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Measuring mosaic diversity based on land use map in the region of Madrid, Spain

J. Velázquez[a,b,*], J. Gutiérrez[a,*], A. Hernando[b], A. García-Abril[b], M.A. Martín[c], P. Irastorza[d]

[a] Catholic University of Ávila, Spain
[b] SILVANET Research Group, E.T.S. de Ingenieros de Montes, Technical University of Madrid, Spain
[c] Rey Juan Carlos University, Spain
[d] Iberdrola España SA, Spain

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ABSTRACT

Ecological sustainable landscapes require that their ecological processes can be sustained over time. Spatial heterogeneity is recognized as a very influent factor in biological diversity, but there is still a need to evaluate how this heterogeneity changes with scale and how pattern or processes change with the definition of the detail level, so this is the aim of this study.

A six level hierarchical land use map, comprising 7244 patches and 646 different land units was generated for the Region of Madrid. We calculated heterogeneity pattern indices, based on information theoretic measures (Shannon diversity index, Evenness) and fractal geometry index. The study area has been the Region of Madrid (8000 Km^2) and three partitioning zones (sub-regions or macro-landscapes) of the territory, using vector-based techniques.

Territorial diversity is measured and different detail levels are compared from the hierarchical land use map. This analysis could establish the appropriate level of information necessary to reflect significant heterogeneity measurements.

The analysis shows that index values rise for each level and for the three studied zones. These values suggest that when the hierarchical classification has an increment in the detail level, the amount of information is broader and explains the spatial heterogeneity results. Zone analysis suggests that the woodland area contribution to Shannon index is higher than for less forested zones.

The conclusions drawn are that the regional level is not adequate for territorial diversity evaluation, whenever it contains macro-landscapes and sub-regions with wide physical or land-use differences. Another conclusion is the importance of increasing forest area in agricultural areas or high urban component, to increase landscape diversity.

This study allows for a better comprehension of territorial patterns and their meaning. It identifies the most influential land uses to heterogeneity from variations on the territorial pattern diversity, providing a simple and accessible methodology for the study of landscape processes.

1. Introduction

The development of ecological sustainable landscapes requires that patterns of future landscapes sustain the necessary ecological processes in the landscape. It is important to determine the actual forces that maintain diversity and habitats in particular (Lovett et al., 2005; Hernando et al., 2010; Velázquez et al., 2010). Therefore, landscape ecology must co-evolve with spatial planning (Opdam et al., 2002).

The concept of territorial diversity is concerned with relationships between ecological processes and spatial patterns, particularly at large scales (Dranstad et al., 1996; Sheppard and McMaster, 2007). In this sense, both ecological processes and the spread of disturbance occurring in the landscape have important spatial components (Turner and Gardner, 1991; Forman, 1997; Herzog and Lausch, 1999; Saura et al., 2011).

On the other hand, biodiversity refers to the variety of life forms, especially the number of species, including the number of ecosystem types and the genetic variation within species (Hong et al., 2007). In line with this concept of biodiversity, it is found that the effect of patch size on species number has been much studied in terms of several issues, like the structure of the mosaic, that strongly affects crop growth and erosion on a farm, biodiversity and aesthetics in a park, wood

* Corresponding authors at: Catholic University of Ávila, Calle Canteros s/n, CP:05005, Ávila, Spain. Tel.: +34660947280; Fax: +34920251030.
E-mail addresses: javier.velazquez@ucavila.es (J. Velázquez), javier.gutierrez@ucavila.es (J. Gutiérrez).

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production and fish in a forest, wildlife movement and extinction in a refuge, water and livestock production on a ranch, and ecological characteristics of a town (Forman, 1997). However, habitat diversity and disturbance are the most important factors to explain patch species richness in terrestrial ecosystems (Forman and Collinge, 1995; Rodríguez-Loinaza et al., 2015; Song and Kim, 2015).

Landscape Ecology emphasizes the spatial and temporal arrangements of ecosystems and the resulting ecological effects at broad spatial scales (Turner, 1989). In quantitative landscape ecology, as in spatial pattern analysis, there is a need to evaluate how heterogeneity changes with scale (Dale 1999; Castilla et al., 2014; Shen et al., 2013; Makalew et al., 2015). Exactly how pattern or processes change continuously with scale is still unresolved (Blaschke and Petch, 1999; Wu, 2004; Wu, 2006; Zhao et al., 2012; Liu et al., 2013).

Quantitative analysis of the above mentioned relationships require the development of quantitative measures of landscape pattern (McGarigal and Marks, 1994). A wide variety of pattern indices may be necessary to accommodate the many different data types and formats used by landscape ecologists.

> "Because human land also uses have the capacity to alter landscape diversity, changes due to an increased human population and altered patterns of agriculture and forestry need to be incorporated into predictions of future landscape diversity" (Schulze and Mooney, 1994). The human impact has been widely discussed in several researches (Ulrich 1986; Jenerette and Wu, 2001; Lambin and Geist, 2006; Ruiz and Domon, 2009; Carabelli and Scoz, 2008; Núñez et al., 2011). In particular, the influence of the spatial pattern of forest patches on other ecological phenomena and processes such as biodiversity have been also investigated (Newton, 2007; Mlandenoff and Baker, 1999; Hooper et al., 2005; Mitchley et al., 2006; Saura et al., 2011). Practical tools in the study of landscape are landscape indices, such as Fractal dimension and Shannon Diversity were used to characterize spatial heterogeneity and spatial pattern processes (Pan et al., 2001; Crawford et al., 2006; Farina, 2007; Rodríguez-Loinaza et al., 2015). As Krummel et al. (1987) proposed, Shannon Diversity and Evenness indices (Shannon and Weaver, 1962) and fractal dimension (Mandelbrot, 1983) are reasonably independent from each other and capture gross features of landscape pattern, especially in forested landscape.

Although many studies have identified the influence of forest patches on ecological phenomena and process, and spatial heterogeneity has been widely studied, less is known about the influence of suitable scales to monitor landscape diversity. This study aims to fill this gap, focusing its objectives in; firstly, testing if the specific data sets (land use map) may determine different detail levels to study landscape diversity. Secondly, finding a suitable way of quantifying the contribution of forest to landscape diversity. Within this study different levels of information that reflect different scales are established. If patterns and processes change continuously with scale, then the results at one scale can be extrapolated to other scales, once the scaling factor is known (Farina, 2007; Blaschke and Petch, 1999).

2. Material and methods

2.1. Description of the research. background

The study area is the Region of Madrid (Spain) (Fig. 1). The research was undertaken for the whole Region (800,000 ha) and for three different zones within Madrid (Zone 1-North; Zone 2-Center; Zone 3-South), as shown in Fig. 2.

The study area was divided into three zones for two reasons. First, it considers the different geomorphological formations present in the region. Generally, the Zone 1 is mostly mountain range (heights between 800 and 2400 m), where acid rocks (granite and gneis) are presented; Zone 2 is central area (heights between 500 and 800 m) characterised by extensions of dry farming and shrublands, accompanying periurban Mediterranean forest, where sedimentary sandy acid rocks are dominant. Madrid City and suburban towns with industrial areas, are included within this Zone. Finally, Zone 3 is a lowland area (300–800 m), characterised by a plateau and valley landscapes on gypsum and limestone soils, dominated by agricultural uses. Second, the division sets a similar area for the three zones (Fig. 2).

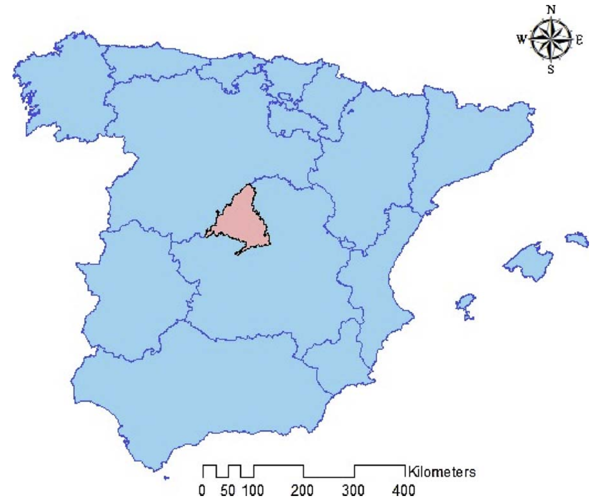

Fig. 1. Location of study area, Region of Madrid (Spain).

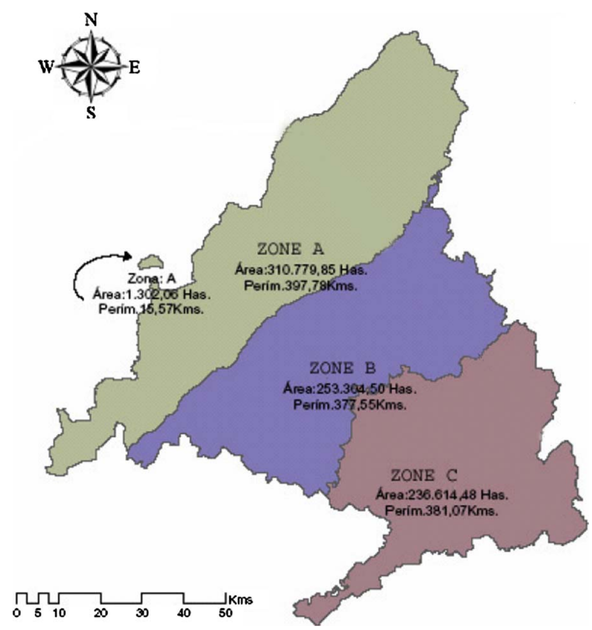

Fig. 2. Division of the three zones in the study area.

2.2. Description of the land use map

The land use map used as the basis of the work, was created digitising over SPOT satellite images (20 × 20 m resolution), with the assistance of colour aerial photos on 1:18000 scale searching for as much detail as possible, and with ground truthing. The minimum area set for the identification of land use categories is 0.2 ha. As a result 7244 independent patches were identified for the whole study area within the hierarchical classification of the homogeneous land use unit performed (Fig. 3). The land use unit represents the occupational use of land either if there is vegetation or not. The classification of land units was based on physiognomy, structure and dominant species, and present mosaics.

The result of this classification is a legend with 646 categories at its