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Ecogeomorphological consequences of land abandonment in semiarid Mediterranean areas: Integrated assessment of physical evolution and biodiversity

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ABSTRACT

This paper is based on an integrated assessment of abandoned farmland in the Iberian Southeast, a representative area of rich-biodiversity landscapes subject to strong physical stress and highly sensitive to environmental change. It is framed within the concept of natural reforestation and seeks an integration of physical and biodiversity features relevant for management. In pilot areas of different lithology (marly, limestone, and metamorphic) and abandonment age (< or >20 years), several physical (soil characteristics, evidences of erosion) and biodiversity (flora and birds) indicators have been assessed. It is concluded that these two sets of indicators often follow divergent or contrasting trajectories, particularly in the less coherent substrates where soil degradation and erosion concur with steppic physiognomy and high ornithological value. Lithology conditions the compositional and structural development of woody vegetation, but local landscape degradation can also reduce the pool of potential colonizers. Ecosystem development can be described as the interplay of positive and negative forces acting on physical evolution and biodiversity change. Abandonment *per se* is not a widely applicable management option but in many instances it can naturally improve soil and vegetation conditions. In more resistant lithologies, succession could lead to landscape homogenization, although recovery is usually slow and can eventually be arrested in stages dominated by a few woody species. Although our results are not generalizable to all semiarid land abandonment, they provide a framework for selecting management measures and for setting the scale and intensity of their application.

1. Introduction

1.1. Farmland abandonment in the Iberian Peninsula: consequences and management options

Agricultural land abandonment is a common phenomenon in the Mediterranean Basin (Rey-Benayas et al., 2007), taking place over different types of lithological substrates and in varied environmental and socio-economic contexts. In the Iberian Peninsula, it has occurred since the end of the XIXth Century, but with maximum intensity during the decades of 1960 and 1970 (García-Ruiz and Lana-Renault, 2011). Its main causes have been socio-economic changes and the corresponding economic and demographic synergies, as well as, more recently, the subsidies for land set-aside from the European Union's Common Agricultural Policy (CAP). It has taken place mainly in mountain areas (Lasanta, 1989; García-Ruiz, 2010), although large extensions of lower altitude semiarid lands have also been affected (Romero-Díaz et al., 2007; Lesschen et al., 2008a). In Spain there are many published studies on the hydro-geomorphological consequences of farmland abandonment, most made on the eastern part of the Iberian Peninsula (Cerdà, 1997a; Cammeraat et al., 2010; García-Ruiz and Lana-Renault, 2011).

The effects of abandonment can be positive or negative (Kosmas et al., 2000; Zaragozí et al., 2012), depending on soil and climate. Deeper soils under wet climates may ameliorate with time since abandonment, gaining organic matter inputs, enhancing microbial and faunal activity, improving their structure, increasing their infiltration capacity and reducing the erosion

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potential (Trimble, 1990). On the contrary, under dryer climates, abandoned crops on degraded soils are a favorable scenario for erosion (Navarro and Pereira, 2012). If plant colonization is not enough to generate a progressive vegetation dynamics, as it is usual in arid and semi-arid areas (Navarro et al., 1993), land degradation can become very important (Romero-Díaz, 2003). Vegetation, however, cannot be evaluated solely by its soil protection effect (De Baets et al., 2009). The biological value of plant communities and their associated fauna need also be taken into consideration (Navarro et al., 2003; Plieninger et al., 2013).

Oldfield management must consider a range of options, from the active maintenance and restoration of the abandoned spaces, to the stewardship of natural reforestation or rewilding processes (Navarro and Pereira, 2012). The choice is conditioned by the successional dynamics, resulting from the interaction between biophysical characteristics, natural ecological processes, and the agricultural legacy (Rey-Benayas et al., 2007). This restricts in practice the eligible options for each specific field or territory.

As a general feature, the traditional Mediterranean agriculture contributes greatly to the biological and cultural richness of landscapes, either compositionally, structurally or functionally (Reidsma et al., 2006; Blondel et al., 2010; Peco et al., 2012). In an abandonment scenario, biodiversity is also expected to play a critical role in the dynamics of the secondary habitats that develop since the end of farming (Bonet and Pausas, 2007). The particular role of key structural and functional components of the biota, like woody vegetation (Cortina et al., 2011) and vertebrate fauna (Jordano, 2000), can vary considerably depending on the lithological and geomorphological framework, even in similar climatic contexts. Different responses are also predicted for different plant and animal taxa, with some thriving in early or intermediate successional stages and others in late ones (Russo, 2007; Sirami et al., 2008; Blondel et al., 2010).

Thus, a compromise has to be achieved between the mitigation of physical impacts (erosion, soil loss and degradation, disruption of the hydrological cycle) and the conservation of the biodiversity associated to the different successional stages (Debussche et al., 1996; Bonet and Pausas, 2007; Vallecillo et al., 2008). Despite the importance of these issues (Detsis, 2010), few studies have addressed them from an integrated perspective, coupling the underlying physical and ecological factors involved in land degradation and biodiversity loss. Similarly, approaches are missing which, in the same socio-environmental context, seek an integration of the measures addressed to the physical environment and those focused on biodiversity (Robles et al., 2009; Cañadas et al., 2010; Martínez-Duro et al., 2010).

In the Spanish Mediterranean, a great deal of scientific work has been focused at the restoration of oldfields and other spaces in risk of physical degradation (Bonet, 2004; Bocio et al., 2004; Valdecantos et al., 2006; Bonet and Pausas, 2007). However, studies on forest restoration techniques seem much more developed than those dealing with the management or stewardship of the self-recovery of abandoned farmland (Bocio et al., 2004; Vallejo et al., 2005). Although techniques assayed for vegetation implantation are diverse and adapted to different situations (Vallejo et al., 2012), active reforestation has historically been the preferred solution and the only available to owners of marginal farmland (Maestre and Cortina, 2004; Nainggolan et al., 2012; Sánchez-Oliver et al., 2014).

Although the topic of land abandonment and its management has been addressed here mainly through representative studies from Spain, concern about its importance is much more widespread. This has boosted a great deal of research around the world, especially in the Mediterranean countries (see e.g., MacDonald et al., 2000; Abu Hammad and Tumeizi, 2012; Debolini et al., 2013; Jones et al., 2014).

1.2. Biodiversity and fragility of Mediterranean semiarid landscapes: the case of the Iberian Southeast

In Mediterranean semiarid regions, the greater physical fragility and consequent risk of degradation, is often associated with the presence of unique biodiversity features, related to the transition towards desert biomes (Blondel et al., 2010). Thus, they represent an ideal scenario for studies that integrate these two features. Among these regions, the Iberian Southeast (ISE, thereafter) is a territory of rich biodiversity (Armas et al., 2011), and a representative scenario of research on actions to combat erosion and desertification (García Ruiz and López Bermúdez, 2009; Romero-Díaz, 2010), being recognized as one of the areas of Spain with higher risk regarding these processes (PAND, 2008; Romero-Díaz et al., 2011a).

Our case studies are located in the Region of Murcia, a core area of the ISE. It is a true biogeographical ecotone between the Mediterranean Basin and the southern sub-tropical deserts (Esteve-Selma et al., 2010), hosting a rich biological diversity determined by two nested sets of causes (Calvo et al., 2000): (i) at a biogeographical scale, by its position regarding the center of the Mediterranean domain and the consequent frontier character and (ii) at a local one, by a high intrinsic physical heterogeneity (geological, topographic, geomorphological, edaphic, etc.), resulting from a long sedimentary evolution and an intense tectonic activity.

Many semiarid abandoned lands are included in steppe-like landscapes with scarce forest potential, but prone to strong physical risks if not properly used (Le Houérou, 2002). Their management requires a simultaneous focus on the conservation of natural resources like soil and water, the protection of livelihoods and man-made infrastructures, and on the preservation of their most representative biodiversity. Steppization of abandoned fields can be considered an undesirable state (Martínez-Fernández and Esteve, 2010), although it can result in ecologically valuable landscapes (Suárez et al., 1991; Cañadas, 2008). In the ISE, as a result of marginal land overexploitation and subsequent rural depopulation (Puigdefábregas and Mendizábal, 1998), large extensions of land have been converted into subdesertic xerosteppes, one of the land cover types experiencing a greater expansion in recent decades (Martínez-Fernández and Esteve, 2010).

Despite all, there is a lack of integrated studies about the contribution of different physical and biotic components to the ecogeomorphological dynamics of semi-arid abandoned areas, which can help to set specific guidelines for action against desertification and in favor of biodiversity. Precedent research in the ISE has focused on a specific type of substrate (Romero-Díaz, 2003), on a single biological component, usually the plant community (Cañadas, 2008), or taking a limited approach to biodiversity (floristic studies, e.g., Navarro et al., 2003). Since different responses are expected for each type of substrate, depending on the component evaluated (Table 1), an integrated assessment is essential to guide any management policy addressed at the whole biophysical system.

1.3. Research framework and objectives

This work is based on a first characterization of succession dynamics in oldfields of Murcia Region in course of spontaneous naturalization. It is framed within the concept of natural reforestation (Sitzia et al., 2010) supported by the proximity to patches of natural vegetation and by the existence of active dispersal processes from these sources (Fuentes-Castillo et al., 2012). For this, the study covers pilot areas of different substrate type and age since abandonment, in which different trajectories are expected as a result of the interaction of their physical and biological characteristics (Table 1). Previous knowledge predicts