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Evaluation of forest cover change using remote sensing techniques and landscape metrics in Moncayo Natural Park (Spain)

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ABSTRACT

Monitoring the change in land cover in natural places, such as ecotones, has become an important tool for forest management, especially in protected areas. The present work analyses the spatial and temporal changes in forest cover in Moncayo Natural Park (Spain) from 1987 to 2010 using remote sensing techniques, geographical information systems (GIS) and quantitative indices of landscape ecology. Four Landsat images were used to map nine representative land cover categories in this preserved area in both years. The overall classification accuracies in land cover cartographies in 1987 and 2010 were 87.65% and 84.56%, respectively. Landscape metrics obtained at the landscape level show an increase in fragmentation and, as a result, an increase in landscape spatial diversity. Focusing on the class level, the results show a forest expansion of sessile oaks (*Quercus petraea*) and beech forest (*Fagus sylvatica*), two important bioclimatic indicators in this natural park, because they are the southernmost locations for these species in Europe. The decrease of mainly introduced pine forest and the transformation of mixed shrub areas into natural forested areas explain the aforementioned increase in fragmentation. These results are in agreement with the strategies for nature conservation designed by forest managers during the period evaluated.

Introduction

An ecotone is a transitional area between two neighbouring biomes that contain different vegetation types (Risser, 1995). These areas contain more biodiversity than other adjacent areas. In addition, they are more sensitive to environmental disturbances and are, therefore, interesting locations for studies of vegetation dynamics. In the ecotones, many species are at their distributional limits; therefore, ecotones are regarded as a sensitive monitor of global climatic change (de Andrés, Camarero, & Büntgen, in press; Risser, 1995).

Moncayo Natural Park is a mountain ecotone in a transitional zone between the Eurosiberian and Mediterranean biogeographical regions (Longares Aladrén, 2004). Within a small area, this hotspot contains an important assortment of vegetation types, such as beech, sessile oak, Pyrenean oak, Holm oak, Scots pine, European black pine, mountain pine, maritime pine, birch, gallery forests, junipers, other shrubs, mixed Mediterranean scrubs and mountain pastures.

This area, like the majority of Mediterranean mountains, has been highly influenced by resource exploitation over time because the Mediterranean landscape is one of the most modified places on Earth (Myers, Mittermeier, Mittermeier, da Fonseca, & Kent, 2000). However, the intense use of natural resources by rural societies until the first half of the 20th century has been followed by an important decrease in traditional uses since then (Heredia-Laclaustra, Frutos-Mejías, & González-Hidalgo, 2013; Lasanta, Gonzáez-Hidalgo, Vicente-Serrano, & Sferi, 2006). In the last three decades, land has been mostly abandoned in terms of human uses, and as a result, ecosystems have changed and evolved naturally (García-Ruiz et al., 1996). Some of these ecosystems have high natural values and protection through forest management actions, and a protection policy is necessary to guarantee the preservation of natural values. Forest ecosystems are especially important not only for sustaining biodiversity; they also have important functions

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from a social and economic point of view (Çakır, Sivrikaya, & Keles, 2008). This area was declared to be an area of environmental protection in 1927 and renamed as a natural park in 1978 due to the importance of Moncayo mountain biodiversity and the presence of one of the southernmost sessile oak and beech forest stands in Europe. Thereby, the study of forest cover dynamics in an objective manner and with a replicable procedure in this area is necessary to evaluate whether management plans applied for natural conservation are working correctly.

The generation of land-cover cartography from satellite image processing is one of the most important and contrasted remote sensing applications. From this cartography, it is possible to obtain and analyse the spatial pattern of vegetation cover in a territory. This information has been used in the field of landscape ecology to study the territorial spatial pattern, which helps to understand many ecological processes with a strong spatial component. From the point of view of biodiversity conservation and sustainable development, considering these processes is a fundamental requirement for applying spatial management plans for establishing administrative rules and for designing strategies for nature conservation (Burel & Baudry, 2002). In addition, monitoring forest cover change through time to define the forest structure and dynamics has become increasingly important as a resource for forest management for determining the wealth of biodiversity (Başkent & Jordan, 1996; Esbah, Deniz, & Kara, 2010).

Remote sensing techniques have many advantages over other traditional techniques based on field work or only in geographical information systems (GIS) such as a visualization of the global Earth surface; the acquisition of information in non-visible zones of the spectrum; and the use of different scales, high frequency and homogeneous information, historical records and low-cost information (Chuvieco, 2008; Pôças, Cunha, Marcal, & Pereira, 2011). Considering these characteristics, remote sensing has become one of the most powerful and useful tools for studying global processes such as global warming (Chuvieco & Justice, 2008; Lillesand, 2006). In this context, Landsat images have been used the most for determining forest cover and measuring forest cover change (Townshend et al., 2012). Detecting land cover change in mountainous areas using land-cover cartography from satellite imagery is the principal aim of studies such as Pôças, Cunha, Marcal, et al., 2011; Çakır et al., 2008 or Keles, Sivrikaya, Çakır, & Köse, 2008, and the knowledge of these changes has been useful to forest management of protected areas (Jones et al., 2009; Kim & Daigle, 2011; Shen, Sakal, & Kaji, 2011).

Conversely, landscape ecology has developed a simple nomenclature (Forman & Godron, 1986) and some quantitative indices to describe and analyse the landscape pattern (Haines-Young & Chopping, 1996), which have permitted the quantification of the fragmentation, connectivity and diversity of landscapes – three basic concepts for describing landscape structure. The ability to quantitatively describe the structure is a prerequisite for the study of landscape function and change (McGarigal & Marks, 1995). Several studies evidence the value of these indices for the evaluation of protected areas, Mediterranean forests and mountainous areas (Bracchetti, Carotenuto, & Catorci, 2012; Cohen, Varga, Vila, & Barrussaud, 2011; Geri, Rocchini, & Chiarucci, 2010; Lasanta et al., 2006; Pelorosso, Della Chiesa, Tappeiner, Leone, & Rocchini, 2011). In this context, many studies using remote sensing techniques and landscape ecology metrics can be found in the literature (Başkent & Kadıoğulları, 2007; Çakır et al., 2008; Keles et al., 2008; Pôças, Cunha, Marcal, et al., 2011; Teixido, Quintanilla, Carreño, & Gutiérrez, 2010; Terzioğlu, Başkent, & Kadıoğulları, 2009).

The aim of this work is to describe and analyse land cover changes in Moncayo Natural Park from 1987 to 2010 through quantitative landscape indices over land cover cartographies of both years obtained with a supervised classification of four Landsat images. Despite the ecological value of this natural park, it has never been studied before under this perspective. The results of this study can be useful for evaluating the strategies for nature conservation designed by forest managers during the period evaluated, and they are also vital to future management.

Study area

Moncayo Natural Park is located in the Iberian range in the northeast of the Iberian Peninsula (coordinates of centroid X, Y: 602418 E, 4624152 N, UTM 30T, European Datum 1950; EPSG 23030). The area covers 11.226 ha, and the elevation ranges from 580 m to 2.314 m above sea level (Fig. 1).

Moncayo Mountain belongs to the Mediterranean biogeographical region, which is characterized by hot and dry summers, mild winters and seasonal precipitation during winter and spring. However, the climatic conditions change along the altitudinal gradient, becoming more cold and humid. The contrasting climate conditions allow the growth of different types of vegetation, from several species of oaks (*Quercus ilex*, *Quercus pyrenaica* and *Quercus petraea*), pines (mostly *Pinus sylvestris*, *Pinus nigra* and *Pinus uncinata*), beech forest (*Fagus sylvatica*) and mountain pastures at high altitudes.

Traditionally, forest logging and cattle exploitation have been intensely operated by locals in this region. At the beginning of the 20th century, forest plantations were established, and the pine species mentioned were introduced. Beech and sessile oak forests are isolated in this natural park, limited by warm and dry conditions to the base of the mountain. This is one of the southernmost locations for these species in Europe.

Materials and methods

Satellite imagery and data processing

Landsat Thematic Mapper (TM) satellite imagery was used to map land cover, focusing on forest classes, and to obtain a

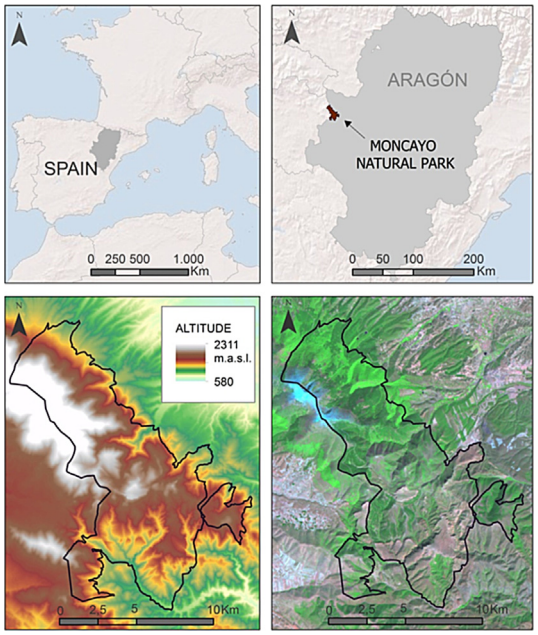

Fig. 1. Location map of Moncayo Natural Park (surrounded by a solid black line). The altitudinal gradient and Landsat TM image of the study area are shown below.