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ScienceDirect

Landscape and Urban Planning 83 (2007) 154–167

LANDSCAPE AND URBAN PLANNING

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Monitoring landscape fragmentation in an inaccessible mountain area: Celaque National Park, Western Honduras

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Received 19 May 2006; received in revised form 27 March 2007; accepted 5 April 2007
Available online 11 May 2007

Abstract

Many protected areas across the world are in locations marginal for human uses. Debate remains about the impact of these parks on land-cover change, which may be confounded by the role played by the biophysical landscape. To test whether parks limit landscape fragmentation due to their designated protection or biophysical location, one must control for features that render the park inaccessible. We examine the effect of Celaque National Park, Honduras, on landscape fragmentation from 1987 to 2000 using remote sensing, GIS and landscape pattern analysis. Multivariate analyses of variance and covariance were conducted to examine differences in landscape fragmentation within the park and the surrounding landscape adjusting for differences in accessibility. Indicators of patch fragmentation were significantly correlated with slope, elevation and distance to roads. Different management categories within the park were found to have significant differences in land-cover change and landscape fragmentation, and the impact of management category was even more significant after accounting for the differences in accessibility that exist across these zones. Thus, the park boundaries have been important in mediating land-cover change pressures, even after accounting for the substantial differences in the accessibility of forestland for conversion to agricultural land use.

Keywords: Parks; Fragmentation; Land-cover change; Multivariate analysis of variance; Accessibility; Honduras

1. Introduction

The creation of parks and other formally protected areas around the globe has gained dramatic momentum in recent years. At the Fifth World Parks Conference in 2003, it was announced that the global network of protected areas now comprises some 11.5% of the world's surface (Rodrigues et al., 2004, p. 640). Park formation appears to relate to the process of environmental globalization (Zimmerer et al., 2004), and is occurring in most tropical locations. Parks are established to maintain carbon sinks, protect biodiversity, stabilize global climate and ultimately to "protect the common good" (Pfeffer et al., 2001) for the rest of the world. There is much current controversy about the effectiveness of parks as management regimes; such controversy is further complicated by the dearth of empirical evaluations of the regional impact of parks over time (Bruner et al., 2001; Ostrom and Nagendra, 2006).

Parks are a function of the larger landscape within which they are embedded (Sánchez-Azofeifa et al., 1999; Rivard et al., 2000; Kinnaird et al., 2003). The location of protected areas is often constrained by political considerations that favor their establishment in inaccessible areas that are unsuitable for economic land uses, and can thus be easily set aside for "conservation" (Pressey et al., 1996; Lunney et al., 1997). The "worthless lands" hypothesis, described in detail by Runte (1979), has gained wide support. In its essence, this hypothesis states that for the United States, only marginal lands that were incapable of exploitation for commercial purpose were set aside for protection. Scott et al. (2001) supports this claim, indicating that most nature reserves in the

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0169-2046/$ – see front matter
doi:10.1016/j.landurbplan.2007.04.001

US are found at higher elevations and in less productive soils that are not in as much demand for urban and agricultural land use.

In landscapes subjected to intense human use, remote areas may be the only remaining landscapes available for conservation. Inaccessible mountain regions, by virtue of their isolation, tend to have higher concentrations of rare, endemic species and demand conservation for this very reason alone (Heywood, 1995). Further, the US experience does not hold for all protected areas across the world, especially for those areas where native peoples have demonstrated extensive opposition to park establishment (e.g., see Wright and Mattson, 1996; Tucker et al., 2005). Nevertheless there have been a number of studies that support the "worthless lands" hypothesis (Hampton, 1981; Hall and Shultis, 1991; Star, 2002), demonstrating a bias toward the preservation of mountainous areas in large parts of the world (Rouget et al., 2003).

Irrespective of the reason why these mountainous protected areas were established, their inaccessible nature will continue to provide protection against landscape fragmentation to some extent. Hence, many parks are environmentally distinct from their surrounding landscape, and comparisons between a park and the surrounding landscape must be undertaken with due care. How, then, are we to evaluate whether parks, as institutional structures, are an effective conservation tool when they are so often located in inaccessible regions? Patterns of land use within protected areas are often influenced by the land use of the surrounding region (Kinnaird et al., 2003; Ostrom and Nagendra, 2006), making it essential to consider landscape change within a park relative to the broader land use system within which it is embedded. Approaches that allow us to evaluate the separate and combined impacts of park boundaries and factors of inaccessibility on slowing or inhibiting land-cover change and fragmentation are required. This task is daunting, in part because of the complex relationships between these factors, and the difficulty of obtaining information at the desired spatial and temporal levels of resolution.

Increasingly, those studying human–environment interactions rely on such tools as remote sensing and geographic information systems (GIS) to study the relationships between the biophysical environment and the human societies which impact them (Turner, 2003). Applications of remote sensing techniques to analyze social incentives and actions, and explore environmental and social change have been increasingly explored over the past few years (Liverman et al., 1998; Fox et al., 2003; Moran and Ostrom, 2005).

The biophysical and socioeconomic environment, including factors such as topography, soils and distance to markets or roads are known to impact the likelihood, nature and extent of land-cover change (Green and Sussman, 1990; Dale et al., 1993; Moran et al., 1994; Kaimowitz, 1997; Radeloff et al., 2000; Laurance et al., 2001; Nepstad et al., 2001; Munroe et al., 2002). Institutions governing resource use also shape and mediate patterns of landscape change. Land relations reflect access to land, the time horizon over which users make decisions, and the relative power of various user groups. The institutional framework has been shown to be a crucial driver of land-cover change (Wear et al., 1996; Nagaike and Kamitani, 1999; Kline et al., 2001; Stanfield et al., 2002; Nagendra et al., 2004, 2005; Bray and Klepeis, 2005). Protected areas are a particular type of institutional arrangement that can restrict or prohibit particular land uses. For formally protected areas, national (or international) authorities impose restrictions on local resources, and the credibility or enforcement of these restrictions may vary. In addition, there may be examples where conservation objectives are combined with other objectives (such as sanctioning local access to key resources), to restrict some activities while facilitating others. As such, how protected areas are designed and implemented will greatly influence landscape pattern.

Neither biophysical nor institutional processes exist in isolation, however, and institutions and management regimes act in conjunction with the biophysical landscape to affect land-cover change and landscape fragmentation (Turner et al., 1996; Crow et al., 1999). Assessments of the impact of ownership on land-cover change are thus often confounded by the interactions between social and biophysical causal factors (Wimberly and Ohmann, 2004). How much of the variation in land-cover change that is attributed to a protected area (or any other such institutional structure) can be explained by biophysical and socioeconomic context?

An approach often utilized is to examine land-cover change across a range of management regimes, and conduct statistical analyses to understand the separate and combined impacts of ownership and biophysical factors on land-cover change and landscape fragmentation (Turner et al., 1996; Buergi and Turner, 2002; Stanfield et al., 2002; Wimberly and Ohmann, 2004). Helmer (2000) studies a single landscape in Costa Rica, and employs logistic regression to evaluate the extent to which ecological and socioeconomic variables can explain changes in landscape pattern. Kline et al. (2001) utilize a gravity approach to land-cover modeling in order to jointly assess the impact of ownership, economic and ecological variables in driving future change. Crow et al. (1999) utilize a different approach, creating a 2×2 matrix of ownership compared to ecosystem type, and conducting analyses of variance to test the separate and combined impacts of each of these variables on landscape composition and structure.

In this paper, we examine Celaque National Park, a protected area located in an inaccessible mountainous region in Western Honduras (Fig. 1). We divide the landscape into four regions with different institutional restrictions on use and access and explore the evolving spatial patterns within each of these regions. Our objectives are (1) to determine whether the nature of land-cover change (in terms of direction, pattern and composition) is significantly different in separate management categories of the park over the study period 1987–2000; (2) to test whether these differences are robust after accounting for variations in key biophysical characteristics and accessibility in each zone. Prior analyses of forest cover change in the larger landscape that surrounds Celaque National Park found a trend towards reforestation between 1987 and 1996 (Aguilar, 2005; Southworth and Tucker, 2001; Southworth et al., 2002, 2004; Nagendra et al., 2003, 2004). This trend represents a local reversal in the dominant national trend of deforestation; it is especially interesting to