Environmental and socioeconomic factors of abandonment of rainfed and irrigated crops in northeast Spain

Juan José Vidal-Macua[a],[*], Miquel Ninyerola[b], Alaitz Zabala[a], Cristina Domingo-Marimon[c], Oscar Gonzalez-Guerrero[a], Xavier Pons[a]

[a] Grumets Research Group, Dep Geografia, Edifici B, Universitat Autònoma de Barcelona, 08193 Bellaterra, Catalonia, Spain
[b] Grumets Research Group, Dep Biologia Animal, Vegetal i Ecologia, Edifici C, Universitat Autònoma de Barcelona, 08193 Bellaterra, Catalonia, Spain
[c] Grumets Research Group, CREAF, Campus UAB, Edifici C, Cerdanyola del Vallès 08193 Catalonia, Spain

ARTICLE INFO

ABSTRACT

Changes over the last century in the economic model of European countries and the development of the market economy have led to intense shifts in land occupation patterns. Agricultural abandonment is an important consequence of these processes and has modified natural and cultural landscapes, involving side-effects for society. Understanding how environmental and socio-economic factors influence the abandonment process can provide useful insights for managing investments, whether from the public or the private sector. In Spain, the Pyrenees and the Ebro Depression are two differentiated areas in terms of land-use dynamics, particularly in terms of the agricultural model carried out. In this paper we have analyzed the agricultural abandonment in these areas during the 1987–2012 period in relation to several potential explanatory factors. The analysis focuses on the abandonment of rainfed and irrigated herbaceous crops in order to derive specific explanations according to the crop type and geographical region. Crop covers were classified from four Landsat scenes, and conditions were described by topographic variables, human factors and drought occurrence. Boosted regression trees (BRT) were used to identify the most important variables and to describe the relationships between agricultural abandonment and key factors. Topography derived variables were found to be the main determinants, except for irrigated crops in the Ebro Basin, where locational factors play a more important role. BRT models allowed us to identify other significant patterns such as: the vulnerability of irrigated crops to drought; the higher dependence of agricultural activity in the Pyrenees on internal networks; pattern shifts of land abandonment in the analyzed sub-periods, and; evidence of the importance of economic diversification for maintaining cropland.

1. Introduction

In the 20th century, especially during the second half, economic growth and development of mass markets in Europe resulted in a depopulation of marginal areas and a densification of those areas better placed to supply the expanding cities and industrialized zones (Collantes & Pinilla, 2004; Fielding, 1989). Agricultural land abandonment and intensification have continued to be widespread land-use changes since then (Ramankutty & Foley, 1999), especially in the Mediterranean area (Gerard et al., 2010).

Land abandonment has been treated as a phenomenon involving negative or positive effects according to the analysis approach and/or the territorial context (Benayas, Martins, Nicolau, & Schulz, 2007; Keenleyside et al., 2010; MacDonald et al., 2000). Soil erosion and reduced water yield of catchments are some of the most conspicuous

issues that have been frequently addressed in the Mediterranean area, which is more prone to these problems (Gallart & Llorens, 2004; García-Ruiz, 2010; Kosmas et al., 2015; López-Moreno et al., 2006). There are also associated benefits, like soil and nutrient recovery and carbon sequestration due to vegetation re-growth in abandoned lands (Molinillo et al., 1997; Schröter et al., 2005; Tiessen, Salcedo, & Sampaio, 1992). The effect of cropland abandonment on landscape structure has been reported as a disturbance that can positively affect landscape connectivity and increase forest species (Beilin et al., 2014; Farina, 2008; Navarro & Pereira, 2015). In addition, other analyses have shown a positive association between abandonment and rural development (Beilin et al., 2014). On the other hand, several studies have reported the negative effects on biodiversity (Bezák & Halada, 2010; Farina, 2008; Halada, Evans, Romão, & Petersen, 2011), highlighting the importance of the seasonal-disturbance regime of croplands in

maintaining the diversity and environmental range of species. Fire occurrence is another negative effect, especially regarding woodland recovery (Lloret, Calvo, Pons, & Díaz-Delgado, 2002; Moreira et al., 2011). Finally, during the last decade special attention has been paid to the drivers of agricultural abandonment, including environmental and socioeconomic variables as explanatory variables in statistical-based methods (Gellrich & Zimmermann, 2007; Serra, Pons, & Saurí, 2008; Lieskovský et al., 2014; Sang, Dramstad, & Bryn, 2014; Pazúr et al., 2014). These approaches are very useful for determining patterns of land abandonment and for identifying which places are more prone to being abandoned within a given territory.

The above-mentioned issues are especially relevant for land abandonment analyses in a country like Spain, which has high land-use heterogeneity due to its topographic and climatic spatial variability, and a long and complex human history. Spain, and the Mediterranean in general, has followed intense land cover dynamics that have led to high heterogeneity of land occupation patterns. Moreover, in recent decades the region has also been particularly influenced by climate change dynamics (IPCC 2007, 2013; Vicente-Serrano et al., 2014). However, apart from some works describing the phenomenon through landscape metrics for relatively small areas (e.g., Bielsa, Pons, & Bunce, 2005), there are few detailed analyses of the conditions leading to agricultural abandonment in Spain, and more specifically, focused on the likelihood of abandonment based on empirical data.

In mountainous regions like the Spanish Pyrenees, the ecological succession of vegetation has advanced after a general abandonment of traditional activities (Cohen, Varga, Vila, & Barrassaud, 2011; García-Ruiz, 1990; Lasanta, Vicente-Serrano, & Cuadrat-Prats, 2005; Roura-Pascual, Pons, Etienne, & Lambert, 2005; Serra, Vera, Tulla, & Salvati, 2014) driven by the combination of the rural exodus and the physical constraints to modernization (Benayas et al., 2007; Collantes & Pinilla, 2004). The cultivated area is mainly divided into cereals and fodder production. After the decline of the traditional system, based on a subsistence economy, cereals were less competitive (as a food supply) and have become an important source of fodder, while other forage crops and managed meadows have increased their area due the abandonment of transhumance in most counties (García-Ruiz & Lasanta, 1993; IAEST; IDESCAT). The expansion of tourism in this region has led to economic readjustments in rural households. Many areas maintain a balanced symbiosis between tourism and agricultural production (Cánoves, Villarino, Priestley, & Blanco, 2004), but livestock farming and land cultivation have clearly decreased in the areas with more touristic development (Garcia-Ruiz et al., 1996; 2011). In contrast, modernization (strong mechanization and limited labor) and agricultural intensification have taken place in other geographical regions of Spain, such as the Ebro Depression, a semi-arid region where modern irrigation systems have been developed since the middle of the 20th century (Pinilla, 2006). During the economic liberalization and capitalist development of Spain, this region was better placed to benefit from the expansion of industrialization and external markets, and the modern irrigation techniques increased the productivity of croplands. At the same time, this process contributed to the depopulation and agricultural abandonment in the Spanish Pyrenees due to the construction of reservoirs in valleys to supply the irrigated lands (Duarte, Pinilla, & Serrano, 2014; Pinilla, 2006). Non-irrigated lands are mainly used to cultivate winter cereals, and although they occupy a greater extent of land, output per hectare for irrigated crops (mostly maize) is 5–6 times higher (Pinilla, 2006). Land intensification is a common trend in the Mediterranean fringe of Spain, and although it leads to higher crop yields, its environmental and social viability depends on the pressures on the landscape and external market fluctuations (Nainggolan et al., 2012).

Although the external factors that have led to agricultural abandonment in Spain have already been described in several works, as we mentioned above, there are still few studies on the internal factors (Lasanta et al., 2017) controlling this phenomenon. Here, we analyze the influence of a series of internal environmental and socioeconomic factors on the land abandonment in northeast Spain from 1987 to 2012. In order to determine particularities regarding types of land cultivation and territorial contexts, the analysis differentiates between the abandonment of rainfed and irrigated crops in the Spanish Central Pyrenees and the Central Ebro Basin. Two sub-periods have been included in the analysis, 1987–2002 and 2002–2012, in order to take into account the variability in human and climatic factors. The ambits correspond to refined land-cover classifications of Landsat scenes. The importance of several factors and how they influence cropland abandonment was analyzed using boosted regression trees (BRT), also known as stochastic gradient boosting (Friedman, 2001, 2002; Hastie and Tibshirani, 2009). This relatively new machine-learning technique (Breiman, 2001), in which hundreds or thousands of decision trees (Breiman, Friedman, Stone, & Olshen, 1984) are sequentially and progressively fitted, has been demonstrated to have a high prediction performance (Crase, Liedloff, & Wintle, 2012; Elith, Leathwick, & Hastie, 2008, 2006; Kawakita, Minami, Eguchi, & Lennert-Cody, 2005; Leathwick, Elith, Francis, Hastie, & Taylor, 2006) for the following main reasons: this approach does not assume any data distributions or data models, but rather it aims to determine dominant patterns by combining many classification trees; it identifies relevant variables and complex interactions; it is much less influenced by correlated information or irrelevant variables than other statistical approaches; it produces stable predictions (variance reduction); and it provides graphical depictions of the relationship between the response variable and predictors. We found this method particularly useful for multicausal scenarios, given its capacity to define the role played by the explanatory factors, even when the contribution (relative weight/importance) is low.

The general aim of this work is to better understand the internal conditions that lead to agricultural abandonment. We consider this study as groundwork for the development of sectoral studies and to improve the decision-making process for policy making and land management. Thus, the main objectives of this study are to determine: 1) the most important internal factors in the abandonment of rainfed and irrigated crops in two geographical regions, the Spanish Central Pyrenees and the Central Ebro Basin; and 2) the role of key factors in identifying particularities within each type of land cultivation and territorial context.

2. Material and methods

2.1. Study areas

Two areas of northeast Spain were included in this work as different scenarios for model development. These areas are within the limits of land-cover classifications of four Landsat scenes, identified by their path-row: 198-030, 198-031, 199-030 and 199-031 (Fig. 1).

The first study area corresponds to the mountainous region of the Spanish Central Pyrenees and, as previously explained, it is representative of an extensive and less-developed (less mechanized) agriculture. It includes areas with altitudes from 600 m up to the Spanish border with France (reaching altitudes of 3000 m and more), although in some locations the perimeter at its lower altitudinal limit has been adapted to natural boundaries with the Central Ebro Valley. Interior valleys below 600 m are also included within this geographical