ASSESSING INTERACTION BETWEEN LANDSCAPE CHANGE AND LAND MANAGEMENT POLICY: OPEN SPACE POLICY AS A MODEL SYSTEM

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This proposal describes a 2-year project intended to advance the landscape change agenda first sponsored by the NSF through the Landscape Change Workshop in 2001. The objectives of the study are to better understand the interaction between landscape change and land management activities using open space preservation as a model system and to advance the study of landscape change as both relating to technical and political understandings of the processes shaping our landscapes.

The project seeks to explore the intersection between ongoing landscape change, the policies intended to shape open space preservation and the characteristics of the land acquired for preservation. Landscape change can impact the capacity of preservation policies to achieve their goals by altering the condition of both preserved and unpreserved lands. Furthermore, because they result in landscape change themselves, open space policies can be one of the drivers of landscape change. For example, preserved open space may attract development at its margins, making it more difficult for large tracts of contiguous open space to be assembled over time.

In order to elucidate the interactions between landscape change and open space policy and preservation, it will first be necessary to identify landscape conditions and changes over the past 30 years in the study areas, the Highlands and Pinelands regions of New Jersey. Geographic information technologies (GITs) will be used to develop multiple measures of change for existing and compatible land use and land cover data sources. Next the open space policies implemented in these areas will be examined to determine their goals for preservation. These goals will be translated into geographic criteria and a GIT representation of these criteria will be developed. A GIT data set will be developed that describes both the location of properties acquired for acquisition and the year of their acquisition.

The interaction of open space policies with landscape change will be explored by examining three questions:

- Does landscape change impact the subsequent acquisition of open space?
- Does open space acquisition impact subsequent landscape change?
- Does landscape change impact the ability of open space preservation programs to meet their goals?

Through the analysis of the interaction of landscape change and open space policy, a model that generalizes this interaction will be developed. From this model, recommendations of how landscape dynamics can be better accounted for in open space policy development and implementation will be developed, and specifics regarding the role of GIT applications and infrastructure in this process will be provided. As a demonstration of the feasibility of this project, a pilot project has been performed showing that the project is realistic and meaningful.

PROBLEM STATEMENT

All landscapes are dynamic, whether as a result of natural processes or human interventions. Traditionally, we have often distinguished between the two by the pace at which the change has occurred. However, under some circumstances, it is becoming increasingly difficult to discern between landscape changes caused by natural processes and those resulting from artificially constructed processes. It becomes particularly difficult to identify the full impact of policies meant to impede or prevent landscape change, especially as those impacts extend beyond the specific areas targeted by the policies.

In the United States, urban development has emerged as the major driver of landscape change. In many areas the public or government response has favored open space protection practices (e.g., purchase, deed restrictions, tax incentives) over the use of restrictive government regulations (e.g. zoning, permitting). Consequently, significant effort and funding is being put into open space preservation efforts that will have long-term consequences on the landscape.

The central problem studied by this project is the interaction between landscape change and open space policies. Advancing this understanding allows study of two additional problems: the effectiveness of measures of landscape change, and the overall success of specific open space policies. This positions this project to have a significant impact as open space preservation emerges as a significant phenomenon in the US. Examining the interactions between landscape change and open space policies is expected to identify a three-way relationship (see Figure 1). Including open space acquisition as a separate component from open space policy makes explicit the need to consider both the conceptual goals of open space policy and the impacts of actual open space acquisitions. Practical compromises required to carry out acquisitions may not always support or may even undermine some of the goals of preservation policy. Perceived or actual landscape change spurs the development of open space policies and open space acquisition, but those policies and acquisitions also have the potential to affect the pace and pattern of landscape change. As properties are set aside through acquisition or prohibitive regulation (like wetlands laws) adjacent properties become more desirable for development because the preserved lands are viewed as amenities. Conversely, faster rates of landscape change appear to result in more aggressive open space policies.

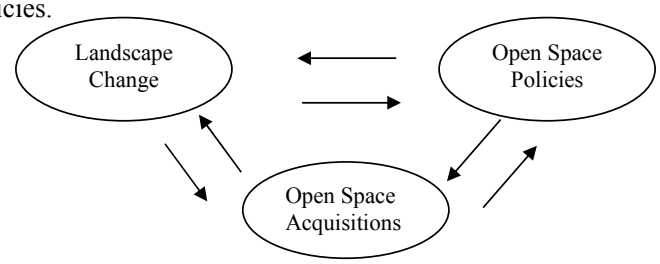

Figure 1. Hypothesized relationship between landscape change, open space policy and open space acquisition.

BACKGROUND

Landscape change research is an emerging multidisciplinary field combining elements of a variety of disciplines including geography, landscape architecture, ecology, planning, and regional studies. The elements of landscape change have recently received significant attention through the NSF-sponsored Workshop in Landscape Change in Santa Barbara, CA (Workshop in Landscape Change 2001). The Workshop identified four major components of landscape change research that needed to advanced in concert with one another:

- Information technology,
- Decision making,
- Landscape perception and assessment, and
- Environmental and Social Science.

Workshop participants noted that the field has been difficult to move ahead because it straddles disciplinary boundaries including blurring the boundaries between basic and applied research. The workshop worked towards: promoting the building of a collaborative research community; developing a joint research agenda; and facilitating the exchange of ideas. Ahern (1999, 2001) describes how different academic traditions are converging on the topic of landscape change to help achieve these goals.

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

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

Coincident with this scale shift and emphasis on remotely sensed data has been an increasing concern with anthropogenic landscape change. The time period over which suitable satellite imagery has been available has seen a dramatic increase in both human impacts on land cover and concern over their effects. Remotely sensed data can be used

to identify and quantify landscape change. In the past decade the increasing capacity of geographic information technologies to integrate data from different sources has lead to the combining of remotely sensed data with other sources of geographic information to produce more nuanced investigations that not only delineate landscape change but also incorporate additional data to model its causes and consequences (e.g Amissah-Arthur 2000, Smits and Annoni 1999).

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

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

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

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

- Modeling future change – Once the variables that seem to be driving landscape change have been tested for significance, empirical models are often extended to predict future change (e.g. Levia 1998). Cell and agent based modeling have also been used to model future change, requiring a rule-based or hybrid quantitative/rule-based approach. Alternatively, future change may be projected using current conditions as a starting point and current or potential constraints on change as rules governing change. Build-out analyses and many other spatially explicit policy analyses (Bradshaw and Muller 1998, Espejel et al. 1999, Musacchio and Coulson 2001) are examples of this type of landscape change modeling.

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

LANDSCAPE CHANGE AND LAND MANAGEMENT

Landscape change is impacted by a variety of policies both directly and indirectly related to land use. A variety of models from different academic perspectives have been used to describe landscape management processes (Ndubisi 2002). Additionally, various methods of land-use planning (see Westphal 2001 for brief review) have been implemented as policies and have direct effects on landscape change. In the United States, the differential zoning of land uses is the most prevalent of these methods, and clearly places constraints on the trajectory of land use change by directly prescribing and prohibiting certain classes of land use in any given zone. Policies that direct land management activities such as timber extraction and endangered species protection also impact landscape change by constraining the type, intensity and location of various land uses.

Land management covers a broad spectrum of activities, including such landscape-scale endeavors as open space preservation and planning (Tulloch 2000). Open space preservation policy becomes a particularly interesting element in the context of studying landscape change. Implementing open space preservation programs is a common policy response to perceived or actual landscape change (Kline and Alig 1999). Open space policies do impact landscape change processes, but often in a manner less visible than policies that directly control land use. The acquisition or regulation of properties intended to prevent development or preserve open space acts invisibly as a means for preventing at least certain types of landscape change. However, these policies can also shape larger processes by influencing the pace and pattern of potential change not just on the actual preserved properties but also in the entire area in which they are implemented. For example, different farmland preservation mechanisms have lead to different levels of fragmentation of agricultural land (Brabec and Smith 2002). The degree to which open space policies promote or prohibit fragmentation or other spatial characteristics of landscapes clearly has an effect on future landscape change, which implies that landscape change and open space policies interact in complex and adaptive ways.

Open space preservation is emerging as a phenomenon that is receiving large amounts of public funding in NJ, the US and worldwide. Despite this recent heightened level of preservation activity, it remains unclear how open space policies will impact future land use decisions and landscape characteristics. The lack of scrutiny to which these practices and policies have been subjected is of great concern. This concern is only sharpened by the realization that open space preservation will have significant and long-term consequences on the landscape because most preservation efforts preserve land in perpetuity. Given both the levels of public funding involved and its permanent landscape impacts, it is clear that open space preservation warrants significant research attention.

Open space preservation has been the object of increasing academic interest for over a decade. Studies have ranged widely in focus and methodology. Studies include include multinational policy surveys (Alterman 1997), GIS intensive landscape studies (Brabec and Smith 2002), exploration of the philosophical underpinnings (Bunce 1998), and examination of public preferences (Kline and Wichelns 1998). Recently, critical investigations of open space preservation have begun to appear in newspapers (Chambers

2003), especially in areas like New Jersey where significant public funding is being directed towards preservation.

METHOD

The research project will begin with a thorough examination of the study areas leading to a series of **characterizations of landscape change**. The characterization includes measuring areal change of different types of land use/land cover at approximately decadal intervals between the 1970's to year 2000. There is a great need for the simplification and synthesis of land use/land cover change data to provide information that is useful to land managers and policy makers. The simple metrics for analyzing, monitoring, and communicating information about change are often referred to as *environmental indicators* within the environmental management literature (Hof et al. 1999, ERMS 2000, Jones and Simmers 2001). There has been a strong push by U.S. Federal agencies to develop land cover data sets and indicators that are suitable for measuring and monitoring land cover and associated environmental change at broad regional scales (Jones et al. 1997; United States Environmental Protection Agency 1998). We propose to use the environmental indicator concept as a means of measuring landscape pattern over time.

The objective of the landscape characterization is two-fold: 1) to provide an analysis of the changes in land use/land cover over the past three decades; and 2) derive a series of environmental indicators of landscape pattern. A combination of classified Landsat Multispectral Scanner and Thematic Mapper satellite imagery, digital orthophotography, and existing (LU/LC) data sets has already been used to create a time series of land cover data for 1972, 1984, 1995 and 2000. The resultant LU/LC data set will enable the derivation of indicators of landscape integrity and fragmentation. We propose to use the following suite of landscape level indicators to quantify the environmental condition of these landscapes: 1) percentages of altered and unaltered land cover; 2) indices of forest fragmentation; 3) percentage of impervious surface cover; 4) percentage of the riparian areas of permanent streams that are in a vegetated, as compared to developed state; and 5) measures of configuration, such as contagion, for developed, forest and agricultural land.

While the characterizations of existing change will develop new data, it will also be incorporating data from a variety of existing sources (Table 1). New Jersey is a relatively data-rich state benefiting from geospatial data developed by a number of organizations including the New Jersey Department of Environmental Protection (http://www.state.nj.us/dep/gis) and the Grant F. Walton Center for Remote Sensing and Spatial Analysis at Rutgers (e.g. Lathrop 2000). Some of these existing data sets include historic land use/land cover. However, generating meaningful maps of landscape change from these sources will require significant effort and modification. This project will also rely on newly derived data describing the present-day landscape and the nature of change occurring there.

Table 1. Primary Existing Data Sources

Land Use/Land Cover Data Sets:
1884-1895 Topographic Atlas Sheets with Forest Cover
1972 Landsat MSS Derived Land Cover
1984/5 Landsat TM Derived Land Cover
1994/5 Landsat TM Derived Land Cover
2000 Landsat TM Derived Land Cover
1986 Orthophoto Derived Land Use
1995/7 Digital Orthophoto Derived Land Use
2000 SPOT Pan Derived Land Use

Imagery:
1930-9 Aerial Photography
1986 Aerial Color Infrared Orthophotography
1991 Aerial Panchromatic Orthophotography
1995/7 Digital Aerial Color Infrared Orthophotography
2002 Digital Aerial Color Infrared Orthophotography

Other:
NRCS County Soil Survey (SSURGO available for most of study area)
NJDEP Landscape Project Critical Wildlife Habitat
NJ Natural Heritage Program Priority Sites for At-Risk Plants, Animals and Communities
NJDEP Preserved Open Space
NJDEP Hydrology
NJ Department of Agriculture Preserved Farmland

The project will identify the multiple policies and regulations impacting the patterns of open space preservation. This **characterization of current open space policies** in the study areas will include a determination of the goals of the policies and the construction of spatial representations of the goals. The researchers will determine goals by reviewing the planning documents that describe the implementation of the policies. These policy goals will be translated into geographic criteria than can be represented in GIT. A time-series data set of open space acquisitions will also be generated. These data will be tested to determine if there have been any variations or trends in the qualities (overall amount, size, shape and contiguity of acquisitions, land-use/land-cover) of preserved properties over time. This dataset will also be used in conjunction with the landscape change data to analyze the landscape changes occurring in preserved areas, which is poorly understood but has obvious impacts on the function of open space preservation programs.

The project team will identify the parcels or tracts of open space that have been preserved. This **characterization of current open space preservation** will focus will on open space that has been permanently preserved through the use of state funds. Table 2 shows a typology of such permanently preserved open space in New Jersey. All permanently preserved farmland is privately owned and deed restricted against non-agricultural development. In contrast, non-farmland open space can be held by

individuals or non-profit groups and deed restricted against development or can be owned outright by municipalities, counties or the state. Those protected by easement are usually preserved for their environmental value, while those lands purchased outright by a government may be preserved for number of reasons. Since the type and purpose of preservation will likely impact the nature of the preserved land, the typology of open space presented here will be used to interpret the proposed analyses.

Table 2. Typology of New Jersey's Permanently Preserved Open Space

Type	Preservation Method	Purpose	Examples
Farmland	Easement	Retain Agriculture	
Non-farmland Open Space	Easement		
	Publicly Owned	Recreation	High Use Parks
			Low Use Parks
		Resources	Wildlife Management
			Timber Resources
			Watershed Protection

After completing the first three components, the project will then **analyze interactions** between landscape change, open space preservation policies, and open space preservation practice (see Figure 2). Three types of interactions will be explicitly tested for:

1. Does landscape change directly impact the subsequent acquisition of open space?
2. Does open space acquisition impact subsequent landscape change?
3. Has landscape change impacted the ability of open space preservation programs to meet their goals?

Examining the first two interactions will require analysis of the landscape change data in concert with open space acquisition data. The landscape change data will also be compared with the time-series open space acquisition data set to see if any trends or patterns in acquisition can be linked with landscape change.

One interaction of particular interest is whether open space serves as an attractor to development or is neutral. The time series of landscape change data will be compared with the time-series of open space acquisition data to examine the significance of the spatial relationships at each time period. Using spatial statistics we can test whether the proximity to existing open space is an important determinant in the spatial pattern of development. As demonstrated in the pilot study, this can be done by measuring the proximity of development to open space in each of the three time periods using several techniques. The significance of this proximity (i.e. the strength of the attraction) will be tested against a neutral random model. As the research program at the Center for Remote Sensing and Spatial Analysis moves forward in developing regional lands use change models (U.S. Forest Service 2002) a better understanding of how open space affects future development patterns to properly parameterize these models is needed. This analysis will provide that necessary information.

Investigating the third interaction will require analysis of the landscape change and open space goal data. The short lag time between the passage of the Garden State Preservation Trust Act in 1999 (Hamill and Sturm 2003) and subsequent increase in the rate of preservation indicates that, at least for recent efforts, there is little delay between the implementation of preservation policy and landscape change resulting from the policy. The proposed research would assist in determining whether prior preservation legislation had similarly fast impacts on the landscape.

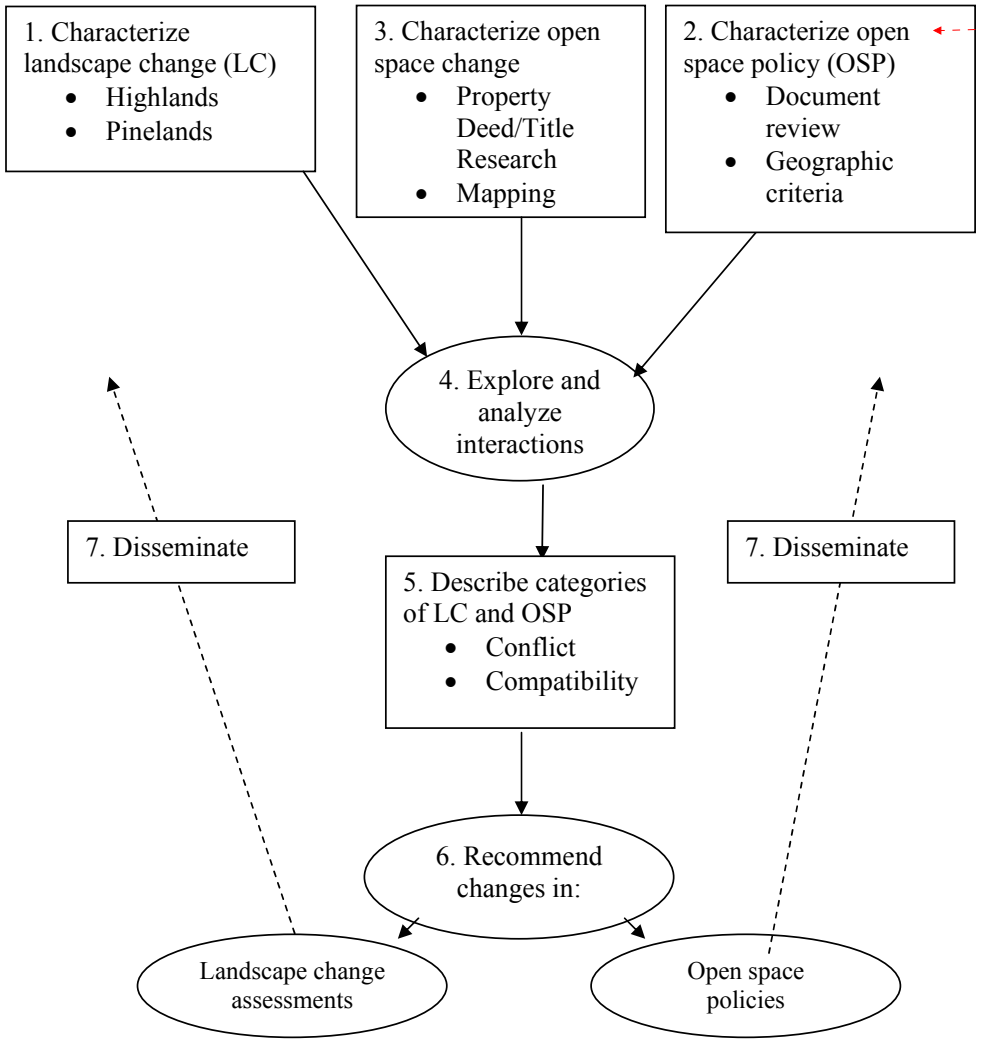

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Figure 2. Diagram of research process.

Once the interactions between landscape change and open space preservation have been analyzed, the project will develop **descriptions and a categorization of the interactions** between landscape change and open space policy. The nature of the available methods means that these relationships will be analyzed in a correlative rather than causative manner. The categorization will be based on the degrees of conflict and compatibility that exist between the observed landscape changes and the open space preservation goals. We will identify policies and patterns of change that could contribute to more successful achievement of open space and development goals for different kinds of communities.

The project will result in **recommendations for changes in policies and measures of landscape change**. Alterations in open space policies will be recommended with the intent of providing more realistic goals and more appropriate tools for achieving the policies' goals. Landscape change measurement and description practices will be recommended that could better inform policy decision-making and research.

Since landscape change is still an emerging field, we feel a broad **dissemination of the findings** is critical to advancing the work in the field. We intend to make a special effort to integrate this work into the growing landscape change literature, contributing to the theoretical foundations of the field, as a means of helping formalize landscape change efforts. We will share technical recommendations about the practices of measuring and assessing landscape change. We will share the more practical recommendations about the policies shaping open space and the larger process of landscape change with the decision makers who are actively shaping our landscapes. Figure 2 presents a diagrammatic summary of the proposed research process.

STUDY AREAS

Although New Jersey may be unique in that nearly the entire state is subject to significant development pressure, the factors driving the urbanization of farmland and forest are similar to those operating in other metropolitan areas across the United States. Located between two major metropolitan areas (Figure 2), New Jersey has a relatively long history of open space preservation, pioneering several of the techniques now being implemented across the country.

This history in preservation is coupled with a recent increase in preservation activity at both the state and local levels. In 1999 the Garden State Preservation Trust Act was signed into law, dedicating $98 million a year for 10 years and authorizing up to an additional $1 billion in bonds for the preservation of farmland and open space (Green Acres 2002). The goal initially set by the state was to preserve an additional 417,000 hectares (1 million acres) of land, although the current administration has suggested that quality of preserved land may be stressed more than quantity. Considering that New Jersey has already preserved approximately 417,000 hectares of its 2.1 million hectares, it is unclear whether the million-acre goal was attainable. This concern is only amplified when the rate of development of unpreserved open space is taken into account. Between 1984 and 1995, the amount of developed land in New Jersey increased by 17%, from 500,000 hectares to 585,000 hectares (Lathrop 2001). Regardless of the exact nature of the preservation goal, it is clear that the considerable amount of money currently

allocated to open space preservation in New Jersey demands a better understanding of how landscape change interacts with open space policies.

Two areas within New Jersey have been selected as preliminary study areas, the Highlands and the Pinelands (Figure 3). These areas stand out as containing significant ecological, recreational and aesthetic resources while differing enough in their physical, biological and regulatory components to generate useful comparisons. As preliminary results are generated during the course of the study, additional areas both inside and outside of New Jersey may be included to assist in comparison and understanding.

Figure 3. Study areas.

The Highlands of northern NJ covers 290,000 hectares and is a complex mosaic of land use types and land ownership patterns currently experiencing strong development pressure (United States Forest Service 2002). Land use and development decisions occur primarily at the local level. The primary regulations which control land use and development are municipal zoning ordinances and state wetlands regulations. Significant amounts of land are under public ownership, but these public lands are fragmented in many areas and the intervening lands have the potential to be developed. Preservation efforts are fragmented as well. A number of government agencies at the federal, state and local levels have active land acquisition and preservation programs aimed at protecting natural resources, preserving farmland and providing recreational opportunities through open space preservation. These are complemented by the preservation activities of local, regional and national non-profit and non-governmental organizations such as The Nature Conservancy and The New Jersey Conservation Foundation.

In contrast to the Highlands, the Pinelands has had a strong regional management plan in place since 1980 (State of New Jersey 1980). The 458,000-hectare area covered under the plan was delineated in 1978 as a federal reserve, and an independent state commission administers the plan. The management plan does not prohibit growth in the entirety of the reserve but rather directs it to defined growth areas and restricts it within preservation and protection areas. The plan also defines goals and criteria for the acquisition efforts directed by the commission within the reserve. Similar to the

Highlands, a variety of non-profit and non-governmental organizations are also active in open space preservation efforts in the Pinelands. Previous research has shown that the establishment of the reserve has had an impact on the trajectory of landscape change within the reserve (Luque 2000b). However, no evaluation of how this might interact with the preservation goals has been undertaken. Furthermore, no work has been done examining how changes along the edges of the reserve might be interacting with open space preservation efforts both within and around the preserve.

PILOT PROJECT

In order to explore the potential for GIT to answer questions about the interactions between open space acquisition and development, we conducted a pilot study using data for Hunterdon County, in northwestern New Jersey. The pilot study was restricted to exploring two significant aspects of the proposed research. The first was how difficult would the collection of acquisition dates for preserved areas be, while the second was what spatial measures could be use to examining interactions between open space preservation and development.

The first step of the pilot study was to collect information about the acquisition year of permanently preserved open space in Hunterdon. Hunterdon County was chosen for several reasons. Although a detailed and reasonably comprehensive GIS data layer of preserved open space was available for the county current to the year 2000, it did not contain the year the properties were acquired as open space. The acquisition year data was obtained from sale records maintained by the Hunterdon County records office. The open space data was classified by acquisition date in the following manner: pre-1973, 1973-1985, 1985-1995 and 1995-2000. The breakpoints for these classifications correspond to the 1972, 1984/5, 1994/5 and 2000 land use/land cover data current available (Table 3, Figure 4).

Table 3. Summaries of open space data based on acquisition year.

			Percent	**Ownership**	
Time period	Hectares (acres) acquired	State	County	Municipal	Nonprofit
Pre-1973	2449 (6051)	63	37	>1	>1
1973 – 1985	1595 (3939)	66	32	2	0
1985 – 1995	1263 (3120)	64	28	0	8
1995 - 2000	1112 (2747)	28	44	10	18

Figure 4. The first map represents the study area of the pilot project, Hunterdon County, NJ. The second map is a close-up depicting areas of open space mapped for the pilot where lighter gray represents earlier preservation and darker gray represents more recent acquisitions/preservation. The third map shows development, with light gray being older and dark gray being more recent.

Acquisition rates were steady in the two middle time periods at 123 hectares and 115 hectares per year, respectively. The increase in acquisition rate evident in the final time period (158 hectares per year) is indicative of the increase in interest in and funding of open space acquisition. Since acquisitions often take months or even years to plan, the impact of the significant funding made available in 2000 by the passage of the Garden State Preservation Trust Act in 1999 is most likely not fully reflected in these numbers. The significant increase in county and non-profit land acquisition by the last time period is a result of increased funding made available by county open space taxes and increased activity by land trusts and other nonprofit groups with similar goals. Both the county and the non-profit groups benefited by state-level policies that promote joint funding of open space acquisitions.

In order to characterize and test interactions between the land use/land cover data and the open space acquisition data, several landscape pattern measures were derived for the data using Fragstats 3.3 (McGarigal et al. 2002). First, the developed areas were extracted out of the 1972, 1984/5 and 1994/5 land use/land cover data into separate data layers. The cumulative open space parcels for each of these dates were also extracted into separate data layers. The developed areas and open space parcels were then combined into a single raster data layer for each date. These three layers were analyzed for clumpiness and inverse similarity using Fragstats. Clumpiness measures aggregation of a particular class, while the inverse similarity measures the relative likelihood of a patch of one class being within a predetermined distance of a patch of another class. In this case, 60 m was chosen as an appropriate distance to use in this measure. It is wide enough to span road features. The results are presented in Table 4.

Table 4. Measures of clumpiness and similarity for developed lands and preserved open space derived for three different years.

	1972	**1985**	**1995**
Clumpiness			
Developed	0.9107	0.7993	0.8084
Open Space	0.9256	0.925	0.9451
Mean Inverse Similarity			
Developed	111.0	62.1	270.4
Open Space	102.9	304.3	1794.1

As indicated by the clumpiness measure, development has become more diffuse over time. This is evident by visual inspection of the GIS data layer. In 1972, development was concentrated around historic centers of development, while in 1985 and 1995 development spread throughout the county. On the other hand, open space became slightly more aggregated from 1972 to 1995. This is an indication that the open space preservation goal of creating contiguous areas of preservation is currently being met. The mean inverse similarity shows that as development became more diffuse in between 1972 and 1985, it became less likely that a particular development was located within 60 meters of preserved open space. The converse was not true, however. Over that time period it became more likely that a given patch of preserved open space was within 60 m of development. Between 1985 and 1995, however, both development and open space have become more likely to be located within 60 meters of one another. This may hinder open space preservation planners from continuing to achieve their goals of creating relatively large areas of continuous open space. Additionally, proximity to development increases the level of human disturbance in preserved open space, which may negatively impact sensitive species and ecological communities that are preserved there.

The pilot study in Hunterdon County shows that complex interactions between development and open space preservation are occurring in New Jersey, and that these interactions may have significant impact on the capacity of open space preservation plans to meet their goals. In relation to the larger study proposed, the pilot study indicates that open space acquisitions dates corresponding to the time periods of available land use data should be available, although their collection will require visits to the property records office of 13 of New Jersey's 21 counties. The lack of digital parcel maps for all but 3 of these counties means that additional work will be required to gather the lot and block identifier information for open space parcels in these counties, but the availability of paper tax maps, digital scanners and image rectification software make this work feasible.

In order to further characterize the nature of the relationship between development and open space preservation over time, a proximity analysis was performed. Examining the aggregate statistics shows that in all three time periods, areas within 1 km of preserved open space are more likely to be developed than areas greater than 1km from preserved open space. The values for the individual 100 meter buffers indicate that land in the buffer closest to preserved open space is far less likely to be developed than those at greater distances. If this buffer is excluded, the areas between 0.1 and 1 km from preserved open space are even more likely to be developed than areas greater than 1 km

from preserved open space in all three time periods. As overall development increased between 1972 and 1995, areas between 0.1 and 1 km of preserved open space was developed a disproportionately higher rate than areas greater than 1 km from open space, as evidenced by the increasing difference between the percentage of developed land inside the buffer versus outside the buffer.

OUTCOMES AND IMPACTS

Most studies of landscape change concentrate on measuring or modeling the physical and ecological impact of change, which reduces the human-environment relationship to a one-way flow of human impact on the environment. By focusing on the interaction of landscape change and land management, this study does not restrict itself to a uni-directional conception of the human-environment relationship. The underlying conceptual model of human-environment relationship adopted for this study is inherently two-way. It reflects an acknowledgement that the relationship is an adaptive one, where anthropogenic landscape change induces a change in land management goals and implementation. One of the fundamental questions this study will answer is whether these goals and implementation may then need to be modified because of continuing landscape change. The interaction is rendered more complex by the fact that land management activities themselves contribute to the pace and pattern of landscape change, which makes a bi-directional conception of the human-environment relationship even more important.

Because the study focuses on open space preservation as a model system, the results derived from the research are expected to be especially relevant to open space policy planners and managers. However, because open space preservation shares many characteristics with other forms of land management, the conclusions and models derived from the research should be applicable to many land management activities that take place in changing landscapes. Given the level of importance and funding that open space and other preservation measures are receiving across the county, the results of the study will represent a timely contribution to the knowledge that can be brought to bear on a topic that the public in many places perceives of as important.

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