected and developed lands. Two counties that performed better than expected are Marion County, Florida and Boulder County, Colorado. While Marion (L) was the lowest performing county in Florida, it was generally successful at retaining high quality lands. And while most high and moderate level counties performed similarly, the developed/preserved land difference for Boulder (H) is double that of the moderate-level green infrastructure planning county in Colorado, Arapahoe. The most likely explanation is that the two have very large forested areas. Marion County has Ocala National Forest, the second largest national forest in the country, and the western half of Boulder County is mountainous and heavily forested with large portions owned by the federal government and by the county itself. Large hubs of forest have significant core area and are highly supportive of biodiversity, particularly when they are not fragmented by other types of development, which is true of forests in Boulder and Marion. Furthermore, protected areas within the large forested hubs – mostly state of federal government lands – are high quality and raise the mean ecological quality of protected lands in each of the counties, beyond what would be expected for the county otherwise.

Connectivity

Patch metrics for the nine counties indicate a relationship between the level of green infrastructure planning a county employs and the county's success in retaining or improving connections between green spaces. Results also confirm the importance of large hubs and a critical mass of green space in anchoring a green infrastructure network.

There are two ways for a county to impact green infrastructure connectivity over time: 1) retain existing connections between green spaces, either through preserving them or guiding development to other areas, and 2) add additional connections through planting or restoring areas where connections have been degraded. The former – the 'an ounce of prevention is worth a pound of cure' strategy – is simpler, and the strategy most commonly adopted by counties interested in such connections. However, the second can happened naturally in areas where land is cleared for development, but grows in over subsequent decades to near-forest levels of vegetation.

For forested land connections, the only two counties that deviate from the H/M/L ordering are Alachua County (M), and Marion County (L), Florida (Table 7-3). The explanation again is Ocala National Forest. The Forest covers the eastern half of Marion and is one large contiguous hub. That portion of Marion is perfectly connected. Since metrics are area-weighted, Ocala National Forest provides Marion County enough base connectivity that significant fragmentation in the western half of the county – which has less forest to begin with – has less impact than it does in Alachua. The Cross-Florida Greenway also bisects Marion, providing additional connectivity. Alachua County had less fragmenting development than Marion, but with far less state and federal green space experienced more overall loss of connectivity. The result shows the importance of preserving large hubs of green space. The areas serve as anchors for a green infrastructure network, boosting overall connectivity.

Table 7-3. Interpretation of change in landscape metrics for forested lands and grasslands in nine counties in Colorado, Florida, and Maryland. White = Minimal Change; Darker Colors = Greater Change. For full results see previous tables. For full results, see Chapters 3-6.

	Colorado			**Florida**			**Maryland**		
Metrics	**H**	**M**	**L**	**H**	**M**	**L**	**H**	**M**	**L**
Patch Length (GYRATE_AM)									
Patch Shape Complexity (SHAPE_AM)									
Distance to Like Patch (ENN_AM)									
Index of Patch Size and Distance (PROX_AM)									

Connectivity is highly important for forested lands. In forested areas, large interconnected green spaces support species movement, overall environmental quality, and ability to provide ecosystem services. Direct adjacency is not important for agricultural lands, but a critical mass is. Agricultural areas must have enough large farms to support an agricultural economy with farm support industries. In agricultural areas, connectivity means clustering. For agricultural lands, two counties in a different state deviate from the H/M/L ordering. Adams County (L), Colorado outperformed Arapahoe County (M), Colorado in retaining the size and proximity of farmlands over time (Table 7-4). While the result is difficult to explain with precision, one reason could be the difference in agricultural economies. Both have significant agricultural land, but Adams County has superior soils, some of the best in Colorado. Farm revenues for Adams County in 2007 were $153 million, but only $29 million in Arapahoe (United States Department of Agriculture 2009). Farms in Adams are also larger, with an average of 784 acres, compared to 489 in Arapahoe (ibid). The large farms bolstered patch size and length metrics, while the high quality and value of farms likely encouraged landowners and the county to retain agricultural land in key districts. In addition, Arapahoe and Adams received the same score for Principle 1 ("Create linkages and foster connectivity"), despite Arapahoe's overall higher Framework score. The result suggests that, absent differences in connectivity planning, the quality and economic importance of a resource impacts connectivity outcomes.

Table 7-4. Interpretation of change in landscape metrics for agricultural lands in nine counties in Colorado, Florida, and Maryland. White = Minimal Change, Darker Colors = Greater Change. For full results, see Chapters 3-6.

	Colorado			Florida			Maryland		
Metrics	H	M	L	H	M	L	H	M	L
Patch Length (GYRATE_AM)									
Patch Shape Complexity (SHAPE_AM)									
Distance to Like Patch (ENN_AM)									
Index of Patch Size and Distance (PROX_AM)									

WHAT CONTRIBUTES TO THE POSITIVE RELATIONSHIP?

The relationship between level of green infrastructure planning and green space outcomes in the nine case study counties is strong enough to reject the null hypothesis and support the alternative hypothesis that counties that employ many green infrastructure policies and strategies are more effective at retaining green space quantity, quality, and connectivity over time than those that use fewer. But it is also important to understand which policies, strategies, and other factors may have made the difference.

The completed Green Infrastructure Planning Evaluation Framework identifies the types of policies and programs that have an impact. Framework results by state show which of the seven green infrastructure planning principles exhibit the greatest variation in score between high-level and low-level green infrastructure planning counties. For example, in Table 7-5a, the first principle is 'Create linkages and foster connectivity. The difference between the score for Leon County (14) and the score for Marion County (3) is 11, one of the greatest. A large score difference suggests that the principle is one of high variation and likely to make a difference in green infrastructure planning outcomes.

Table 7-5a. Maximum difference between Framework scores by principle for Florida Counties. Differences greater than 6 are shaded.

Green Infrastructure Principle	FLORIDA: Framework Score (Out of 20)			Max. Score Difference
	Leon (H)	Alachua (M)	Marion (L)	
Create linkages and foster connectivity	14	8	3	**11**
Value areas of ecological quality and local importance	11	12	7	4
Support a variety of landscapes and ecosystem services	14	10	6	**8**
Restore and mitigate damage to green infrastructure	11	10	4	**7**
Manage green infrastructure to support ecosystem services	14	14	9	5
Enact land use planning strategies to protect and retain all scales of GI	13	12	6	**7**
Protect and support GI through a collaborative and cooperative process	12	12	8	4

Table 7-5b. Maximum difference between Framework scores by principle for Maryland Counties. Differences greater than 6 are highlighted.

Green Infrastructure Principle	MARYLAND: Framework Score (Out of 20)			Max. Score Difference
	Baltimore (H)	Anne Arundel (M)	Charles (L)	
Create linkages and foster connectivity	13	14	7	**7**
Value areas of ecological quality and local importance	15	11	10	5
Support a variety of landscapes and ecosystem services	10	7	5	5
Restore and mitigate damage to green infrastructure	7	6	5	2
Manage green infrastructure to support ecosystem services	12	8	9	3
Enact land use planning strategies to protect and retain all scales of GI	15	13	5	**10**
Protect and support GI through a collaborative and cooperative process	15	12	10	5

Table 7-5c. Maximum difference between Framework scores by principle for Colorado Counties. Differences greater than 6 are highlighted.

Green Infrastructure Principle	COLORADO: Framework Score (Out of 20)			Max. Score Difference
	Boulder (H)	Arapahoe (M)	Adams (L)	
Create linkages and foster connectivity	7	6	6	1
Value areas of ecological quality and local importance	12	11	12	1
Support a variety of landscapes and ecosystem services	15	9	9	6
Restore and mitigate damage to green infrastructure	7	5	4	3
Manage green infrastructure to support ecosystem services	12	9	8	4
Enact land use planning strategies to protect and retain all scales of GI	18	14	9	**9**
Protect and support GI through a collaborative and cooperative process	16	12	9	**7**

In Framework results for Colorado, Florida, and Maryland, differences range from 1 to 11, with a natural break (low frequency point) in the middle, at 6. Principles with a maximum score difference greater than 6 in more than 1 state are most likely to influence the differences in green infrastructure planning outcomes. Two principles fit this criterion: '6: Enact land use planning strategies to protect and retain all scales of green infrastructure,' and '1: Create linkages and foster connectivity.'

Based upon score variation and overall outcomes, these are the two facets of green infrastructure planning that have the greatest potential impact on outcomes: land use planning for green space - mostly growth management strategies - and connectivity planning. They corroborate the findings from the three state analyses, which identified growth management, land preservation program activity and strength, and the extent of green infrastructure network planning and protection as critical areas.

Connectivity Policies and Strategies

The Framework includes 11 policies and strategies under the connectivity heading. Many are related to the general culture of green infrastructure planning and whether a given county plans green infrastructure using a network concept. The first, 'uses a network design/concept' exhibits the greatest variation among counties and could make the most difference. The network idea is fundamental to green infrastructure planning. Counties that do not use a network concept will have difficulty achieving positive connectivity outcomes. Yet, only 4 of 9 counties clearly use the strategy in their planning documents. The same is true of 'maps green infrastructure network components (conceptually or actually).' Most counties map some network components, say state and federal land, but overlook private green space, potential open space, or other types of green infrastructure. Only 3 out of 9 counties extensively map green infrastructure networks. Related, only three counties establish greenways or green corridors, which are a useful way to guide future land use decisions.

On the positive side, most counties do consider connectivity in the land preservation process, either through prioritizing lands in delineated target areas or parcels adjacent to existing preserved lands. Most counties also consider the connectivity between green spaces or open space dedications and adjacent lands in the development review process. Higher-level green infrastructure planning counties require open space dedications to be put under a conservation easement. The requirement has potential since permanently preserved, interconnected, local open spaces are a boon to urban and suburban green infrastructure networks.

Implications for County Green Infrastructure Planning
Nearly all counties in the study consider connectivity in prioritizing land for preservation and in delineating open space dedications in the subdivision or site planning process. Most planning documents mention fragmentation, at least in passing, and include a map with existing green infrastructure components such as parks and other protected areas. These strategies are the status quo of planning for connectivity in the nine study counties. But they are not network approaches. Each of the four strategies considers green space one parcel at a time rather than as a countywide system.

Policies and strategies with a landscape approach are characteristic of higher-level green infrastructure planning counties. The three high-level counties (and one moderate-level) use a network design or concept for their green space planning, and most go a step further to identify critical connections or gaps in protection of that network. Consequently, they outperform the remaining counties in retaining connections. Without a large-scale understanding of green infrastructure interconnections – protected or not – a county cannot adequately target protection to support connectivity. So counties seeking to protect connectivity over time should adopt a landscape-scale network approach to green space planning. But, while an open space or green infrastructure plan is one way to support such a system, plans are not always effective. In this study, two counties with green space plans rooted in rigorous analysis were outperformed by counties without them due to a lack of implementation of plan recommendations. If a county chooses a green infrastructure plan to support green space connections, it should include an action plan and supportive implementing policies. Otherwise, regulatory strategies may be more effective (e.g. Baltimore County, MD (H) and greenway protection).

Land Use Planning Policies and Strategies
The Framework includes 15 policies and strategies that indicate support for Principle 6: Enact land use planning strategies to protect and retain all scales of green infrastructure. The majority of policies and strategies under the principle relate to growth management. The three state analyses (Chapters 4-6) corroborate that growth management is an area of

variation across high-, moderate-, and low-level green infrastructure planning counties. As indicated in earlier sections of this chapter, there are several approaches to Principle 6 that are used widely in this nine-county sample (Shown in Table 7-1). Three relate to directing development to growth areas using infrastructure planning and agricultural zones and two to dedicated local funding. Eight counties have dedicated funding sources for parks and open space, mostly sales tax revenue. They are indicative of high levels of resident support for green space across the nine study counties.

Purchase of development rights programs and, more broadly, open space preservation programs are common among the counties. Counties with older land preservation programs (i.e. Boulder County, CO and Baltimore County, MD) have tens of thousands of acres of preserved land. For example, Baltimore County has nearly 50,000 protected acres and Boulder County has preserved close to 57,000 acres, by far the highest values of the nine counties. But preserved acres are not the only important aspect of green infrastructure planning; counties must have other supportive policies (Daniels and Lapping 2005). For example, Anne Arundel County slightly outperforms Baltimore County in acres of land developed per capita, despite having preserved far fewer acres (Table 7-6). But an active land preservation program *is* an indicator of broader dedication to open space. With one exception, the acreage of land preserved through PDR or open space programs between 2000 and 2010 relates strongly to a county's overall level of green infrastructure planning. If you include Colorado's county sales tax-funded preservation programs, the only two counties without local purchase of development rights programs are Marion County, FL and Charles County, MD, both low-level counties.

Table 7-6. Acres of land preserved between 2000 and 2010.

	High	**Moderate**	**Low**
Colorado	34,276	16,825	6,756
Florida	3,600	13,400	3,200
Maryland	22,300	7,307	13,599

Marion and Charles Counties do have modest transfer of development rights (TDR) programs, as does the other low-level green infrastructure planning county, Adams. For the nine study counties there is a higher incidence of TDR programs among low-level counties than high-level counties and no moderate-level counties use TDR. The result could be due to strong developer interests or development pressure in low-level counties that make PDR, down-zoning, or other protective strategies less feasible than the incentive-based TDR.

Two other strategies are more common among high-level green infrastructure planning counties and could make a difference in green infrastructure quantity outcomes: urban growth boundaries and strong open space or rural zoning. All three high-level green infrastructure planning counties have urban growth boundaries or urban service areas, as do two-moderate level counties. No low-level green infrastructure planning counties have functional growth boundaries. The same is true of open space or natural resource zoning.

All three high-level green infrastructure planning counties have restrictive rural zoning, most moderate-level counties have somewhat restrictive zoning, and most low-level counties have relatively permissive zoning in rural areas. Cluster development and conservation subdivisions are also more common among high-level green infrastructure planning counties than low-level counties, but the counties studied here rarely *use* the regulations, so they did not impact green infrastructure outcomes.

Implications for County Green Infrastructure Planning

The majority of case study counties use growth management strategies to minimize the spread of development into rural resource areas. They define and map growth areas and support them with grey infrastructure planning. Most also use some county appropriations, fund open space acquisition from a dedicated source such as sales tax revenue, and have some type of land preservation program, either PDR or TDR. These activities comprise the baseline of green infrastructure planning through conventional land use strategies. The *more* successful counties also use urban growth boundaries and restrictive rural zoning to limit the spread of development. Counties interested in supporting green infrastructure through planning strategies should consider strengthening rural zoning and enacting or shoring up urban growth boundaries.

In addition, results show that land preservation is associated with positive green infrastructure outcomes, but is not the only factor in green space success. Most critically, land preservation is less effective when unsupported by other programs. Counties in which land preservation is complemented by urban growth boundaries and restrictive rural zoning are more successful in retaining and connecting green space over time than counties that use land preservation alone, even if the program is prolific (e.g. Charles County). Counties with land preservation programs should be aware that green infrastructure outcomes are greater when the program is used synergistically and consider adopting a supportive growth boundary or strengthening rural and natural resource zoning. These supportive programs are one of the defining features of high-level green infrastructure planning counties. No low-level counties in this study used them.

Culture of Green Infrastructure Planning

The overall objective of green infrastructure planning is to support green spaces that provide important ecosystem services. Some of the principles important in achieving this goal are related to easily measured greenspace outcomes (i.e. quantity, quality, connectivity) and others are not. The three green infrastructure planning principles clearly related to on-the-ground county greenspace outcomes have already been discussed, but other principles are also important in supporting ecosystem services. The four remaining principles relate more broadly to relationships, systems, diversity, and restoration and management of existing green space. They are:

3) Support a variety of landscapes and ecosystem services
4) Restore and mitigate damage to green infrastructure
5) Manage green infrastructure to support ecosystem services

7) Protect and support green infrastructure through a collaborative and cooperative process

Normalized scores for the four convey a county's overall green infrastructure culture; the county's dedication to a healthy resilient natural environment that provides ecosystem services. In addition, a county's culture score provides an indication of a county's environmental ethic, that is its dedication to small-scale and/or low key activities that are collectively important in supporting high quality, productive, green space. In all nine cases, a county's green infrastructure planning culture score matches its level of overall green infrastructure planning (Table 7-7).

Table 7.7. 'Green infrastructure planning culture' scores (out of 80) for nine counties in Colorado, Florida, and Maryland. Derived from the sum of the normalized Framework scores for the four principles indicative of green infrastructure planning culture (Principles 3,4,5,7).

Colorado			**Florida**			**Maryland**		
H	**M**	**L**	**H**	**M**	**L**	**H**	**M**	**L**
50	36	30	50	46	25	45	34	30

All high-level counties and low-level counties fall into the same culture score range, 45 to 50, and 25 to 30, respectively. Two moderate-level counties also have a similar culture score (mid-30s), but Alachua County, Florida (M) has a higher score, in the range of the high-level counties, at 46. The most likely explanation for the result is that Alachua County is more environmentally or ecologically progressive than the other moderate-level green infrastructure planning counties. Alachua County's high level of green infrastructure planning culture is corroborated by the county's land preservation and green space quality successes, which rival that of Leon County (H).

Non-Framework Factors

Several factors not included in the Framework could also help explain green space outcomes, most prominently background environmental quality and funding for green infrastructure. Since not all land is the same, one possible explanation for green infrastructure outcomes is that counties with important, high quality environmental features perform better than those with fewer or degraded features. The prevalence of sensitive environmental features such as wetlands, streams, and core forest could motivate local governments to undertake policies and programs that are supportive of green infrastructure. But quality results do not support this explanation. The ecological value matrix for each county uses data on wetlands, streams, forests, road size and distance (interior), prime farmland, species distributions, and other important natural attributes to estimate the relative value of each 30 meter by 30 meter patch of land. However, in Maryland, Charles County (L) has a mean countywide ecological value of 55 while Anne Arundel (M) comes in at 29 and Baltimore County (H) at 30. Results for Florida are similar. Marion County (L) has a mean ecological value of 44, Leon County (H) is slightly lower at 43 and Alachua (M) is lowest at 34. In these states, a greater amount of high quality land remains in low-level green infrastructure planning counties because they tend to be less developed. Since less fragmented areas have more core area and support higher quality natural systems, the counties have a greater average ecological value. But the data also show that high-level green infrastructure planning counties tend to have slightly higher overall ecological values than moderate-level counties. In Colorado, Boulder (H) has a mean countywide ecological value of 55, higher than Arapahoe (M) with a value of 45. So the existence of ecological features such as wetlands and important species habitat in a county may slightly relate to the incentive to plan for ecosystem services, and to green space outcomes, but only in relatively developed counties that have already experienced significant loss of green infrastructure.

Another non-Framework factor that could impact green space outcomes is funding. In general, high-level green infrastructure planning counties do appropriate more funding for green space planning and management than lower level counties in the same state. They also tend to take on more projects and to allocate funds for restoration and management projects. In this way, county funding is related to green space outcomes. However, outside funding sources, state programs in particular, are less connected to green space results. During the study period, Alachua County (M) received the most state funding, with $30.5 million, while Leon County (H) received about half of that ($16 million) and Marion received none. In Maryland, Charles County (L) received an annual average of 88% of its green infrastructure funding from state programs. Baltimore County (H) received 84% and Anne Arundel (M) lagged behind with 60%.

RECOMMENDATIONS AND AREAS FOR FURTHER RESEARCH

This study shows that counties that incorporate many green infrastructure planning policies and strategies have better green space outcomes than those that use fewer. In taking a three-faceted approach to assessing green infrastructure planning (quality, quantity, and connectivity), this research corroborates that measures traditionally associated with conservation biology and landscape ecology have relevance for environmental planning. Literature clearly shows that the quality and connectivity of green space impacts its ability to support ecosystem services. But quality and connectivity cannot be measured using conventional quantity-oriented metrics such as preserved acres and acres developed per capita. This work suggests that patch metrics can help communities to track the size and proximity of green infrastructure. While the measures are not useful on an annual basis, tracked over five years or longer they can show the results of planning activities. Even counties without GIS capabilities can estimate the area-weighted average distance between patches of the same land cover over time and understand the overall connectivity of their landscape.

This study also examines the specific policies and strategies that impact green space quality, quantity, and connectivity over time. The actions with the greatest potential to support these characteristics are green infrastructure hub characteristics, connectivity/network planning, and growth management. Counties interested in supporting ecosystem services should focus efforts on these general areas. Quality and connectivity outcomes highlight the particular importance of retaining large hubs of green space over time. Results show that counties with weak green infrastructure planning programs were able to rival or outperform counties with stronger programs in quality and connectivity outcomes due to the size and quality of their forested green space hubs. More successful counties with large forested hubs also performed better than expected. This result suggests that counties with low levels of green infrastructure planning that seek to support long-term green space quality and connectivity should focus on maintaining at least one large block of contiguous green space to anchor their network. The hub will buffer green space quality and connectivity scores over time. The action could be a feasible way for counties that have lagged behind in green space planning to catch up, particularly rural and fringe area counties that have significant undeveloped forest or farmland and low to moderate development pressure.

Connectivity results also suggest that using a network concept in green infrastructure planning is associated with positive outcomes, but that landscape-scale green space plans may not be as important. Two counties without landscape-scale open space plans outperformed two with strong countywide green space plans, likely due to poor implementation of the plans. The counties without plans had prolific land preservation programs and used adjacency as one of many prioritization criteria, but did not focus on the connections between green spaces or how protected lands fit together. Yet, both were successful in maintaining the size and interconnectedness of their green space network. While using parcel-wise decision making to create a connected network is counterintuitive, individual evaluations are far simpler than those involving an entire county. Implementation mechanisms for landscape scale plans may be vague or nonexistent, but evaluating a single parcel for its conservation merits or regulated resources is a straightforward process and a routine task for planners and decision-makers. More research is needed to understand the implementation mechanisms necessary for green infrastructure plans to be supportive of long term green space outcomes and the potential for less comprehensive strategies (e.g. prioritized land preservation and regulatory protection) to support interconnected green space. Further research is also needed on other connectivity strategies such as identifying gaps in the green infrastructure network. When network gaps are prioritized in land preservation, the action has great potential for supporting green space connections. Yet only one county uses the strategy.

Results also corroborate that urban growth boundaries, urban service areas, and restrictive rural zoning help communities to retain green infrastructure in rural areas. All three high-level counties used the strategies and had better outcomes than lower level counties, which did not. Results also support the relationship between land preservation and green space outcomes, to an extent. While land preservation is associated with positive green space outcomes, it is most successful when supported by other actions such as urban growth boundaries and protective zoning. Land preservation alone (e.g. not backed by other strategies) was less successful. So, growth management does support positive green infrastructure outcomes and counties seeking to support green space over time should consider strengthening their growth management and support land preservation programs with restrictive zoning and infrastructure planning.

The result that growth management impacts green infrastructure outcomes has particularly strong implications for Florida. In 2011, the state dramatically reduced the level of state oversight of local land use planning. The action means that many of the land use planning activities and emphases that were required during the study period are likely to be discontinued and the overall level of green infrastructure planning will decline. This research suggests that a reduced level of growth management – and land use planning, more broadly – will lead to diminished green space outcomes over the following decade. The result is concerning for a state with a booming population, diverse and sensitive natural environment, and tourist industry that depends on environmental quality. In fact, green infrastructure will be increasingly important throughout the United States as climate uncertainty and population grow in tandem. Identifying and supporting the actions through which local governments can support green spaces and consequently ecosystem services is a key step in building and maintaining livable and resilient communities.

APPENDIX

3-A. Green Infrastructure Planning Evaluation Framework

Green Infrastructure Planning Principle	**County**		
1) Create linkages and foster connectivity (11)	**#1**	**#2**	**#3**
Uses a network design/concept			
Discusses fragmentation			
Explains the network concept and its components			
Maps network components (conceptually or actually)			
Identifies gaps (disconnections) in the green infrastructure network			
Establishes and delineates county greenbelts or greenways			
In preservation, prioritizes gaps between existing green infrastructure areas			
In preservation, prioritizes land adjacent to existing public parks, open spaces, or preserved areas			
In preservation, prioritizes land in designated areas (e.g. Rural Legacy Areas, agricultural zones)			
In forest/resource protection regulations, emphasizes connectivity (e.g. between woodlands)			
In development review, includes connectivity of green space, parks, and/or open space dedications			
Raw Score			
Normalized Score (Max 20)			

2) Value areas of ecological quality and local importance (17)	**#1**	**#2**	**#3**
Identifies ecologically valuable features			
Identifies culturally or historically important features			
Maps ecological assets (i.e. wetlands, woodlands, farmland, rare plant and animal species)			
Identifies major anchors of the green infrastructure network			
Identifies and ranks potential conservation areas in the county			
In preservation, prioritizes large - economically and ecologically viable - tracts of land			
In preservation, prioritizes rare or important environmental resources			
In preservation, prioritizes culturally or historically important areas			
In preservation, prioritizes land in designated areas (e.g. Rural Legacy Areas, agricultural zones)			
In development review, requires natural resources assessment			
In development review, includes rare or important environmental resources			
Sets forest/native vegetation protection regulations and impact/offset policies			
Designates stream buffer widths and impact/offset policies			
Creates agriculture districts for highly productive areas			
Has right to farm laws for high value agricultural areas			
Markets green infrastructure products and services			
Uses overlay/agricultural zones for prime soil or resource areas			
Raw Score			
Normalized Score (Max 20)			

3) Support a variety of landscapes and ecosystem services (11)	**#1**	**#2**	**#3**
Identifies cultural, working, recreational, and natural landscapes			

	#1	#2	#3
Identifies a variety of ecosystem services/benefits			
Identifies landscapes or ecosystems that are underrepresented green infrastructure network coverage (e.g. through gap analysis)			
In preservation, prioritizes underrepresented landscapes and ecosystems			
In preservation, considers historic and cultural resources			
In preservation, prioritizes lands that provide multiple benefits			
In preservation, considers viewsheds			
Views parks and trails and centers for community			
Protects historic resources in parks and open space			
Designates a system of scenic roads and/or views			
Capital improvements program balances funds for recreation and preservation			
Raw Score			
Normalized Score (Max 20)			

4) Restore and mitigate damage to green infrastructure (11)	**#1**	**#2**	**#3**
Requires mitigation of impacts on lands within a designated green infrastructure/greenway network			
Requires mitigation of impacts on wetlands			
Requires mitigation of impacts on other natural resources (e.g forests, habitat)			
Requires that loss of land in the green infrastructure network be offset with preservation within the network			
Identifies best sites for off-site mitigation			
Identifies areas in the green infrastructure/greenway network in need of restoration			
In development review, requires restoration where appropriate			
Requires use of local/native vegetation in mitigation and restoration efforts			
Involves public in restoration and reforestation programs			
Restores vacant, tax foreclosed, distressed, and surplus lands to bring them into the green infrastructure network			
Capital Improvement Program includes funds for restoration			
Raw Score			
Normalized Score (Max 20)			

5) Manage green infrastructure to support ecosystem services (14)	**#1**	**#2**	**#3**
Identifies environmentally sensitive areas (e.g. steep slopes, floodplains, wetlands, coastal areas)			
Maps environmentally sensitive areas			
Uses overlay zones to restrict development of environmentally sensitive areas			
In development review, requires special treatment of environmentally sensitive areas			
In development review, requires removal of invasive species			
In development review, requires a forest/resource management plan			
Requires use of local/native vegetation in landscaping and maintenance of public open space			
Develops resource management plans for county green infrastructure network anchors (i.e. major parks and preserved areas)			
Creates management strategies for county woodlands or other resource lands			
Ensures physical and/or visual access to preserved areas, where appropriate			
Provides landowners incentives to allow public access (e.g. insurance coverage, tax incentives)			
Creates an incentive program to reward individuals and organizations for sound management of green infrastructure			

	#1	#2	#3
Conducts environmental education programs to encourage sound stewardship of green infrastructure			
Uses 'backyard conservation' and natural landscaping programs to connect residential areas to natural resources			
Raw Score			
Normalized Score (Max 20)			

6) Enact land use planning strategies to protect and retain all scales of green infrastructure (15)

	#1	**#2**	**#3**
Defines and maps growth areas			
Allows for development flexibility in growth areas			
Uses resource conservation or open space zones to limit development outside of growth areas.			
Uses agriculture protection zones to limit development outside of growth areas			
In preservation, targets properties that help bound and separate communities			
Plans grey infrastructure servicing to reinforce growth and conservation areas			
Supports conservation design/cluster development			
Provides density bonuses for properties that maximize preservation of environmental areas			
Requires that development projects leave a portion of buildable area as park/open space			
Requires permanent preservation of dedicated park/open space			
Has an active transfer of development rights program			
Has a county purchase of development rights program			
Funds green infrastructure protection from continuous, dedicated sources (e.g. taxes, fees)			
Strength of urban growth boundary (none, changeable, strict)			
Invests significant county funds in green infrastructure (not just leveraging of state/federal funds)			
Raw Score			
Normalized Score (Max 20)			

7) Protect and support green infrastructure through a collaborative and cooperative process (9)

	#1	**#2**	**#3**
Outlines how the public is involved in the green infrastructure planning process			
Helps landowners to develop and implement resource stewardship plans			
Works with landowners of high quality lands to manage or restore habitat and other resources			
Coordinates conservation efforts with other local jurisdictions			
Works with local land trusts and other NGOs			
Participates in optional state and federal programs			
Leverages state and federal funds for green infrastructure			
Shares list/map of priority conservation areas with nonprofit organizations and other governments			
Shares green infrastructure and local ecological information with other organizations			
Raw Score			
Normalized Score (Max 20)			

TOTAL (Max 140)			
PERCENT			

4-A. Green Infrastructure Planning Framework for Maryland

Green Infrastructure Planning Principle	County		
1) Create linkages and foster connectivity (11)	**BC**	**AA**	**CC**
Uses a network design/concept	1	2	0
Discusses fragmentation	1	2	1
Explains the network concept and its components	1	2	1
Maps network components (conceptually or actually)	2	2	1
Identifies gaps (disconnections) in the green infrastructure network	1	2	0
Establishes and delineates county greenbelts or greenways	1	2	0
In preservation, prioritizes gaps between existing green infrastructure areas	0	0	0
In preservation, prioritizes land adjacent to existing public parks, open spaces, or preserved areas	2	1	1
In preservation, prioritizes land in designated areas (e.g. Rural Legacy Areas, agricultural zones)	2	1	1
In forest/resource protection regulations, emphasizes connectivity (e.g. between woodlands)	2	1	2
In development review, includes connectivity of green space, parks, and/or open space dedications	1	1	1
Raw Score	14	16	8
Normalized Score (Max 20)	**12.7**	**14.5**	**7.3**

2) Value areas of ecological quality and local importance (17)	**BC**	**AA**	**CC**
Identifies ecologically valuable features	2	2	2
Identifies culturally or historically important features	1	1	1
Maps ecological assets (i.e. wetlands, woodlands, farmland, rare plant and animal species)	1	1	2
Identifies major anchors of the green infrastructure network	2	2	1
Identifies and ranks potential conservation areas in the county	0	0	0
In preservation, prioritizes large - economically and ecologically viable - tracts of land	2	0	1
In preservation, prioritizes rare or important environmental resources	0	1	0
In preservation, prioritizes culturally or historically important areas	1	0	0
In preservation, prioritizes land in designated areas (e.g. Rural Legacy Areas, agricultural zones)	1	0	0
In development review, requires natural resources assessment	1	1	1
In development review, includes rare or important environmental resources	2	1	1
Sets forest/native vegetation protection regulations and impact/offset policies	2	2	2
Designates stream buffer widths and impact/offset policies	2	2	1
Creates agriculture districts for highly productive areas	2	2	2
Has right to farm laws for high value agricultural areas	2	2	2
Markets green infrastructure products and services	2	0	0
Uses overlay/agricultural zones for prime soil or resource areas	2	1	1
Raw Score	25	18	17
Normalized Score (Max 20)	**14.7**	**10.6**	**10.0**

3) Support a variety of landscapes and ecosystem services (11)	**BC**	**AA**	**CC**
Identifies cultural, working, recreational, and natural landscapes	1	2	1
Identifies a variety of ecosystem services/benefits	1	2	2
Identifies landscapes or ecosystems that are underrepresented green infrastructure network coverage (e.g. through gap analysis)	0	1	0

In preservation, prioritizes underrepresented landscapes and ecosystems	0	0	0
In preservation, considers historic and cultural resources	1	1	0
In preservation, prioritizes lands that provide multiple benefits	0	0	0
In preservation, considers viewsheds	2	0	0
Views parks and trails and centers for community	1	0	1
Protects historic resources in parks and open space	1	1	1
Designates a system of scenic roads and/or views	2	0	0
Capital improvements program balances funds for recreation and preservation	2	1	1
Raw Score	11	8	6
Normalized Score (Max 20)	**10.0**	**7.3**	**5.5**

4) Restore and mitigate damage to green infrastructure (11)	**BC**	**AA**	**CC**
Requires mitigation of impacts on lands within a designated green infrastructure/greenway network	0	0	0
Requires mitigation of impacts on wetlands	2	2	2
Requires mitigation of impacts on other natural resources (e.g forests, habitat)	2	2	2
Requires that loss of land in the green infrastructure network be offset with preservation within the network	0	0	0
Identifies best sites for off-site mitigation	0	0	0
Identifies areas in the green infrastructure/greenway network in need of restoration	0	0	1
In development review, requires restoration where appropriate	0	0	0
Requires use of local/native vegetation in mitigation and restoration efforts	1	0	1
Involves public in restoration and reforestation programs	2	1	0
Restores vacant, tax foreclosed, distressed, and surplus lands to bring them into the green infrastructure network	0	0	0
Capital Improvement Program includes funds for restoration	2	2	0
Raw Score	9	7	6
Normalized Score (Max 20)	**8.2**	**6.4**	**5.5**

5) Manage green infrastructure to support ecosystem services (14)	**BC**	**AA**	**CC**
Identifies environmentally sensitive areas (e.g. steep slopes, floodplains, wetlands, coastal areas)	2	1	2
Maps environmentally sensitive areas	0	1	2
Uses overlay zones to restrict development of environmentally sensitive areas	2	2	1
In development review, requires special treatment of environmentally sensitive areas	2	1	2
In development review, requires removal of invasive species	0	0	0
In development review, requires a forest/resource management plan	2	2	2
Requires use of local/native vegetation in landscaping and maintenance of public open space	0	0	0
Develops resource management plans for county green infrastructure network anchors (i.e. major parks and preserved areas)	1	1	1
Creates management strategies for county woodlands or other resource lands	2	0	0
Ensures physical and/or visual access to preserved areas, where appropriate	1	1	0
Provides landowners incentives to allow public access (e.g. insurance coverage, tax incentives)	0	0	0
Creates an incentive program to reward individuals and organizations for sound management of green infrastructure	1	1	0
Conducts environmental education programs to encourage sound stewardship of green infrastructure	2	1	1

Uses 'backyard conservation' and natural landscaping programs to connect residential areas to natural resources	2	0	1
Raw Score	17	11	12
Normalized Score (Max 20)	**12.1**	**7.9**	**8.6**

6) Enact land use planning strategies to protect and retain all scales of green infrastructure (15)	**BC**	**AA**	**CC**
Defines and maps growth areas	2	2	1
Allows for development flexibility in growth areas	2	1	0
Uses resource conservation or open space zones to limit development outside of growth areas.	2	1	0
Uses agriculture protection zones to limit development outside of growth areas	2	1	1
In preservation, targets properties that help bound and separate communities	0	0	0
Plans grey infrastructure servicing to reinforce growth and conservation areas	2	2	1
Supports conservation design/cluster development	1	2	0
Provides density bonuses for properties that maximize preservation of environmental areas	0	0	0
Requires that development projects leave a portion of buildable area as park/open space	2	2	2
Requires permanent preservation of dedicated park/open space	2	2	1
Has an active transfer of development rights program	1	0	1
Has a county purchase of development rights program	2	2	0
Funds green infrastructure protection from continuous, dedicated sources (e.g. taxes, fees)	1	2	1
Strength of urban growth boundary (none, changeable, strict)	2	0	0
Invests significant county funds in green infrastructure (not just leveraging of state/federal funds)	2	2	0
Raw Score	23	19	8
Normalized Score (Max 20)	**15.3**	**12.7**	**5.3**

7) Protect and support green infrastructure through a collaborative and cooperative process (9)	**BC**	**AA**	**CC**
Outlines how the public is involved in the green infrastructure planning process	1	1	0
Helps landowners to develop and implement resource stewardship plans	1	1	1
Works with landowners of high quality lands to manage or restore habitat and other resources	2	2	1
Coordinates conservation efforts with other local jurisdictions	1	1	1
Works with local land trusts and other NGOs	2	2	1
Participates in optional state and federal programs	2	1	2
Leverages state and federal funds for green infrastructure	2	1	2
Shares list/map of priority conservation areas with nonprofit organizations and other governments	1	1	0
Shares green infrastructure and local ecological information with other organizations	1	1	1
Raw Score	13	11	9
Normalized Score (Max 20)	**14.4**	**12.2**	**10.0**

TOTAL (Max 140)	**88**	**72**	**52**
PERCENT	**63**	**51**	**37**

BC: Baltimore County
AA: Anne Arundel County
CC: Charles County

5-A. Green Infrastructure Planning Framework for Florida

Green Infrastructure Planning Principle	County		
	LC	AC	MC
1) Create linkages and foster connectivity (11)			
Uses a network design/concept	2	0	0
Discusses fragmentation	1	1	1
Explains the network concept and its components	2	0	0
Maps network components (conceptually or actually)	2	1	0
Identifies gaps (disconnections) in the green infrastructure network	1	0	0
Establishes and delineates county greenbelts or greenways	2	0	0
In preservation, prioritizes gaps between existing green infrastructure areas	1	0	0
In preservation, prioritizes land adjacent to existing public parks, open spaces, or preserved areas	1	2	1
In preservation, prioritizes land in designated areas (e.g. Rural Legacy Areas, agricultural zones)	0	1	1
In forest/resource protection regulations, emphasizes connectivity (e.g. between woodlands)	1	2	0
In development review, includes connectivity of green space, parks, and/or open space dedications	2	2	0
Raw Score	15	9	3
Normalized Score	**13.6**	**8.2**	**2.7**

2) Value areas of ecological quality and local importance (17)	**LC**	**AC**	**MC**
Identifies ecologically valuable features	2	2	2
Identifies culturally or historically important features	1	1	1
Maps ecological assets (i.e. wetlands, woodlands, farmland, rare plant and animal species)	1	2	0
Identifies major anchors of the green infrastructure network	2	1	1
Identifies and ranks potential conservation areas in the county	2	1	0
In preservation, prioritizes large - economically and ecologically viable - tracts of land	1	2	1
In preservation, prioritizes rare or important environmental resources	1	2	0
In preservation, prioritizes culturally or historically important areas	1	0	0
In preservation, prioritizes land in designated areas (e.g. Rural Legacy Areas, ag zones)	0	0	1
In development review, requires natural resources assessment	2	2	1
In development review, includes rare or important environmental resources	2	2	0
Sets forest/native vegetation protection regulations and impact/offset policies	2	2	1
Designates stream buffer widths and impact/offset policies	1	2	1
Creates agriculture districts for highly productive areas	0	0	1
Has right to farm laws for high value agricultural areas	0	0	0
Markets green infrastructure products and services	0	1	1
Uses overlay/ag zones for prime soil or resource areas	1	0	1
Raw Score	19	20	12
Normalized Score	**11.2**	**11.8**	**7.1**

3) Support a variety of landscapes and ecosystem services (11)	**LC**	**AC**	**MC**
Identifies cultural, working, recreational, and natural landscapes	2	1	1
Identifies a variety of ecosystem services/benefits	2	2	1
Identifies landscapes or ecosystems that are underrepresented green infrastructure network coverage (e.g. through gap analysis)	0	0	0

In preservation, prioritizes underrepresented landscapes and ecosystems	1	1	0
In preservation, considers historic and cultural resources	2	1	0
In preservation, prioritizes lands that provide multiple benefits	2	2	1
In preservation, considers viewsheds	1	0	0
Views parks and trails and centers for community	1	1	0
Protects historic resources in parks and open space	1	0	0
Designates a system of scenic roads and/or views	2	2	2
Capital improvements program balances funds for recreation and preservation	1	1	1
Raw Score	15	11	6
Normalized Score	**13.6**	**10.0**	**5.5**

4) Restore and mitigate damage to green infrastructure (11)	**LC**	**AC**	**MC**
Requires mitigation of impacts on lands within a designated green infrastructure/greenway network	0	0	0
Requires mitigation of impacts on wetlands	2	2	
Requires mitigation of impacts on other natural resources (e.g forests, habitat)	2	2	1
Requires that loss of land in the green infrastructure network be offset with preservation within the network	0	1	0
Identifies best sites for off-site mitigation	2	0	0
Identifies areas in the green infrastructure/greenway network in need of restoration	0	0	0
In development review, requires restoration where appropriate	2	2	1
Requires use of local/native vegetation in mitigation and restoration efforts	1	2	1
Involves public in restoration and reforestation programs	1	1	0
Restores vacant, tax foreclosed, distressed, and surplus lands to bring them into the green infrastructure network (N/A?)	1	0	0
Capital Improvement Program includes funds for restoration	1	1	1
Raw Score	12	11	4
Normalized Score	**10.9**	**10.0**	**3.6**

5) Manage green infrastructure to support ecosystem services (14)	**LC**	**AC**	**MC**
Identifies environmentally sensitive areas (e.g. steep slopes, floodplains, wetlands, coastal areas)	2	2	2
Maps environmentally sensitive areas	1	1	1
Uses overlay zones to restrict development of environmentally sensitive areas	2	2	1
In development review, requires special treatment of environmentally sensitive areas	2	2	2
In development review, requires removal of invasive species	1	1	0
In development review, requires a forest/resource management plan	2	2	1
Requires use of local/native vegetation in landscaping and maintenance of public open space	2	2	1
Develops resource management plans for county green infrastructure network anchors (i.e. major parks and preserved areas)	2	2	1
Creates management strategies for county woodlands or other resource lands	1	1	0
Ensures physical and/or visual access to preserved areas, where appropriate	2	2	1
Provides landowners incentives to allow public access (e.g. insurance coverage, tax incentives)	0	0	0
Creates an incentive program to reward individuals and organizations for sound management of green infrastructure	1	1	1
Conducts environmental education programs to encourage sound stewardship of green infrastructure	1	1	1

Uses 'backyard conservation' and natural landscaping programs to connect residential areas to natural resources	0	0	0
Raw Score	19	19	12
Normalized Score	**13.6**	**13.6**	**8.6**

6) Enact land use planning strategies to protect and retain all scales of green infrastructure (15)	**LC**	**AC**	**MC**
Defines and maps growth areas	2	1	1
Allows for development flexibility in growth areas	2	2	1
Uses resource conservation or open space zones to limit development outside of growth areas.	2	1	0
Uses agriculture protection zones to limit development outside of growth areas	0	1	1
In preservation, targets properties that help bound and separate communities	0	0	0
Plans grey infrastructure servicing to reinforce growth and conservation areas	2	2	0
Supports conservation design/cluster development	2	1	1
Provides density bonuses for properties that maximize preservation of environmental areas	0	1	1
Requires that development projects leave a portion of buildable area as park/open space	1	2	1
Requires permanent preservation of dedicated park/open space	2	1	0
Has an active transfer of development rights program	0	0	1
Has a county purchase of development rights program	1	1	1
Funds green infrastructure protection from continuous, dedicated sources (e.g. taxes, fees)	2	2	0
Strength of urban growth boundary (none, changeable, strict)	1	1	0
Invests significant county funds in green infrastructure (not just leveraging of state/federal funds)	2	2	1
Raw Score	19	18	9
Normalized Score	**12.7**	**12.0**	**6.0**

7) Protect and support green infrastructure through a collaborative and cooperative process (9)	**LC**	**AC**	**MC**
Outlines how the public is involved in the green infrastructure planning process	2	2	2
Helps landowners to develop and implement resource stewardship plans	1	1	1
Works with landowners of high quality lands to manage or restore habitat and other resources	0	0	0
Coordinates conservation efforts with other local jurisdictions	2	2	1
Works with local land trusts and other NGOs	1	1	1
Participates in optional state and federal programs	1	1	1
Leverages state and federal funds for green infrastructure	2	2	1
Shares list/map of priority conservation areas with nonprofit organizations and other governments	1	1	0
Shares green infrastructure and local ecological information with other organizations	1	1	0
Raw Score	11	11	7
Normalized Score	**12.2**	**12.2**	**7.8**

TOTAL	88	78	41
PERCENT	**63**	**56**	**29**

LC: Leon County
AC: Alachua County
MC: Marion County

6-A. Green Infrastructure Planning Framework for Colorado

Green Infrastructure Planning Principle	County		
	BO	AR	AD
1) Create linkages and foster connectivity (11)			
Uses a network design/concept	1	0	0
Discusses fragmentation	1	1	0
Explains the network concept and its components	0	0	0
Maps network components (conceptually or actually)	1	1	1
Identifies gaps (disconnections) in the green infrastructure network	0	0	0
Establishes and delineates county greenbelts or greenways	0	0	0
In preservation, prioritizes gaps between existing green infrastructure areas	0	0	0
In preservation, prioritizes land adjacent to existing public parks, open spaces, or preserved areas	2	2	2
In preservation, prioritizes land in designated areas (e.g. Rural Legacy Areas, agricultural zones)	2	0	2
In forest/resource protection regulations, emphasizes connectivity (e.g. between woodlands)	0	0	0
In development review, includes connectivity of green space, parks, and/or open space dedications	1	2	1
Raw Score	8	6	6
Normalized Score	**7.3**	**5.5**	**5.5**

2) Value areas of ecological quality and local importance (17)	**BO**	**AR**	**AD**
Identifies ecologically valuable features	2	2	2
Identifies culturally or historically important features	2	1	0
Maps ecological assets (i.e. wetlands, woodlands, farmland, rare plant and animal species)	2	1	1
Identifies major anchors of the green infrastructure network	1	1	2
Identifies and ranks potential conservation areas in the county	0	0	1
In preservation, prioritizes large - economically and ecologically viable - tracts of land	2	2	2
In preservation, prioritizes rare or important environmental resources	2	2	2
In preservation, prioritizes culturally or historically important areas	2	1	1
In preservation, prioritizes land in designated areas (e.g. Rural Legacy Areas, ag zones)	2	0	2
In development review, requires natural resources assessment	1	2	2
In development review, includes rare or important environmental resources	2	2	1
Sets forest/native vegetation protection regulations and impact/offset policies	0	1	0
Designates stream buffer widths and impact/offset policies	0	0	1
Creates agriculture districts for highly productive areas	0	0	0
Has right to farm laws for high value agricultural areas	0	0	0
Markets green infrastructure products and services	1	1	1
Uses overlay/ag zones for prime soil or resource areas	2	2	2
Raw Score	21	18	20
Normalized Score	**12.4**	**10.6**	**11.8**

3) Support a variety of landscapes and ecosystem services (11)	**BO**	**AR**	**AD**
Identifies cultural, working, recreational, and natural landscapes	2	1	1
Identifies a variety of ecosystem services/benefits	1	1	1
Identifies landscapes or ecosystems that are underrepresented green infrastructure network coverage (e.g. through gap analysis)	0	0	0

In preservation, prioritizes underrepresented landscapes and ecosystems	1	0	0
In preservation, considers historic and cultural resources	2	1	1
In preservation, prioritizes lands that provide multiple benefits	2	1	2
In preservation, considers viewsheds	2	1	1
Views parks and trails and centers for community	1	1	1
Protects historic resources in parks and open space	1	2	1
Designates a system of scenic roads and/or views	2	0	0
Capital improvements program balances funds for recreation and preservation	2	2	2
Raw Score	16	10	10
Normalized Score	**14.5**	**9.1**	**9.1**

4) Restore and mitigate damage to green infrastructure (11)	**BO**	**AR**	**AD**
Requires mitigation of impacts on lands within a designated green infrastructure/greenway network	0	0	0
Requires mitigation of impacts on wetlands	1	2	2
Requires mitigation of impacts on other natural resources (e.g forests, habitat)	2	2	1
Requires that loss of land in the green infrastructure network be offset with preservation within the network	0	0	0
Identifies best sites for off-site mitigation	0	0	0
Identifies areas in the green infrastructure/greenway network in need of restoration	0	0	0
In development review, requires restoration where appropriate	1	1	1
Requires use of local/native vegetation in mitigation and restoration efforts	2	1	0
Involves public in restoration and reforestation programs	2	0	0
Restores vacant, tax foreclosed, distressed, and surplus lands to bring them into the green infrastructure network (N/A?)	0	0	0
Capital Improvement Program includes funds for restoration	0	0	0
Raw Score	8	6	4
Normalized Score	**7.3**	**5.5**	**3.6**

5) Manage green infrastructure to support ecosystem services (14)	**BO**	**AR**	**AD**
Identifies environmentally sensitive areas (e.g. steep slopes, floodplains, wetlands, coastal areas)	2	2	2
Maps environmentally sensitive areas	1	1	1
Uses overlay zones to restrict development of environmentally sensitive areas	2	1	2
In development review, requires special treatment of environmentally sensitive areas	2	2	2
In development review, requires removal of invasive species	0	0	0
In development review, requires a forest/resource management plan	1	1	1
Requires use of local/native vegetation in landscaping and maintenance of public open space	0	1	0
Develops resource management plans for county green infrastructure network anchors (i.e. major parks and preserved areas)	2	1	1
Creates management strategies for county woodlands or other resource lands	2	1	0
Ensures physical and/or visual access to preserved areas, where appropriate	2	2	1
Provides landowners incentives to allow public access (e.g. insurance coverage, tax incentives)	0	0	0
Creates an incentive program to reward individuals and organizations for sound management of green infrastructure	2	0	0
Conducts environmental education programs to encourage sound stewardship of green infrastructure	1	1	1

Uses ‘backyard conservation’ and natural landscaping programs to connect residential areas to natural resources	0	0	0
Raw Score	17	13	11
Normalized Score	**12.1**	**9.3**	**7.9**

6) Enact land use planning strategies to protect and retain all scales of green infrastructure (15)	**BO**	**AR**	**AD**
Defines and maps growth areas	2	2	1
Allows for development flexibility in growth areas	1	1	0
Uses resource conservation or open space zones to limit development outside of growth areas.	2	1	1
Uses agriculture protection zones to limit development outside of growth areas	2	2	1
In preservation, targets properties that help bound and separate communities	2	0	1
Plans grey infrastructure servicing to reinforce growth and conservation areas	2	2	1
Supports conservation design/cluster development	2	1	0
Provides density bonuses for properties that maximize preservation of environmental areas	2	2	0
Requires that development projects leave a portion of buildable area as park/open space	2	2	2
Requires permanent preservation of dedicated park/open space	2	2	0
Has an active transfer of development rights program	2	0	2
Has a county purchase of development rights program	2	1	1
Funds green infrastructure protection from continuous, dedicated sources (e.g. taxes, fees)	2	2	2
Strength of urban growth boundary (none, changeable, strict)	1	2	0
Invests significant county funds in green infrastructure (not just leveraging of state/federal funds)	1	1	1
Raw Score	27	21	13
Normalized Score	**18.0**	**14.0**	**8.7**

7) Protect and support green infrastructure through a collaborative and cooperative process (9)	**BO**	**AR**	**AD**
Outlines how the public is involved in the green infrastructure planning process	1	1	1
Helps landowners to develop and implement resource stewardship plans	1	0	0
Works with landowners of high quality lands to manage or restore habitat and other resources	1	0	0
Coordinates conservation efforts with other local jurisdictions	2	2	1
Works with local land trusts and other NGOs	1	2	1
Participates in optional state and federal programs	2	2	1
Leverages state and federal funds for green infrastructure	2	2	1
Shares list/map of priority conservation areas with nonprofit organizations and other governments	2	0	1
Shares green infrastructure and local ecological information with other organizations	2	2	2
Raw Score	14	11	8
Normalized Score	**15.6**	**12.2**	**8.9**

TOTAL	87	66	55
PERCENT	**62**	**47**	**40**

BO: Boulder County
AR: Arapahoe County
AD: Adams County

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