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Research article

Assessing the effectiveness of sustainable land management policies for combating desertification: A data mining approach

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ABSTRACT

This study investigates the relationship between fine resolution, local-scale biophysical and socioeconomic contexts within which land degradation occurs, and the human responses to it. The research draws on experimental data collected under different territorial and socioeconomic conditions at 586 field sites in five Mediterranean countries (Spain, Greece, Turkey, Tunisia and Morocco). We assess the level of desertification risk under various land management practices (terracing, grazing control, prevention of wildland fires, soil erosion control measures, soil water conservation measures, sustainable farming practices, land protection measures and financial subsidies) taken as possible responses to land degradation. A data mining approach, incorporating principal component analysis, non-parametric correlations, multiple regression and canonical analysis, was developed to identify the spatial relationship between land management conditions, the socioeconomic and environmental context (described using 40 biophysical and socioeconomic indicators) and desertification risk. Our analysis identified a number of distinct relationships between the level of desertification experienced and the underlying socioeconomic context, suggesting that the effectiveness of responses to land degradation is strictly dependent on the local biophysical and socioeconomic context. Assessing the latent relationship between land management practices and the biophysical/socioeconomic attributes characterizing areas exposed to different levels of desertification risk proved to be an indirect measure of the effectiveness of field actions contrasting land degradation.

1. Introduction

Land Degradation is a complex phenomenon occurring when specific biophysical, economic, social, cultural and institutional factors act synergistically to produce and entrench desertification over the long term (Reynolds et al., 2011). Unsustainable use of natural resources, weak economic development and policy inaction are relevant drivers of land degradation and reflect the complex relationship between local ecological conditions, socioeconomic dynamics and policy action (Bisaro et al., 2013). Desertification

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results in a progressive decline of land productivity and ecosystem functions, and is a key issue on the global policy agenda (Stringer and Harris, 2014). Desertification has negative impacts on food security, biodiversity and quality of life (Glenn et al., 1998). Abuse or misuse of land drives regional disparities in the availability of natural resources and results in a spatially-unbalanced development (Johnson and Lewis, 2007).

In the last decades, desertification risk has increased in many parts of the world, with land degradation now becoming severe in both emerging and developed countries (Thomas et al., 2012; Izzo et al., 2013; Yang et al., 2013). In the Mediterranean basin, Land Degradation (LD) is the result of the interplay between natural and socioeconomic systems (Wilson and Juntti, 2005). This process involves a number of biophysical attributes of the landscape (topography, climate, soil, vegetation) and conditions deriving from human activity (e.g. land-use transformations, agricultural intensification, land abandonment, population density, settlement distribution, industry and tourism development).

A large part of the Mediterranean region is classified as vulnerable to LD (Hill et al., 2008). While desert land is relatively scarce, areas with semi-arid climate and socioeconomic conditions which negatively impact soil fertility, biodiversity and ecosystem services are rather common. In such contexts, landscapes have lost part of their ecological and economic potential (Basso et al., 2010). LD processes in the Mediterranean basin are highly variable in time and space, closely influenced as they are by the different speeds of changes in environmental and socioeconomic conditions (Ibanez et al., 2008).

Studies that have addressed the most important causes and consequences of LD from a socio-environmental perspective have identified some of the core proximate drivers and underlying factors of change which lead to desertification risk (Zdruli, 2013). Salvati et al. (2015) have proposed an approach to assess the multiple relationships between biophysical variables and socioeconomic factors in a representative sample of Mediterranean sites, identifying diverging spatial patterns for biophysical and human drivers of LD, with higher variability observed for economic and social variables. Gaps in knowledge on the role of system complexity in shaping land vulnerability to desertification, however, have often been underestimated (Briassoulis, 2015). Research often focused on single - albeit important - factors such as soil degradation, whilst diachronic approaches which draw on data at a national or regional scale with an adequate spatial resolution are relatively scarce (Kosmas et al., 2015). Indicator-based approaches have been developed mainly for permanent monitoring of biophysical conditions characterizing LD processes (Ferrara et al., 2012). Whilst development of proper indicators and decision support systems to inform mitigation policies is a research priority (Glenn et al., 1998), further investigation is required to identify a comparative framework for assessing the impact of regional-scale drivers, and enable the importance of biophysical and socioeconomic factors to be ranked (Salvati et al., 2015).

Based on the issues discussed above, rethinking a non-reductionist approach to LD in relation to the characteristic territorial dimensions and the most suitable policy responses is imperative. Mitigation plans should encompass all of the disciplinary perspectives which impact on the problem (Sabbi and Salvati, 2014). Emphasis should be given to the social, demographic, economic, political and cultural processes that shape LD in any given area, and to the responses that society, in that specific local context, is able to implement (Iosifides and Politidis, 2005).

According to Briassoulis (2015), "human response to land degradation can be considered any planned (formal) or unplanned (informal) actions that purport to directly and explicitly tackle it and/or address other individual and collective socioeconomic goals in affected socio-ecological systems". Depending on the prevailing socioeconomic conditions, stakeholders and other actors may have no option but to continue with business as usual (no remedial action), or to engage in more resource-intensive activities (negative responses). Conversely, in some local contexts, stakeholders may be able to undertake actions to mitigate soil and land degradation (positive responses). Positive responses contribute to sustainable development of the local system preserving critical ecological functions and relevant socioeconomic attributes (Kelly et al., 2015).

Three key issues should be considered when effective responses to LD are proposed. First, a policy response or the implementation of a policy instrument does not always result in the intended impact in every context. Second, responses may have multiple impacts on the target environment and third, a holistic approach (as opposed to a target-specific or process-specific approach) is required in order to cope with a complex and multifaceted phenomenon such as LD (Salvati et al., 2015). The non-linear, highly-diversified nature of LD processes justifies the implementation of responsive and locally-adaptable policy instruments that are suitable to address place-specific environmental patterns (Wilson and Juntti, 2005). Previous studies have also suggested that the lack of relevant policy, due to *lassez-faire* practices or weak decision-making processes can be considered as tangible policy implementation, although inaction costs have been insufficiently acknowledged and investigated (Ferrara et al., 2012). As a consequence, policy implementation is a relatively fuzzy decision-making spectrum of (more or less) integrated measures, instead of a clear process of well-informed and locally-specific decision-making (Briassoulis, 2005).

In fact, to be effective on the ground, responses have take account of diverse components which are operating at various spatial scales and temporal speeds, and their effectiveness will therefore depend on their ability to respond to the relationships amongst these components. An integrative approach based on the concept of 'response assemblage' was recently proposed with the aim of identifying various types of interventions to combat LD (Briassoulis, 2015). Response assemblages reflect the need for humans to use natural resources sustainably to satisfy societal needs and are intended as "geographically and historically unique, provisional, open, territorial wholes, complex compositions emerging from processes of assembling biophysical and human components" (Briassoulis, 2015). A response assemblage operates at multiple spatial scales and is characterized by specific environmental attributes, land-use regimes and socioeconomic profiles.

Apart from the contribution mentioned above, frameworks identifying responses to LD are still relatively scarce (Thomas et al., 2012; Zdruli, 2013). Understanding place-specific LD processes, and identifying the spatial relationship between drivers of LD at different geographical scales, have allowed designing more effective mitigation strategies (MacDonald et al., 2000; Gellrich et al., 2007; Koulouri and Giourga, 2007; Corbelle Rico et al., 2012). Since place-specific factors and socioeconomic changes at multiple spatial and temporal scales have major impacts on LD responses (Sluiter and De Jong, 2007; Weissteiner et al., 2011; Kairis et al., 2014), stakeholder participation in the design of mitigation responses (e.g. a sustainable land management strategy) is crucial in the fight against desertification (Briassoulis, 2005). Iosifides and Politidis (2005) investigated the local context and its impact on individual stakeholder decision-making, and highlighted the importance of an integrated analysis of biophysical and socioeconomic drivers of change in order to identify and understand responses to LD. An in-depth knowledge of the latent relationship between LD drivers and components of the specific local human-biophysical system is an essential baseline when implementing sustainable land management (SLM) strategies (Zdruli, 2013). Sabbi