Land Use Policy 38 (2014) 378–387

Contents lists available at ScienceDirect

Land Use Policy

journal homepage: www.elsevier.com/locate/landusepol

Land use changes in protected areas and their future: The legal effectiveness of landscape protection

Talita Nogueira Terra [a,*], Rozely Ferreira dos Santos [b], Diógenes Cortijo Costa [c]

[a] LABGEO, FEAGRI, UNICAMP, Av. Cândido Rondon, 501 – Barão Geraldo, Campinas, SP, Brazil
[b] Depto of Ecology, USP, Rua do Matão, 321 – Trav. 14, Cid. Universitária, São Paulo, SP, Brazil
[c] Department of Geotechnical and Transportation, UNICAMP, Av. Albert Einstein, 951, 13083-970 Campinas, SP, Brazil

ARTICLE INFO

Article history:
Received 6 September 2012
Received in revised form 28 October 2013
Accepted 2 December 2013

Keywords:
Future land cover
Landscape
Protected area

ABSTRACT

It is expected that the application of a restrictive legal instrument would be an important barrier to human pressures on protected areas in Brazil. One aspect that remains to be determined is whether the applied restrictions will be related to the quality of scenarios at the borders of protected areas. The objective of this work was to analyze the capacity for minimizing the impacts on two protected areas and to identify the effective function of the barrier imposed by an environmental legal border. The borders of two protected areas, the Despraiado Sustainable Development Reserve and the Jureia-Itatins State Ecological Station, as well as the corresponding buffer zone were studied. The historical evolution of the land cover/land use of these regions was analyzed by dividing the regions into 900 m^2 hexagonal units. The scenarios for the years 1962, 1980 and 2007 were overlaid for each hexagon. The hexagons were classified according to the possible effects of conservation, and the results were quantified in terms of the frequency of land use and ecological flows. A simulation of future land use in 2028 was performed using the *Kappa* index, Markov chain modeling, multi-criteria analysis and cellular automata modeling. Based on the trend for the last 45 years, a very dynamic interaction at the legal boundaries was identified; in certain cases, either conservation or degradation were stimulated, and the intended objectives of legal environmental measures were never fulfilled. The simulation showed that by 2028, the frontiers of these protected areas will retain less than 10% of the natural vegetation cover, and 43% of this area will be covered with banana plantations.

Introduction

After 500 years of continuous fragmentation, most of the remaining Atlantic Forest has been disturbed in some way. Throughout the last century, land use/land cover changes (LUCC) have led to a high rate of deforestation and a subsequent recovery of the deforested area. These changes created a fragmented landscape dominated by young secondary forests (Teixeira et al., 2009). As one of the consequences of this process, a large number of border types were established between the forest and areas of human use. These frontiers are the result of spatial interaction patterns among neighboring patches and can be understood both as natural borders between ecosystems and as man-made borders. In legal frontiers of natural areas, adjacent communities have a characteristic set of species combined with those from another community. Thus, there is a superposition of species that strive for resources in an equilibrium condition. In contrast, borders created by human action have a negative influence on the adjacent regions, affecting the density and composition of forest communities, which could lead to changes and strong imbalances (Laurance et al., 1998). This pattern is a very common situation in the areas under protection in Brazil, which suffer strong pressures along their borders. As stated by Roldán-Martín et al. (2006), ecological flows occur along these narrow borders, which define the major or minor damages occurring within the forests. Frequently, it is expected that the implementation of a highly restrictive legal environmental act will result in the formation of a more efficient barrier to human pressure within the protected area. This assumption leads to the following question: is the intensity of such restrictions related to the quality of the border scenarios? If this premise is true, one would expect that there is a damping of the human impacts compatible with the rigidity of the legal act within a certain timeframe.

According to Valverde et al. (2008) and Carranza et al. (2007), it is possible to evaluate border patterns over time to understand the effects of forest exploitation by humans as well as the environmental quality and characteristics of the landscape. Nevertheless, according to Teixido et al. (2010), studies rarely relate the extent of landscape conservation over time to the attributes of the borders.

* Corresponding author. +55 19 33057926.
E-mail addresses: talitanogueiraterra@gmail.com (T.N. Terra), rozefs@uol.com.br (R.F. dos Santos).

0264-8377/$ – see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.landusepol.2013.12.003

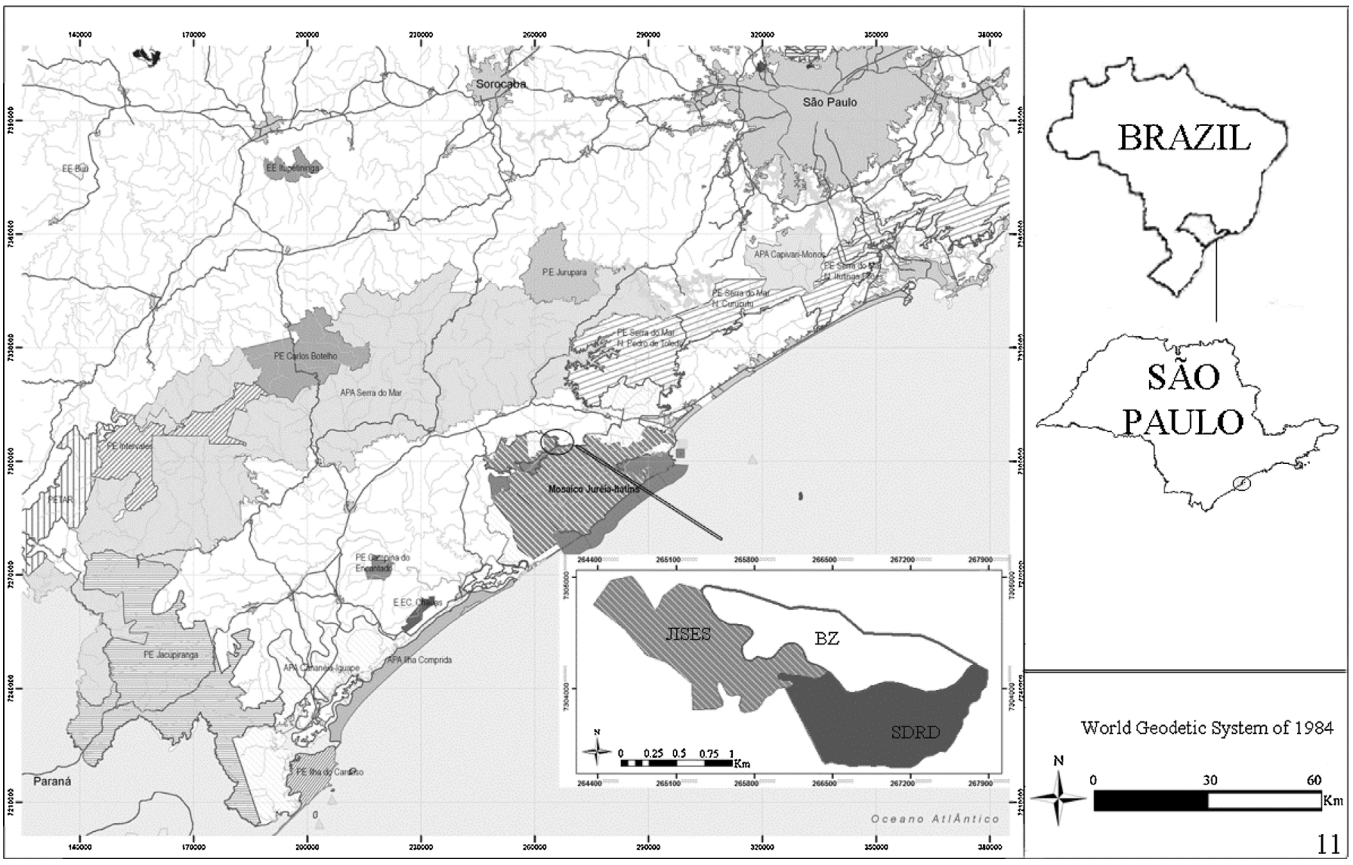

Fig. 1. Location of the study area (circled in black) on the coast of Sao Paulo – BR, covering three regions: the old Sustainable Development Reserve of Despraiado, the Jureia-Itatins State Ecological Station and the buffer zone.

Based on such considerations, this study emphasizes the possibility of recognizing the role of legal regulations in environmental protection over time in border areas with different restrictions regarding land use. The objective was to analyze and compare the buffering capacity of impacts on two protected areas as well as to verify the effective function of a legal barrier. If past scenarios are well recognized, it is possible to deduce how and where the borders will be located within few years and to support future political decisions regarding these areas.

Materials and methods

Study area

The study area is located in southern Sao Paulo State (Brazil) and includes three adjacent regions of 100 ha each that have been subject to different legal restrictions: the Despraiado Sustainable Development Reserve (SDR), the Jureia-Itatins State Ecological Station (SES) and the Buffer Zone (BZ) (Fig. 1).

Construction of the historical series of land use

To determine the land use changes, scenarios of the three areas were constructed for the years 1962, 1980, 2001 and 2007 (Fig. 2). For 1962–2001, digitized aerial photographs were obtained using a Vexcel Ultrascan 5000 photogrammetric scanner with 1200 dpi (dots per inch) resolution. All required radiometric and geometric corrections were performed, resulting in panchromatic images in TIFF format. A World View satellite image with 0.5 m PAN (panchromatic channel) spatial resolution (supplied by Forest Foundation, São Paulo, Brazil) was used for mapping the land use in 2007.

The WGS84 coordinate system was used. To use the digital georeferenced data in ArcGIS 9.2 software, five ground control points (GCPs) were obtained for each year using a TOPCON HIPER® LITE+ receiver. The GCPs were distributed throughout the image, generating an RMS error of less than 5.5 m. A first-order polynomial was applied using the nearest-neighbor procedure. The georeferenced materials were orthorectified using the software ENVI 3.5 (ENVI, 2001) with the Digital Terrain Model (IGC – Geographic and Cartographic Institute of Sao Paulo State, 2004) and the altitudes obtained from the TOPCON receiver with adjustments for local geoid undulation (orthometric altitudes).

The LUCC was mapped using a visual photo-interpretation of the geo-ortho-materials observed at a nominal scale of 1:3000. The mapped categories included secondary medium tropical rainforest, secondary initial tropical rainforest, tropical rainforest with banana plantation, pasture, agriculture, bare soil and human constructions.

Simulating future conditions

The 2028 land use was calibrated and simulated in four phases: (a) Markov Chain modeling; (b) the creation of maps of the landscape-driving forces; (c) multi-criteria analysis; and (d) the use of Markov Chains and cellular automata algorithms to generate a simulated map of land use/land cover (Fig. 2). All of the phases were constructed using the software IDRISI Andes (Kamusoko et al., 2009; Valente and Vettorazzi, 2008; Scarassatti, 2007).

This method was applied to the LUCC maps in raster format with a pixel size of 3 m × 3 m. The calibration was performed from 2001 onward, adjusting the simulation for 1962 and 1980. First, a Markov Chain analysis was applied with a time interval of 18 years (from 1962 to 1980) for the maps, and an interval of 21 years was