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Relationship between landscape heterogeneity and plant species richness on the Mexican Pacific coast

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A B S T R A C T

The present study aims to use landscape heterogeneity as a predictor of plant species richness in a tropical dry landscape area in the coast of Michoacán, Mexico. To understand the relationship between species richness and landscape, a three-step approach was followed: first, landscape spatial heterogeneity was measured by classifying landscape types according to their attributes (i.e., environmental, soil and topographic variables). Second, several diversity standard indices were used to explore biological diversity and to select the best one explaining the relationship between landscape heterogeneity and plant species richness, for this study area. Third, from the obtained results it was possible to calculate biodiversity values on the basis of landscape heterogeneity. The results indicate that it is possible to predict more than 61% of species richness through an indicator of landscape heterogeneity (H'; Shannon–Weaver diversity index). This procedure may be useful in terms of land use, conservation, and management of protected areas, mainly in areas with high biodiversity but with limited biological data, since it allows to obtain an approximation of the spatial distribution of species richness, even with scarce biological information.

Introduction

Biodiversity is a central element in the discussion of the global environmental crisis (Butchart et al., 2010; Walker & Steffen, 1999). The accelerated loss of biodiversity is a complex response to severe environmental changes mainly caused by land-use change and consecutive landscape fragmentation (Butchart et al., 2010; Geri, Amici, & Rocchini, 2010; Lambin et al., 2001; Vitousek, Mooney, Lubchenco, & Melillo, 1997). The development of suitable methods for assessing components of current diversity and for predicting the negative effects of land-use change on biodiversity is still an important task of landscape ecological research (Schulz, Cayuela, Echeverria, Salas, & Rey-Benayas, 2010; Waldhardt, Simmering, & Otte, 2004). Over the past decade, great efforts have been made to develop and refine assessment methods to identify priorities for conservation planning (Margules & Pressey, 2000; Pressey, Cabeza, Watts, Cowling, & Wilson, 2007). Due to the speed at which negative processes of land-use change are causing landscape fragmentation and habitat loss, it has become necessary to develop theoretical and methodological tools that facilitate the prediction of species richness (alpha diversity) in complex territories through indicators of spatial variability (Gaucherel, 2007; Lubchenco et al., 1991), mainly in territories where available information about biodiversity is scarce.

Species distribution models attempt to provide detailed predictions of distributions by relating the presence or abundance of species to environmental predictors. Predictions of species' distributions are important for practitioners to properly evaluate the impact of climate and land use on the distribution, composition and structure of biodiversity (Geri et al. 2010; Guisan & Thuiller, 2005).

Research on biodiversity and geographical structure has been achieved on the basis of various criteria, primarily on vegetation types because they summarize the most tangible expression of the environmental components (Fahrig et al., 2011; Forman, 1995, 632 pp; Myers, 1990). Species richness is one measure that is commonly used to determine priority areas for conservation and protection at regional and global scales (Lindborg et al., 2008; Margules & Sarkar, 2007; Myers, Mittermeier, Mittermeier, Fonseca, & Kent, 2000). Several approaches have used wildlife species information to make

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predictions of species richness and to define priority areas for conservation (see Bojórquez-Tapia, Azuara, Ezcurra, & Flores-Villela, 1995; Kiester et al., 1996; Peterson, Egbert, Sánchez-Cordero, & Price, 2000; Rodríguez-Soto et al., 2011). Different approaches have been applied to different geographical variables, including climate and land-use change (Iverson, Prasad, & Schwartz, 1999); temperature, rainfall and rock type (Wohlgemuth, 1998); slope, aspect, and soil drainage (Nichols, Killingbeck, & August, 1998); and climate variability and soil type (Clinebell, Phillips, Gentry, Stark, & Zuuring, 1995). More recently, spatial heterogeneity and its role in biodiversity distribution has been approached by using topographic variables to assess its relationship with vegetation diversity (Pérez, Mas, Velázquez, & Vázquez, 2008); plant species richness (Hofer, Wagner, Herzog, & Edwards, 2008; Kumar, Stohlgren, & Chong, 2006; Waldhardt et al., 2004); bird, amphibian, and reptile species richness (Atauri & Lucio, 2001; Davies et al., 2007); and butterfly responses to plot-level characteristics (Kumar, Simonson, & Stohlgren, 2009; Weibull, Bengtsson, & Nohlgren, 2000). In many cases, spatial heterogeneity is measured by separating the components of landscape heterogeneity (i.e., environmental, soil and topographic variables) to understand the direct relationship between species richness and each of the biophysical components (Kumar et al., 2006). The landscape approach has been used as a proxy to provide a solid theoretical and methodological basis for understanding the ecological functioning of landscapes and to clarify the influence of spatial heterogeneity in the distribution of biodiversity (Atauri & Lucio, 2001). Most of the abovementioned research used isolated environmental variables or land cover/uses as predictors. In this study, we instead explore the prediction of species richness on the basis of integrated spatial units. In other words, we use landscape heterogeneity.

The main goal of this study is to explore the relationship between landscape heterogeneity and plant species richness in an area of the Pacific coast of Michoacán in Mexico. According to Atauri and Lucio (2001), the parameters referring to landscape structure are essential in any conservation evaluation because of the relationship existing between the landscape structure and the ecological processes. Therefore, our results are further discussed in terms of their potential use in the definition of conservation priorities and land management in this area of the Mexican Pacific coast.

Materials and methods

Study area

This region is part of the Sierra Madre del Sur physiographic province. Running from Northwest to Southeast Central Mexico, it is located at the junction of the transition between the Nearctic and Neotropical bio-geographical regions. This geographic location determines the biological richness of the area (Rzedowski, 1991). The study area is located in the municipality of Coahuayana, southwest of the state of Michoacán. The study area is located between 18° 38′ and 18° 43′ North latitude and 103° 44′ and 103° 40′ West longitude and covers an area of 35.95 km^2 (Fig. 1).

Methodological framework

According to Hasse (1986), the most important feature of landscapes is their heterogeneous structure. Spatial heterogeneity is a structural feature of landscapes that can be defined as the complexity and variability in space of the properties of a natural system (Fahrig et al., 2011; Li & Reynolds, 1994). The heterogeneity may be related to species diversity, resilience or ecosystem function (Huston, 1999), and it has a great influence on major biotic and abiotic processes, such as the alteration of the landscape and the movement of organisms

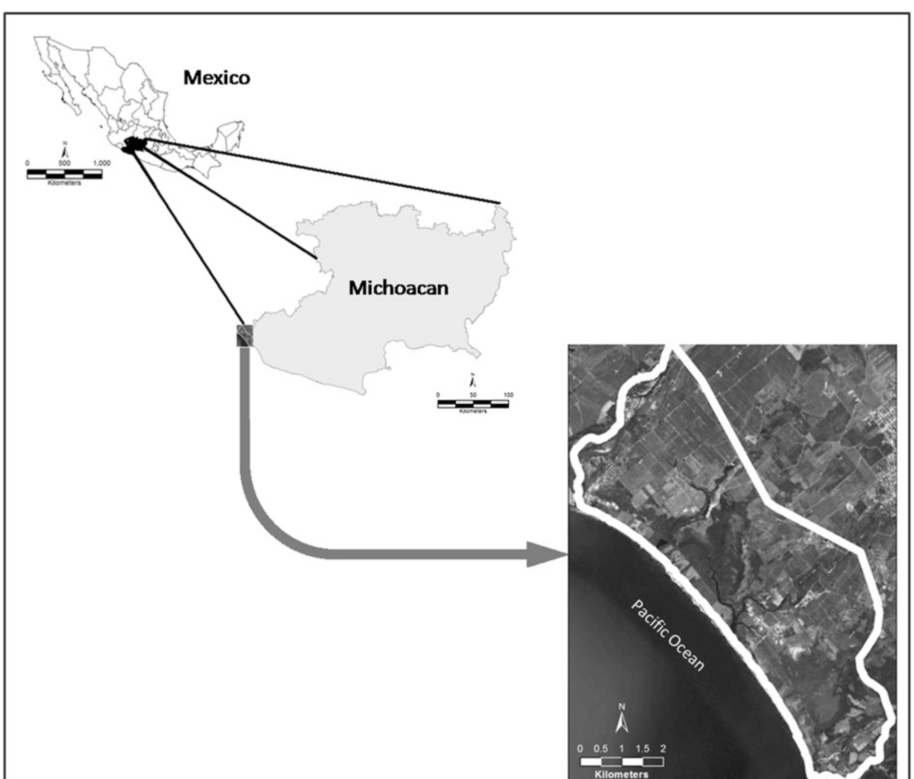

Fig. 1. Location of the study area.