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Consequences of land use change in the New York–New Jersey Highlands, USA: Landscape indicators of forest and watershed integrity

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Abstract

The New York–New Jersey Highlands, a 600,000 ha area of forested uplands, provide vital environmental services to the growing New York City, USA metropolitan region. Urban development and associated land use/land cover change threaten to impair the Highland's natural resource values. In response, the USDA Forest Service, in collaboration with Rutgers University, the U.S. Geological Survey, and the Regional Plan Association, undertook a regional study of the NY–NJ Highlands to characterize the resources at stake and assess the implications of continued land use change. This paper will focus on the Highlands as a case study on the application of landscape-scale indicators to assess the potential impacts of future land use change. A three-pronged approach was adopted: (1) land use/land cover change mapping to assess past changes, (2) build-out modeling to project possible future land use change, and (3) landscape-scale indicators of forest and watershed condition. The coupled build-out and landscape indicator analysis served as a planning tool to assess the potential impacts to forest and watershed integrity based on two different scenarios of future development.

Keywords: Landscape indicators; Remote sensing; Highlands

1. Introduction

The phenomenon of sprawling urban development is one of the major forces driving environmental change in the USA. Most USA metropolitan areas are adding new urbanized land at a much faster rate than they are adding population, resulting in large amounts of land consumed for urbanization while accommodating comparatively small numbers of people (Fulton et al., 2001). While most of this urbanization is occurring as one house or small subdivision at a time here and there across the landscape, taken in aggregate the implications are enormous. Urbanization and associated changes in the regional landscape composition and pattern sets off a cascade of environmental impacts that are of growing concern (Alberti, 1999; Bartlett et al., 2000; McKinney, 2002; Nilsson et al., 2003). The rapid pace and broad scope of urbanization is testing the ability of land use planners and environmental resource managers to address the cumulative degradation of regional ecosystems and the resources and services that they provide.

Examination of the implications of future change is critical to inform the local and regional land use planning process before ill-advised and irreversible land use decisions occur. Land use change scenarios and models provide an increasingly valuable tool for examining future landscapes to investigate the process of change as well as potential future landscape configurations (Lambin, 1997; Lee et al., 1998; Theobald and Hobbs, 1998). Presently, within the landscape ecology and regional planning literature, there is great interest in developing land use change models that focus on simulating the processes that drive the spatial and temporal dynamics of change. However, if the overriding concern is landscape configuration at a future endpoint and the resulting environmental implications, then a build-out model provides an alternative approach to dynamic models (Botequilha Leitao and Ahern, 2002; Conway and Lathrop, 2005). A build-out model can be used to examine the form of the fully developed landscape, while avoiding the uncertainty of predicting when the changes will occur. The build-out modeling approach is only valid where there is some concrete form of spatial planning that constrains the location and type of future development. In USA, spatial

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planning is usually codified through municipal zoning. Zoning regulations define acceptable types of future development but rarely take into account the environmental consequences of development, especially cumulative impacts at the watershed scale.

To make land use change models more relevant to the planning process, there needs to be greater linkage between measurable changes in land cover with the expected environmental consequences of the projected land use change. At the same time, these often-complex model outcomes need to be synthesized and simplified so as to provide information in a form that is readily understandable and relevant for land managers and policy makers. Such simple metrics for analyzing, monitoring, and communicating information about environmental change are often referred to as *environmental indicators*. With the increasing availability of broad-scale data provided by remote sensing along with the insights of landscape ecology, the indicator concept has been expanded to include “landscape” indicators for measuring and monitoring environmental condition at watershed to regional scales. In most instances, landscape indicators take the form of metrics that quantify the composition or some component of the spatial pattern of the landscape (Jones et al., 1997). Where strong relationships exist between landscape composition and pattern (i.e., as measured by a landscape indicator) and the conditions of the environmental resources of interest, then it should be feasible to employ landscape indicators to assess the environmental condition (Kepner et al., 1995). By combining knowledge on how landscape pattern influences environmental condition, landscape indicators can be used to evaluate risk or vulnerability of environmental resources in a given region (Kepner et al., 1995). For example, a number of studies have found that a decline in stream water quality (condition of a key environmental resource) is strongly related to the amount of impervious surface cover in the stream’s watershed. Accordingly, impervious surface is often used as a landscape indicator of watershed integrity (Arnold and Gibbons, 1996; Schueler, 1998).

The New York–New Jersey Highlands, a 600,000 ha area of rugged uplands largely covered in forests, serve as a natural geographic boundary delimiting the northern edge of the New York City metropolitan region (Fig. 1). The distinct possibility that expanding urbanization will overwhelm the Highlands has instigated intense concern and interest in trying to conserve the region’s natural values as watershed, wildlife habitat, and public open space. In response, the U.S. Forest Service in collaboration with Rutgers University, the U.S. Geological Survey, and the Regional Plan Association, undertook the NY–NJ Highlands Regional Study to characterize the resources at stake, assess the implications of continued land use change, and address a potential federal role in the region (Phelps and Hoppe, 2002). This 2002 study updates an earlier USDS Forest Service-sponsored Highlands Regional Study conducted in 1992 (Michaels et al., 1992). This paper will focus on the Highlands as a case study on the application of build-out models coupled with landscape-scale indicators as a planning tool to assess the potential impacts to forest and watershed integrity based on several different scenarios of future development.

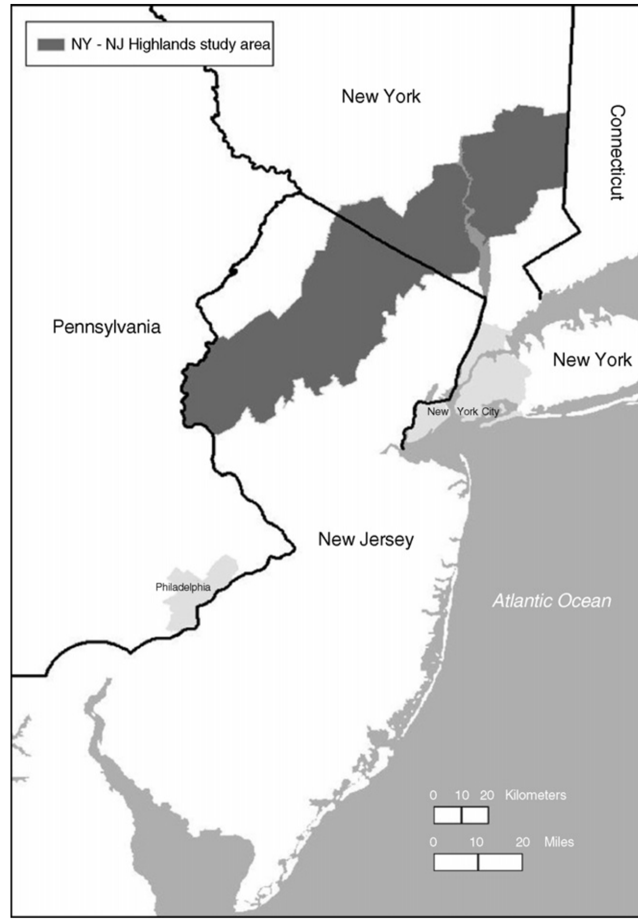

Fig. 1. Location map of New York–New Jersey Highlands study area.

2. Methods

2.1. Overall approach

The two main objectives for this portion of the NY–NJ Highlands study were: (1) to compare the relative impact of the low versus high constraint scenarios at the regional scale and (2) to identify potential hotspots of environmental change that deserve greater consideration in future land management decisions. A three-pronged approach has been adopted: (1) land use (LU)/land cover (LC) change mapping to assess past changes, (2) build-out modeling to project possible future land use (LU)/land cover (LC) change, and (3) landscape-scale indicators of forest and watershed condition. A suite of landscape-level indicators were chosen to assess the condition of the NY–NJ Highlands’ forests and watersheds:

(1) percentage of altered and unaltered land cover;
(2) percentage of impervious surface cover;
(3) percentage of the riparian zones in altered land covers;
(4) percentage of interior forest.

The environmental indicators were analyzed on a watershed basis, aggregating results to the HUC 11 (U.S. Geological Survey Hydrological Unit Code 11) level. There are 51 complete