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Short Note

Temporal change of Distance to Nature index for anthropogenic influence monitoring in a protected area and its buffer zone

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ABSTRACT

This study applied and evaluated the temporal change of the Distance to Nature index (D_2N) for land use and cover monitoring in the Irati National Forest and its buffer zone (Southern Brazil) between 1986 and 2016. This study addressed the following questions: (1) Which land use dynamics were observed between 1986 and 2016 in the Irati National Forest and its buffer zone? (2) Is the analysis of D_2N evolution relevant to assess landscape dynamics in protected areas and their buffer zones? The degree of naturalness decreased after 1986. Statistical analyses showed a significant difference in the D_2N values between 1997 and all other years. We observed an increase of D_2N values in the 30-year period. The spatial D_2N trajectory map between 1986 and 2016 shows where the D_2N values changed, and enables us to infer where the differences observed could compromise the ecological condition of the protected area and its buffer zone. The results demonstrate that an analysis by means of D_2N can be an effective tool to monitor and assess anthropogenic influences on biodiversity in buffer zones around protected areas.

1. Introduction

Among the strategies for biodiversity conservation, we can highlight the legally protected areas, which are portions of land or sea intended for the maintenance of biological diversity and other natural processes *in situ* (Scherl et al., 2006). Land use effects on these areas require to be quantified, especially where there is a direct anthropogenic influence (Davis & Hansen, 2011). Several authors emphasize the need for the management and monitoring of buffer zones around protected areas, and not just the establishment of these areas (Wallace et al., 2005; Andrew & DeFries, 2007; Perelló et al., 2012; Gray et al., 2016). In Brazil, the Brazilian Protected Areas System established buffer zones as areas where the anthropogenic activities are accepted only under specific regulatory restrictions, in order to minimize negative impacts on biodiversity in all the Brazilian biomes (Brasil, 2000).

An important tool to buffer zone management is landscape analysis (Mariota et al., 2012), for detecting and quantifying anthropogenic effects in the landscape (Bogaert et al., 2011), especially by means of landscape pattern indices.

Rüdisser et al. (2012) developed an easily interpretable and highly comprehensible index called "Distance to Nature (D_2N)" as a tool to support the planning and evaluation of policy measures. By applying and analyzing D_2N in temporal sets of data from a periurban area in the Democratic Republic of the Congo, André, et al. (in press) evaluated the evolution of D_2N by a temporal change map. Nevertheless, the study of the temporal evolution of D_2N in protected areas and its buffer zone has not yet been reported.

We therefore analyzed the application of D_2N to study the landscape temporal change in the Irati National Forest and its buffer zone (Southern Brazil) between 1986 and 2016. This study addressed the following questions: (1) Which land use dynamics were observed between 1986 and 2016 in the Irati National Forest and its buffer zone? (2) Is the analysis of D_2N evolution relevant to assess landscape dynamics in protected areas and their buffer zones?

2. Materials and methods

2.1. Study area

The study area consisted of the Irati National Forest and its buffer zone of 10 km width, which encloses an area of 69.077 ha. This width was based on standards predetermined by one of the funding projects,

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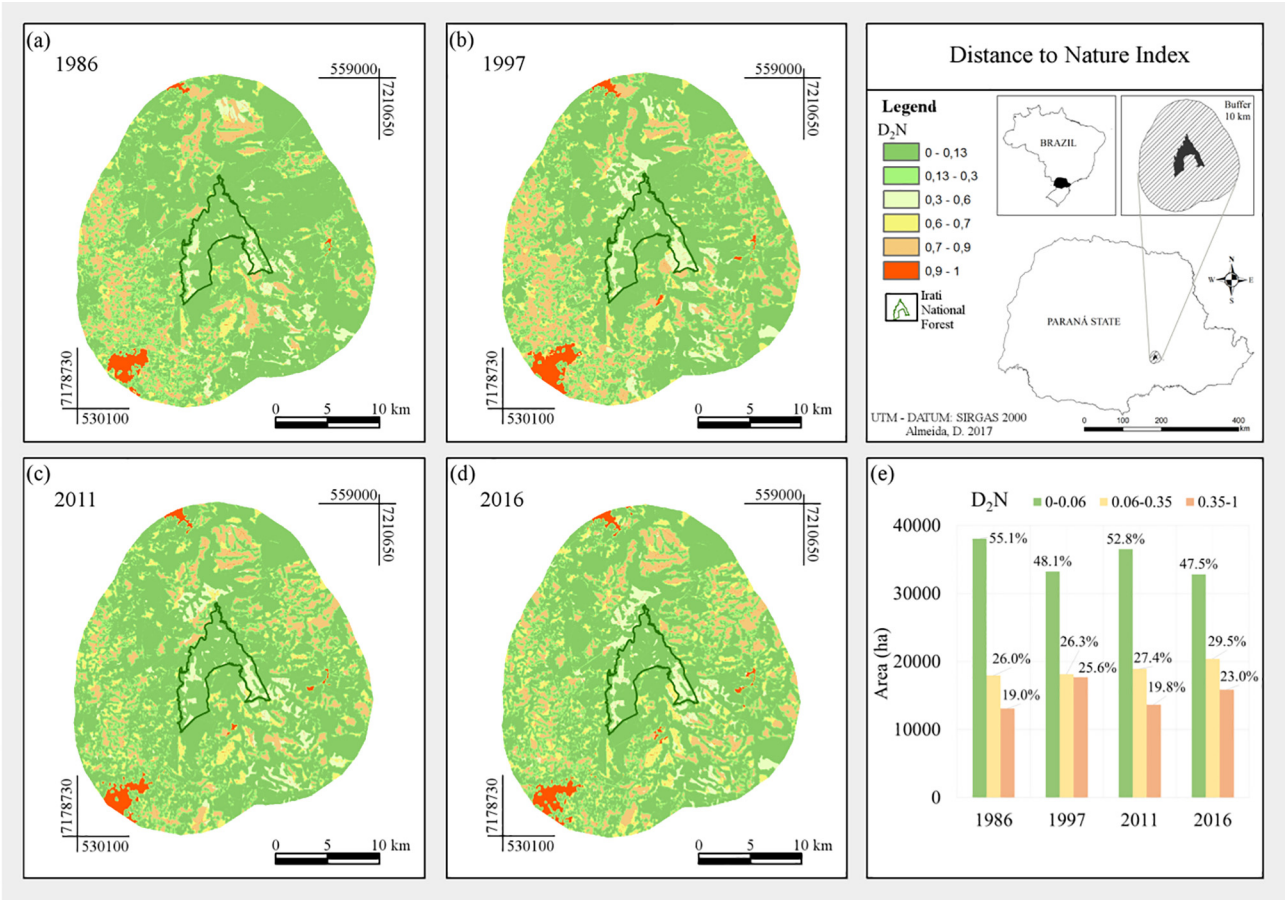

Fig. 1. Distance to Nature (D_2N) index values for the Irati National Forest (Brazil) buffer zone in 1986 (a), 1997 (b), 2011 (c) and 2016 (d). In (e) there is a summary of the D_2N values classified into the three categories. The study area localization is showed at the legend.

the *Conservabio*. This area is situated on the Second Plateau of Paraná (Mazza et al., 2016) (Fig. 1). The climatic region is classified as Cfb (Köppen classification system), Mesothermal – Humid Subtropical, characterized by cool summers, frequent and severe frosts and no dry season (Caviglione et al., 2000). The buffer zone of the Irati National Forest is a transition area regarding geomorphological and phytophysiognomic aspects. The Eastern portion (Teixeira Soares and Fernandes Pinheiro municipalities), is characterized by smoother reliefs and initially by grassland mosaics associated with Araucaria Forest (Maack, 2002). The original landscape in the Central and Western portions (Irati and Imbituva municipalities) was forest-dominated. These biotic characteristics influenced both the human occupation history and, consequently, the development of different agricultural systems. In the Eastern region, intensive farming with large farms can easily be identified, while in the Western region small farms are observed, predominantly related to family farm systems (Almeida, 2017). The Western region also has an important "biocultural" system (Hong, 2014; Bogaert et al., 2014) called *Faxinais*, a silvopastoral system characterized by the extraction of non-timber products (*Araucaria angustifolia* (Bertol.) Kuntze seeds and *Ilex paraguariensis* A. St. Hill. leafs), and concomitant animal subsistence production in shared areas among the local farmers (Yu, 1988). Furthermore, Yu (1988) states that there is some evidence that the *Faxinais* promoted conservation in Paraná State as a whole.

2.2. Land use and cover and D_2N dynamics

The land use classification was carried out in ArcMap 10.2 software by visual on-screen digitizing of LandSat-5 and LandSat-8 imagery obtained for 1986, 1997, 2011 and 2016. These images have a spatial resolution of 30 m and a spectral composition of three bands. We chose the on-screen digitizing due to the unsatisfactory results obtained by the supervised classification, especially due to the similar spectral signature of agriculture and herbaceous vegetation in the study area. We also used topographic maps from the Brazilian Ministry of Defense to identify present road networks. The interpretation key for the land cover was established by visual image interpretation using the criteria of tone, texture, and context (Moreira, 2011), on a scale of 1:50,000, and by field visits in different years.

The D_2N method combines two indicators, the Degree of Naturalness (N_d), that uses a hemeroby scale to classify the land use and cover information, and the Distance to Natural Habitat (D_n), which considers, for each pixel, the Euclidean distance to the next habitat patch within the data set classified as one of the two most natural hemeroby levels: "natural" or "near natural" (Rüdisser et al., 2012). Rudisser et al. (2012) uses a cutoff value for D_n in order to account for the nonlinear decrease related to the influence of nearby natural habitats. We represent this limit by D_{max}, as shown in (Eq. (1)). More details about the D_n and N_d calculations can be found in Rudisser et al. (2012).

$$D_2N = \begin{cases} \frac{\sqrt{D_n}}{\sqrt{D_{max}}} \cdot \frac{(N_d - 1)}{6}, & D_n < D_{max} for\ each\ pixel \\ 1 \cdot \frac{(N_d - 1)}{6}, & D_n \geqslant D_{max} for\ each\ pixel \end{cases} \quad (1)$$

To complement the D_2N methodology, we studied the temporal change by calculating the spatial D_2N dynamics, between 1986 and 2016, by subtracting the D_2N values (raster file) between years (Eq. (2)), using a map algebra tool in ArcMap 10.2 software (André, et al., in