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Ecosystem responses to land abandonment in Western Mediterranean Mountains

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ABSTRACT

Agricultural expansion in the Mediterranean resulted in plant and soil degradation due to the intensive use, climate conditions, and rugged terrain. After abandonment, the recovery of vegetation contributed to improvement in soil quality from a hydrological, pedological and geomorphological point of view. This paper shows three examples of ecosystem evolution in abandoned fields in Valencia, Murcia and Andalucia and the application of different methodological approaches that resulted in similar findings. In Valencia, the main responses were the recovery of vegetation after land abandonment and an increase in organic matter and infiltration capacity of soils. In Murcia, with the exception of some terraced areas on marls, where erosion processes following abandonment were important, land abandonment resulted in vegetation recovery, improved soil properties, and reduced surface wash and soil losses. In Andalucia, research along climatological gradients showed the relationship between vegetation patterns and soil moisture and the control that climate exerts on hydrological and erosive behaviour. The experimental research conducted in three different regions in Western Mediterranean demonstrated that abandonment can result in recovery of the geo-ecosystem as vegetation and soil quality improvements were shown. The marls areas in Murcia were the exception with low soil quality and low vegetation cover, and as a consequence showed evidence of high erosion rates after abandonment.

1. Introduction

Land abandonment is the result of worldwide land use change and is altering the fate of landscapes (García-Ruiz and Lana-Renault, 2011; Cerdà et al., 2014; Arnáez et al., 2015). Land abandonment has been increasingly studied over the last few decades, as shown by the numerous literature reviews carried out, especially in recent years. However, most of them focus on Europe (MacDonald et al., 2000; García-Ruiz and Lana-Renault, 2011; Hatna and Bakker, 2011; Lasanta et al., 2015a), mainly in the Mediterranean and mountainous regions (Sheffer, 2012; Plieninger et al., 2014). The abandonment of land not only results in changes to the soil system, but also in the hydrological cycle and fauna and flora resources (de Araújo et al., 2015; Keesstra et al., 2016a).

This land abandonment has been the result of socioeconomic changes, but the impact will also be environmental as the goods, services, and resources the abandoned land offers to humankind will change. The impact of the abandonment is diverse (MacDonald et al., 2000) and the main changes are determined by pedological, lithological or climatic factors (Romero-Díaz et al., 2007; Navarro and Pereira, 2012; Lasanta et al., 2016). Traditionally, abandonment has occurred in marginal or degraded lands (MacDonald et al., 2000; García-Ruiz and Lana-Renault, 2011), but recently some areas with fertile soils are also being abandoned (Hatna and Bakker, 2011) due to the low income of the farmers (Cerdà et al., 2012). Antropogenic factors are also relevant on the process such as Vicente-Serrano et al. (2005) demonstrated.

The Mediterranean mountains were affected by land degradation due to agricultural development that resulted in degradation of the shallow soils, including increased erosion. García-Ruiz (2010) demonstrated that during the 19th century agriculture changed the fate of many marginal areas, where soils were too shallow for good agricultural production, and soon the land was abandoned. After abandonment vegetation recovery was the key factor that determined which areas

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experienced high erosion rates and additional soil degradation and which ones recovered with improvements in soil quality. Areas that developed dense vegetative cover after abandonment acted as sinks of sediments and water in semiarid ecosystems (Cerdà, 1997a; Cammeraat and Imeson, 1999; Bochet, 2015). Forest fires also played a key role in the fate of abandoned land due to changes in the soil, vegetation, and water resources as a consequence of recurrent forest fires (Keesstra et al., 2014; Pereira et al., 2015; van Eck et al., 2016; Keesstra et al., 2016b).

There is a need for scientific research that advances our understanding of the main environmental features that lead to abandonment, such as the work of Alonso-Sarría et al. (2016) in Southeast Spain. We need better comprehension of the impact of abandonment on water resources (López-Vicente et al., 2016), soil properties (Novara et al., 2015; Brevik et al., 2016; Nadal-Romero et al., 2016) and its impact on the chemical composition of the atmosphere due to changes in the carbon cycle induced by the abandonment (Gabarrón-Galeote, 2016a; 2016b; Nadal-Romero et al., 2016; Novara et al., 2016). Although land abandonment mainly occurred in developed countries during the last century and this is where most of the research has been conducted (Shelef et al., 2015), it is now also a process found in developing countries such as some regions of Ethiopia (Mekonnen et al., 2015; Tesfahunegn et al., 2016), China (Kou et al., 2016; Tengberg et al., 2016; Yu et al., 2016), South Africa (Russell and Ward, 2016) and South America (Ochoa-Cueva et al., 2015; Trabaquini et al., 2015). To this point scientific research has mainly focused on the impact of abandonment from the pedological (Giménez-Morera et al., 2010; Brevik, 2013; Bruun et al., 2015; Colazo and Buschiazzo, 2015), hydrological (Keesstra, 2007; Keesstra et al., 2009; Nadal-Romero et al., 2011; Serrano-Muela et al., 2015; Sanjuán et al., 2016), biological (Russell and Ward, 2016; van Hall et al., 2016), geomorphological (Nadal-Romero et al., 2015), and landscape (Lasanta et al., 2015a, 2015b) points of view. There is also an economic issue behind abandonment due to the lack of income for farmers, and there is an interest in the use of abandoned agriculture fields to increase soil carbon sequestration (Alexander et al., 2015) as once the land is abandoned there may be an increase in soil organic matter as new vegetation grows and covers the soil with a consequent sequestration of carbon (Cerdà et al., 2014; Hombegowda et al., 2016). Changes in agricultural use and management are not only found in the mountains of developed and developing countries, they are also found in urban terrain as there has been an expansion in urban agriculture (Beniston et al., 2015; Brevik et al., 2015) than can result in abandonment within the urban environment.

The objective of this paper is to assess, review and synthesize the impact of agricultural abandonment in Western Mediterranean Mountains, with three different approaches and three study sites to understand how the landscape, soils, vegetation, and water resources behave and are altered after land abandonment.

2. Material and methods

2.1. Study areas

The study areas were selected in the Valencia, Murcia, and Andalucia Regions (Fig. 1) to show the impact of land abandonment in Western Mediterranean mountainous regions. The Valencia study site is located in the municipality of Vallada, within the Canyoles river watershed, in the La Costera district of the Valencia region (East Spain). The parent materials are Cretaceous limestone and Tertiary deposits that develop Typic Xerothent soils. Low levels of soil organic matter (SOM) (<2%) were found when the soils were cultivated, the pH was high (8), and the soil texture was loamy. The climate is typically Mediterranean with 3–5 months of summer drought (June–September). Mean annual rainfall at the study site is 585 mm, which falls primarily in autumn, winter and spring. Mean annual temperature is 13.7 °C. The vegetation cover move from an herbaceous cover (*Brachypodium retusum*) after the abandonment to a dense *Quercus ilex* forest after some decades of abandonment. In Murcia three research sites were selected: Fuensanta, Murta, and Corvera, with metamorphic (phyllite and schist, MET), limestone (LIM) and marl (MAR) parent materials, respectively. At each site we recognized recent (<20 years) and old (>20 years) abandoned fields. Mean annual rainfall is is 286 mm in MET and 335 mm in LIM and MAR, and the mean annual temperature is 16° in MET and 18 °C in LIM and MAR. SOM content was low (<2%) except in the recently abandoned MET area, which had 3.5% organic matter content. Soil texture was loamy in MET, loamy to sandy loam in LIM and loamy to silty

Fig. 1. Location of the study areas. VA = Vallada; COR = Corvera; MU = La Murta; FU = Fuensanta; BE = Berja; COL = Colmenar; AL = Almogía.