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Identifying socio-ecological networks in rural-urban gradients: Diagnosis of a changing cultural landscape

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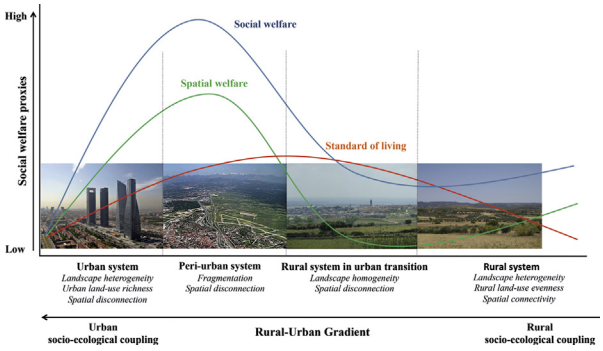
HIGHLIGHTS

- We used a method that detects socio-ecological networks in rural-urban gradients.
- The method links socio-ecological types with spatial patterns and social welfare.
- Our model highlights the coupling between landscape and socioeconomic structures.
- The results detect municipality types along a rural-urban gradient in Madrid Region.
- The proposed model can improve land planning from a socio-ecological perspective.

GRAPHICAL ABSTRACT

Graphic scheme that summarizes the social welfare pattern identified in the rural-urban gradient of Madrid Region. Curve tendencies of social welfare proxies are based on statistically significant values obtained for each socio-ecological group. Landscape pattern of each type of municipalities is indicated along the abscissa axis.



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ABSTRACT

Socio-ecological systems maintain reciprocal interactions between biophysical and socioeconomic structures. As a result of these interactions key essential services for society emerge. Urban expansion is a direct driver of land change and cause serious shifts in socio-ecological relationships and the associated lifestyles. The framework of rural-urban gradients has proved to be a powerful tool for ecological research about urban influences on ecosystems and on sociological issues related to social welfare. However, to date there has not been an attempt to achieve a classification of municipalities in rural-urban gradients based on socio-ecological interactions. In this paper, we developed a methodological approach that allows identifying and classifying a set of socio-ecological network configurations in the Region of Madrid, a highly dynamic cultural landscape considered one of the European hotspots in urban development. According to their socio-ecological links, the integrated model detects four groups of municipalities, ordered along a rural-urban gradient, characterized by their degree of biophysical and socioeconomic coupling and different indicators of landscape structure and social welfare. We propose the developed model as a useful tool to improve environmental management schemes and land planning from a socio-ecological perspective, especially in territories subject to intense urban transformations and loss of rurality.

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1. Introduction

Socio-ecological systems (SESs) are complex adaptive systems, which emerge from coupled social and ecological structures providing a powerful frame for understanding the highly dynamic interactions of ecological and societal changes (Liu et al., 2007; Ostrom, 2009; Gatzweiler, 2014). SESs are co-evolving systems maintaining a constant and reciprocal interaction and feedbacks between territorial and socio-economic structures (Norgaard, 1994; Gual and Norgaard, 2010; Lambin and Meyfroidt, 2010). As a result of these interactions key essential services for society emerge (Reyers et al., 2013).

Human transformation of land uses has led to the loss and abandonment of most intangible ecosystem services, especially those related to the regulation of not only ecological processes, but also cultural, such as local identity, traditional knowledge and spiritual enrichment (Slemp et al., 2012). Thus, current land use changes, mainly due to agricultural intensification and urbanization processes, cause serious shifts in socio-ecological interactions (Lambin et al., 2001; Plieninger et al., 2016). Urban expansion is considered worldwide as one of the primary direct drivers of land change and habitat loss and the most dramatic form of land transformation that profoundly influences biological diversity, ecosystem services and their links to human well-being and social welfare (Luck and Wu, 2002; Foley et al., 2005; Díaz et al., 2006; Fisher and Turner, 2008; Seto et al., 2012; Wu, 2013; Newbold et al., 2015). Urbanization processes not only transform rural or natural landscapes into urban systems, but also modify complex socio-ecological relationships through demographic and economic changes, as well as the associated lifestyles (Antrop, 2004; Seto et al., 2010).

In the last decades the progressive urban expansion, related to the increment in the size of cities and rural abandonment (Vos and Klijn, 2000; Antrop, 2005, 2006), has motivated the interest for understanding urban-rural gradients (McDonnell et al., 1993, 1997; Haase and Nuissl, 2010; among others). The gradient paradigm is a powerful tool for ecological research on urban influences on ecosystems (McDonnell et al., 1997; Metzger et al., 2010; Vizzari and Sigura, 2015; Salvati et al., 2017) and an appropriate framework to study sociological issues related to quality and standard of living (Savitch, 2003; Berry and Okulicz-Kozaryn, 2011; Gómez-Baggethun and Barton, 2013).

Nowadays, there are sophisticated methodological tools to quantify the interactions between nature and society (Salvati and Zitti, 2009; Salvati and Serra, 2016; Schmitz et al., 2012, 2017a). However, there is little consistency in the methods used to characterize and quantify urbanization gradients (Raciti et al., 2012; Gianotti et al., 2016) and to date, socio-ecosystem classifications in urban-rural gradients have been based on land use changes (Antrop and Van Eetvelde, 2000; Aguilera et al., 2011; Rubiera Morollón et al., 2016, among others), but not on socio-ecological interactions.

The aim of the present study is to fill this lack of knowledge by means of a conceptual and methodological approach that allows classifying SESs interactions along rural-urban gradients, based on the quantification of links between ecological and socioeconomic structures. To this end, we applied numerical procedures that enabled us i) to detect types of socio-ecological relationships along urban-rural gradients; ii) to formalize the degree of coupling between landscape and socioeconomic structures; iii) to identify the main socio-ecological indicators of this complex interaction system, and iv) to establish links between socio-ecological typology, landscape patterns and different measures of social welfare. Thus, we used different tools to achieve each of the proposed objectives. In a first step, we performed a multivariate analysis to identify groups of municipalities based on their degree of socio-ecological coupling and to know the main indicators of the interaction system. In a second step, we considered information on social welfare variables and landscape metrics for the characterization of each of the socio-ecological groups.

The outcome of this methodological approach will generate baseline information necessary for the development of socio-ecological models of land planning and management (Kasanko et al., 2006; Hara et al., 2008; Tavares et al., 2012), which can be used as a tool to maintain and restore the multifunctionality of cultural landscapes and its impact on changes in social welfare (Fisher and Turner, 2008; Fisher et al., 2009).

2. Methods

2.1. Study area

We studied the rural-urban gradient of the Madrid Region (Central Spain; Fig. 1), considered nowadays one of the European hotspots in urban development (European Commission, 2006; Kuemmerle et al., 2016). In this area, with *c.* 8000 km^2, the altitude constitutes the major ecological factor (Schmitz et al., 2007), ranging from 400 m asl in the valleys to altitudes of 2000 m on the mountain summits. One-third of the area, to the north and west, is occupied by mountainous siliceous terrain and foothills and exhibits well-differentiated altitudinal belts with oak and pine forests, upland grasslands and silvo-pastoral uses. The remainder area to the centre and east is the sedimentary basin of the Tagus River that originates an agricultural landscape. Along this environmental gradient, there is a clear variation of land cover and land uses, which gives rise to different types of landscape.

From the earliest times, this territory has been used for different human activities, such as traditional mixed rural systems based on agriculture, forestry and grazing (Schmitz et al., 2007; Schmitz et al., 2017b). Until the industrialization process in 1950′s, the boundaries between Madrid City and the countryside appeared fairly well defined. Over the last few decades, this region, as other European cultural landscapes, has changed through a bidirectional process of land use intensification and rural abandonment (Kuemmerle et al., 2016; Schmitz et al., 2017b) which has caused important modifications in the old urban-rural dichotomy (Stellmes et al., 2013). The urban growth of Madrid is a particularly paradigmatic case in Spain due to its importance, size and recent development, which mainly corresponds to the pattern of urban sprawl (Rubiera Morollón et al., 2016). Together with the loss of rurality, different socio-economic drivers have promoted an intense decentralization process, which includes the redistribution of population and employment, very high rates of housing growth and the emergence of new human settlements with important cultural and socioeconomic consequences (European Commission, 2006). A key factor in the decentralization process has been the urban mobility, based on a substantially improved transport infrastructure, with metropolitan network connections (Hewitt and Hernández-Jiménez, 2010; Díaz-Pacheco and García-Palomares, 2014).

2.2. Data collection

We focus on the characteristics of cultural landscapes and upon the socio-economy of local populations, at a municipal scale. For this reason, we considered variables that characterize both the cultural landscape and the socioeconomic structure of the area. Therefore, we collected socioeconomic and land use-land cover (LULC) data of the 179 municipalities that compose the Madrid Region (Fig. 1), using different available databases for the period 2010–2011. We considered the municipalities as analysis units because they are administrative divisions of local landscape management and governance decisions and the socioeconomic information is recorded at this scale (Schmitz et al., 2003; Salvati and Serra, 2016).

For each municipality, we collected: a) 22 landscape descriptors based on LULC (Appendix B, Table A.1; SIGA, 2010). Many of these specific land uses are considered as traditional practices. They have constituted the main traditional economic activity in this territory for centuries and have represented the most important human influence in the configuration of the current landscape (Schmitz et al., 2012); b) 29 socioeconomic descriptors of local population (Appendix B,