

# **Rewilding and restoring cultural landscapes in Mediterranean mountains: Opportunities and challenges**

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## **ABSTRACT**

Farmland abandonment and the decline of livestock activity in the Mediterranean mountains have resulted in dramatic landscape changes, including the generalized expansion of shrublands and forests, and the homogenization of the old cultural landscapes. This process has a variety of consequences from ecological, geomorphological and hydrological points of view, as well as from the perspectives of land management and public awareness. An intense debate currently surrounds the discussion and evaluation of rewilding (the process of passively allowing woody encroachment, as well as the reintroduction of large mammals) as an opportunity for enhancing biodiversity and restoring original landscapes after centuries of human activity versus ecological restoration (activities leading to the recovery of degraded ecosystems, including clearing and light human activity). There is no clear consensus regarding the best way to improve the ecological relationships and functioning within an ecosystem. Biodiversity and sustainability can be seen under different levels of human pressure and landscape transformation; total farmland abandonment is not always the best alternative, particularly when local inhabitants aim to sustain themselves using local resources. Many geographers and ecologists consider that extensive stockbreeding in a partially open landscape is a rational way to (i) improve landscape organization, (ii) increase flows and turnover within the ecosystems, (iii)

increase the diversity of plants and animals that benefit from a relatively light human presence, and (iv) reduce wildfire risk. However, it has proven challenging for land managers and stockbreeders to clear the best old abandoned fields and “construct” a sustainable, balanced landscape that combines forests, shrublands and open lands. Private landowner involvement and support from the general public is crucial for both funding and the long-term maintenance of benefits. The best old fields should be cleared in the context of high-resolution knowledge of the topography, grassland characteristics, grassland cycles and livestock management. Such efforts are likely to be an excellent opportunity to introduce compatibility between light human activity and increases in biodiversity and sustainability for many marginal mountains, where land abandonment and general forest/shrub recovery are the inevitable tendencies. This paper examines some of the contrasting positions of the scientific community regarding the rewilding or ecological restoration of mountain landscapes, and briefly highlights some experiences in which intentional clearing of old abandoned fields has benefited stockbreeding, biodiversity, runoff generation and wildfire risks. Notably, we describe a sub-Mediterranean valley of the Iberian Range, Northern Spain, as an example. In the long term, we find that the intentional clearing of the best old fields allows the slow organization of a final landscape that will be more useful for local inhabitants, thereby helping to reverse human depopulation in these regions.

**Keywords:** Rewilding, Land abandonment, Woody encroachment, Extensive stockbreeding, Cultural landscape, Clearing

## **1. Introduction**

Mediterranean mountain landscapes have a long history of human occupation and land cover changes going back to at least Mesolithic times (e.g., Alcolea et al., 2017). This has resulted in highly complex landscapes that range from eroded hillslopes to well-preserved bench-terraced fields in which hedgerows, isolated trees and small woods enhance biodiversity, productivity and aesthetic satisfaction (Sitzia et al., 2010). Such landscapes are the consequence of numerous political, economic and demographic events spanning thousands of years, all of which have left imprints that we can partially unravel (García-Ruiz et al., 2015a). The history of land use in Europe is a story of deforestation separated by periods of partial farmland abandonment (Kaplan et al., 2009). In the case of Mediterranean mountain areas, forest opening and the

establishment of permanent settlements and crops began during the Neolithic period (Blondel, 2006; Fernández Mier et al., 2014; Navarro and Pereira, 2015; González-Sampériz et al., 2017), together with the progressive deforestation of the subalpine belt to favor livestock grazing (Colombaroli et al., 2010; Pérez-Sanz et al., 2013; García-Ruiz et al., 2016a, 2016b). In general, cultivated areas progressively enlarged throughout the region until the mid-19th century, when the population pressure peaked (Taillefumier and Piégay, 2003; Kizos and Koulouri, 2006; Sancho-Reinoso, 2013). Since then, most of the cultivated slopes have been abandoned, with the fields becoming covered with shrubs and forest within a few decades (Molinillo et al., 1997; Poyatos et al., 2003; Tasser et al., 2007; Sluite and De Jong, 2007). In the subalpine belt, where the upper forest level was wasted, the decline of transhumance systems also resulted in a progressive uplift of the treeline and a consequent decline in the area occupied by summer grasslands (García-Ruiz et al., 2017a; Sanjuán et al., 2018). This collapse of the landscape along the different altitudinal belts of the Mediterranean mountains paralleled a dramatic decline in the human population and the aging of farmers, both of which reflected a socioeconomic change and massive migration towards the main cities.

The generalized process of woody encroachment is a controversial topic among ecologists, engineers, geographers and other scientists. Three major questions are: What can we do with cultural landscapes that tend to be rapidly recovered with shrubs and forests? Is farmland and stockbreeding abandonment the best option for improving biodiversity and sustainability, and for enhancing refaunation? Or is it preferable to actively manage the landscapes in order to enhance their natural heterogeneity with the presence of light human activity? These are critical questions that have not been definitively addressed to date, largely due to the complexity of the ecological, geographical, social and economic factors that contribute to management decisions regarding mountain areas. Decision-makers use to take into account the extreme fragility of mountain ecosystems, in which erosion and land degradation are easily triggered by cultivation of slopes and overgrazing (Lasanta et al., 2006; Thornes, 2007), and that such ecosystems are (or can be) the refuge of many plant and animal species. Consequently, rewilding or landscape naturalization (i.e. the process of natural shrub and forest recovery after farmland abandonment: e.g. Bauer et al., 2009; Nogués-Bravo et al., 2016) is thought to be the best alternative for nature conservation (Soulé and Noss, 1998; Navarro and Pereira, 2012; Pettorelli et al., 2017) in contrast with ecological restoration (i.e. activities leading to the recovery of degraded landscapes,

including clearing and light human activity: e.g. Rey Benayas and Bullock, 2012). Some robust scientific arguments contend that it is precisely the occurrence of human activity that increases complexity and biodiversity (Conti and Fagarazzi, 2005; Enserink and Vogel, 2006; Harrop, 2007; Bauer et al., 2009), and that even though some large mammals may benefit from farmland and livestock abandonment, rewilding could cause landscape homogenization and species simplification (MacDonald et al., 2000; Rey Benayas et al., 2007).

We propose that a decrease of human pressure on mountain areas has positive effects on soil, animal and plant conservation as it has been noted by a number of scientists (e.g. MacDonald et al., 2000; Rey Benayas et al., 2007; García-Ruiz and Lana-Renault, 2011; Regos et al., 2016; Schnitzler, 2014; van der Zanden et al., 2017), but that light human activity can increase biodiversity and long-term sustainability while providing income opportunities for the local population. Besides, it must be taken into account that in most Mediterranean mountain areas both agriculture and stockbreeding are closely related and integrated in a holistic land management, because of stock grazing on cultivated fields once the crop has been harvested and whereas the fields remain in fallow. For this reason, some kind of management is necessary in the best fields in order to ensure the quality of grasslands and their productivity. In contrary case, shrubs and trees recolonize the old fields, disturbing the grazing cycles and the availability of pastoral resources (Lasanta et al., 2005; Chauchard et al., 2007)

This paper examines the most relevant characteristics of the cultural Mediterranean mountain landscapes and the contrasting positions of the scientific community with respect to agricultural activity, farmland abandonment, and the rewilding versus ecological restoration of such landscapes. The ways in which clearing can benefit stockbreeding, biodiversity, productivity, landscape heterogeneity and wildfire risk is briefly discussed in the context of a sub-Mediterranean valley of the Iberian Range in Northern Spain, as a case study. In the long term, the intentional clearing of ecological restoration should be followed by the slow organization of a final landscape that is more useful for local inhabitants and will help reverse or at least delay human depopulation in the region.

## **2. Cultural landscapes, complex landscapes**

### *2.1. What is a cultural landscape?*

The landscape, which is an interpretation of a territory (Martínez de Pisón, 2009), is a mental, social, cultural and physical reality (Palang et al., 2005) that produces emotions and conditions major decisions on the environment (Puigdefábregas and Pérez-García, 2019; van der Zanden et al., 2018). Cultural landscapes can be defined as those landscapes that have been historically constructed by human groups in order to satisfy the livelihoods of local people, and that represent the superposition of distinct cultures, historical facts and market influences adapted to the heterogeneous characters of climate and topography (García-Ruiz and Lasanta, 2018). According to Antrop (2005), cultivated landscapes are the consequence of a progressive “reorganization of the land in order to adapt its use and spatial structure better to the changing societal demands”. They are also called “traditional landscapes”, since they are the consequence of a long history of construction and transformation that acted under rules that are very different from those that today contribute to creating contemporaneous landscapes. Geographers and ecologists usually assign the terms “cultural” or “traditional” to cultivated and grazed areas that are believed to have been relatively well adapted to the environmental conditions based on a high-resolution knowledge of the heterogeneity of the territory; in some cases, however, this is an excessively romantic view of the relationships between local people and the environment. In any case, cultural or traditional Mediterranean mountain landscapes tend to be highly heterogeneous, particularly in the size and form of the fields, the perception of water flows, and the relationships between cultivated fields, forests, hedgerows and grasslands (Olarieta et al., 2008; Agnoletti, 2014).

## *2.2. Creation of cultural landscapes in the Iberian mountains*

It is relatively well known that landscape “construction” in the European mountains began in Neolithic times. By the middle Holocene, forests had ceased being a continuous element in the landscape, as open lands were relatively frequent due to grazing activity by herbivores (Vera, 2000; Montserrat Recoder, 2009; Navarro and Pereira, 2015; Montserrat-Martí and Gómez-García, 2019) and occasional fires. In Central Europe, for instance, Neolithic people lived in an already open landscape (Kunes et al., 2015; Marquer et al., 2017). In Northwest Europe, Svenning (2002, p. 133) noted that “closed forests would predominate, but included localized longer-lasting openings”, with large herbivores and fires as potential key factors. This was the beginning of human-induced landscape transformation. In mountain areas, Neolithic

people had a low influence in transforming mountain landscapes due to the low demographic pressure and the absence of regional markets, impeding the creation of large sheep flocks. The presence of charcoal within soils of the subalpine belt in the Sierra de Urbión (Iberian Range, Northern Spain) reveals the occurrence of fires that would have enlarged open areas and favored the summer grazing of small sheep flocks (García-Ruiz et al., 2016a), although we are not sure if they were mostly triggered by natural causes. In some mountains, the first permanent settlements were likely established during the Bronze Age, as indicated by Fernández Mier et al. (2013) for the Cantabrian Mountains. Palynological studies from lacustrine sediments in the Pyrenees reveal that there were subsequent increases in landscape transformation, forest decline and the presence of human-related taxa, mainly *Cerealia* and also *Olea*, *Vitis*, *Cannabis*, chestnut and walnut trees at distinct moments since Neolithic times (e.g. Galop, 1998). González-Sampériz et al. (2017) summarized the evolution of land cover since the Last Glacial Maximum (MIS2, around 20 ka BP), and particularly during the Holocene in the Pyrenees. These authors stated that the “first important and permanent signs of sedentary agricultural practices and landscape transformations are recognized in the Pyrenees”, with the first clear signs of agriculture being recorded in the Bronze Age, and subsequent expansion of the region’s agriculture seen during the Roman period, mainly in the pre-Pyrenees (Riera et al., 2004).

In mountain areas of the Pyrenees, Iberian Range and Cantabrian Range, the first fields are likely to have been established on flat or slightly inclined slopes located close to the villages; small fields would have been separated by hedgerows, with forests left unaltered between the agricultural areas. Thereafter, population growth would have necessitated the progressive occupation of new cultivated areas on steeper slopes, eventually requiring the construction of the first terraces (Lasanta Martínez, 1997; Lasanta et al., 2017). Archaeological studies have demonstrated that the agrarian landscape is the result of a long process of construction and reorganization. In the western Cantabrian Mountains, Fernández Mier et al. (2013) stated that a deforested landscape existed during the Middle Ages and that between the 8th and 11th centuries, the agrarian landscape underwent a general re-organization that included the construction of terraces (Fernández Mier et al., 2014; Quirós Castillo et al., 2014). These findings are consistent with the results obtained from a multi-proxy study of the neighboring Arreo Lake, which concluded that, in this region, the strongest human pressure of the last 2500 years occurred in the period between the 10th and 12th

centuries (Corella et al., 2013). In some areas of Catalonia, NE Spain, bench-terraced fields have been dated between  $1440 \pm 30$  AD and the 18th century (Turner et al., 2017). In the case of the Northwestern Iberian Range, the agrarian landscape was intensively affected by the crisis of the transhumance systems and the decline of artisanal activities during the 18th and 19th centuries; these changes obligated people to construct a dense network of terraced fields even on very steep slopes (Gómez Urdáñez and Moreno Fernández, 1997). In Tuscany, a well-developed network of terraces was extensively developed beginning around 1000 AD, with intensification from the Renaissance onward (Agnoletti et al., 2015).

At the end of the 19th or the beginning of the 20th century, the landscape of the Mediterranean mountains was like a palimpsest that represented distinct cultures and historical events; it included flat or minimally sloped fields, bench-terraced fields, sloping fields and shifting-agriculture fields (Lasanta et al., 2017). Some sectors (for instance in the Pre-Pyrenees and Iberian Range) show the effects of population pressure during the 18th and 19th centuries. Many hillslopes show examples of soil and land cover degradation; this was due in most cases to the establishment of new cultivated fields necessitated by population growth or the frequent use of fire, which temporarily improved the quality of grasslands but would eventually produce sheet-wash erosion and debris flows (e.g. Cannon et al., 2008; Nyman et al., 2011; García-Ruiz et al., 2013). Other sectors represent well-preserved agricultural fields separated by hedgerows, with the creeks deviated to avoid soil erosion, and dense riparian forests that would control the velocity of floods and bank erosion (Botero-Acosta et al., 2017). In some cases, one can envision the progressive construction of the landscape from the best fields around the settlements to the worst fields on the steepest slopes, where steep, small plots would quickly experience intense erosion. Clearly, we should not think of the cultural landscapes of the Mediterranean mountains as homogeneous systems; instead, they reflected the effects of an intricate history on a heterogeneous topography that has conditioned the adaptation of humans to local aptitudes. Figure 1 shows a schematic representation of the evolution of land-use changes in Mediterranean mountain areas, where progressive deforestation and increasing human pressure were followed by a general crisis that coincided with industrialization in urban centers and depopulation of rural areas. The most usual evolution is characterized by deforestation and the opening of cultivated, marginal areas, with subsequent increases in simplification and soil conservation problems.

In general, the most relevant features of a mountain landscape reflect collective decisions and a detailed knowledge of environmental limitations, including the need to conserve soil, the hazards related to steep slopes and cliffs, and the consequences of living near fluvial channels. Members of the population also needed to know the most fertile areas, how to control overland flow, how trees, small forests and hedgerows contributed to the system, the best sunny places, the location of springs (to optimize the movement of livestock), and the best places to situate rain-fed cultivated fields, orchards, fruit trees and cutting meadows. The final result combines both empirical knowledge and the many errors that contributed to improving the locals' perspectives on how to improve the day-to-day management of their territory (García Ruiz and Lasanta, 2018).

### *2.3. Cultural landscapes: environmental and social implications*

The loss of traditional landscapes is a major cause of concern among geographers, ecologists and agronomists because such landscapes have consequences for biodiversity, soil erosion, landscape quality and ecosystem services (Geri et al., 2010; Navarro and Pereira, 2015). Social scientists also have a stake in the discussion, given the attendant loss of cultural heritage and identity (Bauer et al., 2009; Durán et al., 2015). Such researchers are conscious of the benefits that mountain traditional landscapes have provided to local populations. These landscapes are a shining example of the interdependence of nature, as cultivated fields, grasslands, soils, forests and animals are connected in a complex agroecosystem that has been “constructed” over hundreds or thousands of years. Scientists are also well aware that although it takes a great deal of effort to construct a complex cultural landscape, a simple crisis can destroy it; the more energy that is invested in the construction of a landscape, the more energy is needed for its conservation (García-Ruiz et al., 1988). Although cultural landscapes are resistant to changing factors, they lack resilience once they have been affected by a critical threshold of change (Margalef, 1984; Naveh, 2009). Bench-terraced systems appear to be the best example of this: their construction necessitated the investment of much manpower, but they abruptly collapsed as a consequence of depopulation, the impossibility of mechanization and a lack of maintenance (Tarolli et al., 2004; Arnáez et al., 2015, 2017).

Traditional agricultural systems have been frequently vindicated as a source of heterogeneity and biodiversity. Young et al. (2005) linked biodiversity to a sensitive,



environmentally sustainable management that included grazing, mowing and occasional burning. The persistence of stockbreeding is also believed to contribute to biodiversity (Olea and Mateo-Tomás, 2009). Bernués et al. (2011) stated that pasture-based livestock farming systems play a key role in the conservation of mountainous, less productive areas. These authors emphasized that livestock systems based on extensive grazing are less vulnerable to market variability, contribute to preserving open-mosaic landscapes and biodiversity, and favor the low use of fossil energy, agro-chemicals and external foods. Montserrat Recoder (2009) used the term “agroecosystem” to refer to an ecosystem that is balanced by human activity, and where the local population has historically constructed a cultural landscape characterized by an understanding of the territory’s heterogeneity, such that the human activities are aimed at obtaining annual benefits without threatening the capital (i.e., the quality and diversity of the land). Other authors have used the terms “agroecology” (Altieri and Nicholls, 2017) and “agro-silvo-pastoral systems” (Bernués et al., 2011) to embrace similar concepts. The Mediterranean mountains offer various examples confirming that conservation and landscape heterogeneity can co-exist, albeit in a constantly dynamic or even instable equilibrium. Their continuity depends on many political, demographic and climatic factors; wars, invasions, population growth and/or the occurrence of natural disasters can alter the equilibrium, leading to changes in the spatial organization of the landscape components and lately to disturbances whose restoration can consume a great deal of energy and resources. It is noteworthy that these balanced landscapes were constructed and reconstructed through centuries, such that local inhabitants obtained the maximum benefit from the spatial heterogeneity of mountains. Here, the availability of manpower, the human population and the livestock population were adapted into a complex mosaic that was necessary to maintain and restore the landscape year after year.

Most authors contend that agricultural activity has been responsible for forest wasting, landscape disturbance, soil erosion and the degradation of natural ecosystems since Neolithic times (Benton et al., 2003; Montgomery, 2007; Cerdan et al., 2010; Rey Benayas and Bullock, 2012; Dotterweich, 2013; Navarro and Pereira, 2015; Landis, 2017). In fact, a study on worldwide erosion rates identified agriculture as the most erosive land use, whereas forests and shrublands yielded the lowest rates of erosion (García-Ruiz et al., 2015b). These human-derived problems in Mediterranean landscapes have been demonstrated with empirical procedures, such as at the Aísa Valley Experimental Station of the Central Pyrenees, where plots with cultivated fields

showed the highest soil erosion rates compared with abandoned, meadow, or dense-shrub plots (Nadal-Romero et al., 2013). Examinations of fluvial channel dynamics in distinct sub-Mediterranean mountains have also demonstrated that the period of intense hillslope cultivation resulted in an extremely high degree of sediment transfer toward the alluvial plain and the eventual development of torrential braided channels (Beguería et al., 2006; Keesstra et al., 2005; Liébault et al., 2005; Gómez-Villar et al., 2014; Sanjuán et al., 2016). Stockbreeding has also been identified as a major cause of erosion in both montane and subalpine belts. The enlargement of subalpine grasslands (i.e., for summer grazing) at the expense of forest was found to be responsible for numerous shallow landslides that contributed to a remarkable soil loss (García-Ruiz et al., 2010; 2017), whereas forest recovery decreased the connectivity between slopes and channels (Bathurst et al., 2007).

Multiple International policies, as the United Nations Convention to Combat Desertification, the European Water Framework Directive and the European Common Agricultural Policy (CAP), and National and Regional measures as the Regional Rural Development Programmes have conditioned the processes related to rewilding or ecological restoration. As for the European policies in relation to land abandonment, the most important effects are those related to the Implementation of the Common Agricultural Policy (CAP) in 1986 (Van Leeuwen et al., 2019) (Fig. 2). First, the CAP was focused in the management and conservation of valuable agricultural lands with the introduction of direct payments. After the reforms introduced in 2003 and 2013, the main focuses changed and the payments are provided to farms that use sustainable farming practices and maintain ecological rich landscapes. Since 2014 environmental and agricultural issues are integrated, together with a smart and inclusive growth contributing directly to objectives of climate change adaptation and mitigation. In addition, other subsidies are provided to combat land degradation: subsidies related to reforestation programs were integrated through the Rural Development Programs (RDP).

Land managers and researchers have serious doubts about favor rewilding or restoration processes, and apply different strategies and programmes related to both processes. Some policies favor land abandonment (land retirement and set-aside, between 1988 and 2008) to decrease productivity, other policies support cultural landscapes (for instance, after the Landscape Agreement in 2009) or extensive livestock

(at least from 1986); or environmental policies to rural development and extensification (reform of the CAP in 1992 and its expansion in the AGENDA 2000 package).

### **3. Rewilding or ecological restoration after farmland abandonment: What are their respective purposes?**

The cultural landscapes of the Mediterranean mountain areas were intensively affected by farmland abandonment during the 20th century (García-Ruiz and Lana-Renault, 2011; Lasanta et al., 2015). The extreme importance of farmland abandonment is particularly relevant as follows: in the Spanish Pyrenees and the Iberian Range, where more than 90% of the cultivated land has been withdrawn (Ruiz-Flaño, 1993; Lasanta Martínez, 2014); in the eastern Alps, which evidences approximately 70% withdrawal (Tasser et al., 2007); in the Carpathian Mountains, which shows more than 30% withdrawal (Hostert, 2010); and similar figures for the French Pre-Alps (Taillefumier and Piégay, 2003), Italian Alps, Apennines (Surian et al., 2010) and Greece (Kizos and Koulouri, 2006).

#### *3.1 Rewilding: woody encroachment and the extent of shrublands and forests*

The main visible consequence of farmland abandonment has been the transformation of the old cultivated fields into extensive forests and shrublands. This has masked the main features of the traditional landscapes, including the size and form of the old fields, the hedgerows, and the steps and walls of the bench-terraced fields. It thus represents a complete collapse of the agricultural and stockbreeding systems, including the usual close relationships between agriculture and livestock within a global management of the territory. Studies examining the montane belts in the Spanish Pyrenees and the Iberian Range have allowed researchers to assess the dramatic impact of woody encroachment, some of which has been induced by reforestation programs (Gartzia et al., 2014; Sanjuán et al., 2018). This encroachment has resulted in a general homogenization of the landscape (Fig. 1).

Compared with the original landscapes (i.e., those prevailing at the middle of the 20th century), rewilded landscapes look completely different. As would be expected, their functionality and ecosystem services are also different, as follows:

(i) Rainfall interception and water infiltration during rainstorm events clearly reduce overland flow and limit the time lag and volume of peak flows under forest cover (Beguería et al., 2003; Lana-Renault et al., 2014, 2018), such that the streamflow

shows a declining trend that is parallel to the expansion of farmland abandonment (García-Ruiz et al., 2011).

(ii) Sediment yield and the connectivity between hillslopes and fluvial channels are also reduced after woody encroachment (Sanjuán et al., 2016), resulting in a remarkable slowing of sediment siltation in reservoirs (Valero-Garcés et al., 1999). As cultivated fields were the most important sediment sources in mountain areas, farmland abandonment is expected to contribute to both preserving the soil in steep slopes and producing water of higher quality.

(iii) Diversity (in terms of the variability of landscape units) decreases considerably as shrubs and forests expand, such that the traditional heterogeneity of cultural landscapes (e.g., fields of distinct sizes and shapes, separated by hedgerows, alternating with shrublands and small forest patches) is replaced with a general homogeneity. Taillefumier and Piégay (2003) noted that landscapes have become simpler in the French Pre-Alps: At the beginning of the 19th century, the traditional farming areas were characterized by a fine and varied mosaic of cultivated fields alternating with forest patches and meadows. In the late 20th century, forests and shrubs formed large homogeneous areas and the only diversity was provided by the topography, which was partially masked by natural and/or human-induced reforestation. This is a major problem, since the presence of continuous, uninterrupted forests can enhance the occurrence of large wildfires that are greater in magnitude than those occurring in traditional landscapes. This is one explanation for why large forest swaths have been affected by fires in the Mediterranean mountains during recent decades (Romero-Calcerrada and Perry, 2004; Martínez et al., 2009). In such cases, the positive effects that woody encroachment has on carbon sequestration (Nabuurs et al., 2003) can abruptly disappear in a few days, leaving its negative effects on erosion and runoff generation.

(iv) From the point of view of plant and animal diversity, there are contrasting positions regarding the benefits of farmland abandonment (Gellrich et al., 2007). Navarro and Pereira (2015) stated that biodiversity benefits from forest regeneration and the connection of fragmented natural habitats. However, while they identified 60 species of birds, 24 species of mammals and 26 species of invertebrates that were favored by farmland abandonment, they also found that a similar number (101) of species was negatively affected. Munroe et al. (2013) noted that farmland abandonment has affected biodiversity and ecosystem functions, such as through the reintroduction of

native large mammals, birds and reptiles, but that biodiversity is reduced relative to that seen with cultural landscapes. Blondel (2006) argued that human activities have had positive effects on biodiversity and that “the highest species diversities in the Mediterranean basin are found in areas that have experienced frequent but moderate disturbance” (p. 726). This author also commented that heavy grazing “is not necessarily a monolithic threat to biodiversity in Mediterranean habitats” (p.723).

The process of farmland abandonment and the consequent shrub and forest recovery, together with the arrival or expansion of flora and fauna species, is known as *rewilding*. The concept of rewilding includes a variety of political, environmental and land management perceptions of the environment (Soulé and Noss, 1998; Bauer et al., 2009; Jorgensen, 2015; Merckx and Pereira, 2015; Navarro and Pereira, 2015; Nogués Bravo et al., 2016; Fernández et al., 2017; Galetti et al., 2017; Perino et al., 2019), showing contrasting or even opposing solutions for increasing biodiversity, nature conservation or the development of local, light human activity. Nogués Bravo et al. (2016, p. R88) summarized the distinct perceptions of rewilding, including “Rewilding” (restoring big wilderness), “Pleistocene rewilding” (restoring the ecological potential lost at the beginning of the Holocene), “Passive rewilding” (passive management of ecological succession after farmland abandonment) and “Translocation rewilding” (reintroducing species to restore missing ecological processes). Initially, the term rewilding focussed on the necessity of recovering Pleistocene ecosystems (Donlan, 2005), starting from the idea that most of the abandoned ecosystems have been impoverished after centuries of agricultural and stockbreeding management (Ceasu et al., 2015; Galetti et al., 2017; Root-Bernstein et al., 2017). The local or global extinction of animal species would counsel the re-introduction of large vertebrates (Soulé and Noss, 1998; Faurby and Svenning, 2015; Carey, 2016) in order to recover the functionality of natural ecosystems. Some authors (e.g. Svenning et al., 2016; Fernández et al., 2017) speak on “trophic rewilding”, aiming the restoration of top-down trophic interactions. This concept of rewilding has been the subject of intense debate (Conti and Fagarazzi, 2005; Navarro and Pereira, 2012; Lasanta et al., 2015; Jorgensen, 2015; Nogués-Bravo et al., 2016; Corlett, 2016; Deary and Warren, 2017; Prior and Brady, 2017). In any case, rewilding represents a naturalization of the landscape that in the long term deletes most of the signs introduced by humans, while also enabling the reintroduction of the species characteristics of the original ecosystems. For these reasons, Pettorelli et al. (2017) consider rewilding as a “captivating,

controversial 21st century concept to address ecological degradation “ (p. 1115). A low-intervention forestry management, the creation of no-hunting areas, the enhancement of farmland abandonment, and the consequent restoration of natural flood regimes are considered key factors for passively recover the original wilderness (Perino et al., 2019)), even if climate, soil characteristics (particularly the infiltration capacity and soil depth) are strongly different in many cases, as is the case in sub-Mediterranean mountains.

In general, such a concept of rewilding represents the total abandonment of human activity, favouring the concentration of agriculture only in those areas able to support intensification, where subsidies should increase their sustainability and productivity (Wentworth, 2012; van der Zanden et al., 2017) in order to enhance rewilding. In fact, distinct estimates indicate that European farmers will abandon between 70,000 and 290,000 km<sup>2</sup> of marginal agricultural or grazing areas before 2030 (Verburg and Overmars, 2009; van der Zanden et al., 2017). Of course, this will represent a challenge for the future and will introduce many doubts and questions: Which is the rationale for rewilding in a given case? What is the advantage of a wilder or more natural landscape? How can we be sure that rewilding is the best option for optimizing ecosystem services and plant/animal diversity? In a densely populated world, is this a logical alternative? If rewilding represents the reintroduction of species, is it “based on a sound ecological understanding?” (Nogués-Bravo et al., 2016, p. R87). One can ask himself if this concept of rewilding is the only option, and if we separate clearly human and naturalized/abandoned landscapes; in summary, if we can ethically let cultural landscapes to evolve independently of humans and if deleting the human traces in the landscape is a solution for improving biodiversity and fighting the most relevant problems for the humanity in the short-term (Nadal-Romero and Cammeraat, 2019; Valladares et al., 2019).

### *3.2. Ecological restoration: an opportunity*

The presence of a light human pressure through extensive livestock management and grazing is the more and more considered as an adequate strategy for restoring grasslands, enhance biodiversity and improve the complexity of cultural landscapes (Haller and Bender, 2018). Schnitzler (2014) argues that most people prefer “small scale structural landscapes shaped by millennia of sustainable practices by farmers, and their loss is usually seen negatively” (p. 74).

This position assumes that the Mediterranean mountains are not completely depopulated, but the relatively few human inhabitants need options for survival. Thus, it seems that a certain degree of “controlled” rewilding could perhaps exist alongside farmers who make their livings from extensive stockbreeding and, in some cases, cultivation of the best fields in the valley bottoms and inactive alluvial fans. This introduces the concept of ecological restoration, which is conceived as the whole of the activities leading to the recovery of “an ecosystem that has been degraded, damaged or destroyed” (Society for Ecological Restoration, 2004). Nevertheless, other (more holistic) definitions are also possible. For instance, ecological restoration could be defined as the human-induced activities that lead to the partial recovery of sustainable ecosystems that will ensure high-quality ecosystem services, the preservation of soil, flora and fauna, and the survival of some human population living from extensive agro-silvo-pastoral labors integrated within the natural topographic heterogeneity and water flow systems (see Rey Benayas and Bullock, 2012; Keesstra et al., 2018). This definition includes two critical aspects: First, it proposes that from among the abandoned lands, certain old fields should be cleared of shrubs and young trees and returned to grasslands or cutting meadows that favor stockbreeding. These should be the best fields, such as those located in valley bottoms, alluvial fans, footslopes, concavities and gentle slopes, and the clearing should be designed to include hedgerows or small patches of shrubs and trees that will protect the soil, favor infiltration and increase biodiversity. Second, the above definition proposes that a small number of human residents is needed to conserve cultural landscapes by activating extensive land management systems in the complex landscapes of the Mediterranean mountains. These strategies together will yield a complex mosaic in which forests and shrublands intricately alternate with old fields that have been transformed into grasslands with small trees and shrubs patches (Fig. 1). Such efforts would also include the restoration of artificial drainage systems in the slopes, with the goal of controlling the concentration of overland flow and the development of gullies. Altieri and Nicholls (2007) noted the importance of “rescuing traditional management systems combined with the use of agroecologically based management strategies”.

In the abandoned Mediterranean mountains, the proposed ecological restoration would fulfill five major ecological objectives:

(i) Ecosystems must achieve the maximum possible heterogeneity, and the occurrence of homogeneous landscapes must be avoided. The presence of old fields of

different sizes and shapes covered with grasslands, together with the preservation of isolated trees and shrub patches, will ensure landscape heterogeneity. Studies have demonstrated that complex landscapes (e.g., those with a mixture of fields, grasslands and forests) have the highest quality for visitors (Rescia et al., 2008; Sayadi et al., 2009), also contributing to the expansion of large mammals.

(ii) The spatial organization of landscapes must safeguard the maximum possible level of biodiversity. This is only possible where there are frequent contacts between distinct environments (ecotones), as such places contribute to increasing the presence of insects, birds, reptiles and small mammals by offering them opportunities to find refuge and food. Similarly, isolated trees and shrub patches are considered to be “keystone structures” that have a disproportionately high value for biodiversity (Fischer et al., 2010; Lindenmayer, 2017).

(iii) The landscape management must favor the development of pastoral richness and wide-ranging stockbreeding activities that have very small impacts on the ecosystems. For example, sheep and cattle flocks must be adequately managed to ensure soil conservation and the sustainability of grassland production (e.g., by establishing a maximum number of sheep and cattle and spatially organizing the grazing cycles) through a collaboration among ecologists, geographers, agronomists, stockbreeders and other local stakeholders (Montserrat Recoder, 2009). It is noteworthy that various studies (e.g., Alados et al., 2018) suggest that grazing favors plant diversity and community complexity in subalpine grasslands, and that clearing is a better strategy than burning for efforts to mitigate shrub encroachment. For Haller and Bender (2018) “grazing is an instrument to maintain/restore grasslands as spaces of biodiversity” (p. 1081).

(iv) Rewilding must be compatible with the maintenance of key ecosystem services for the lowlands. One such service is the generation of runoff that will ensure streamflow, riparian vegetation survival, domestic supply and even irrigation of agricultural fields. It has been well shown that streamflow declined after farmland abandonment and forest recovery in the Mediterranean mountains (Beguería et al., 2003; Andréassian, 2004; García-Ruiz et al., 2011). Conversely, it has been empirically demonstrated that the clearing of some of the old fields and the replacement of their shrublands with grasslands would yield a slight increase in water yield with no risk for soil conservation (Nadal-Romero et al., 2013).



(v) Landscape restoration must try to reduce the occurrence of wildfires. As mentioned above, rewilding yields homogeneous woody-encroached landscapes, where fires affect thousands of hectares because there is no interruption in the continuity of forests and shrublands. While the clearing of old fields within forest areas is not expected to reduce the number of fires, it should decrease the extent of the burnt areas. For instance, Sil et al. (2019) recommend the maintenance of landscape heterogeneity in areas affected by farmland abandonment, arguing that this is the outmost strategy to regulate wildfires and to disrupt the fire spread.

(vi) Ultimately, the development of stockbreeding would tend to ensure the permanence of local populations in marginal mountains, contribute to maintaining the functionality and diversity of the landscape, and support the existence of other low-impact activities (e.g., cheese production, small touristic business, etc.).

Keesstra et al. (2018) also add that landscape restoration must be focused on the concept of connectivity, in order to reduce surface runoff, flood risk, drought intensity and soil erosion.

### *3.3. Rewilding and ecological restoration: final considerations*

A multifunctional landscape must ensure both ecological functions and ecosystem services (Holt et al., 2016). Some supporters of rewilding could argue that it is expensive to clear and organize a multifunctional landscape. Indeed, both energy (for the clearing machinery and for reconstructing/maintaining the drainage network) and time (e.g., for organizing the grazing cycles) are required. Nevertheless, the most expensive alternative is to do nothing, as this is associated with a greater fire risk, the definitive migration of local populations, streamflow declines, and the collapse of cultural landscapes that have operated efficiently, in many cases for centuries.

Cultural landscapes are part of the heritage and identity of both individual and local communities, and thus contribute to enhancing individual and societal welfare by helping generations understand the past and increasing the sense of belonging in the age of globalization (Durán et al., 2015). Another (intangible) benefit of the preservation or recovery of cultural landscapes is thus an opportunity to preserve the skills and know-how of our ancestors.

All of these benefits accrue in the long term and have a social dimension, while the costs of restoration are immediate and set in economic terms. Given the public nature of cultural landscapes, our responsibility to future generations and our lack of

knowledge regarding how cultural diversity is affected by the irreversible disappearance of cultural landscapes, we must identify and account for all concerned parties.

Last but not least, when politicians and decision-makers are obligated to design a land management strategy at distinct temporal scales, the history of the territory, its productive potentials and the local and global interests of populations must be balanced. Some territories could accept a rewilding policy aiming to transform large areas into wild parks where vegetation evolves in a natural way and where the animal trophic structures could develop in absence of human activity (e.g. Navarro and Pereira, 2012; Pettorelli et al., 2017), including the reintroduction of large herbivores and their predators (e.g. Carey, 2016). Nevertheless, where the landscape shows a strong human legacy and people is still able of maintaining partially the traditional complexity between cultivated fields, shrubs, forest patches and riparian vegetation in order to manage agropastoral systems, there ecological restoration is not only possible (Bauer et al., 2009; Rey Benayas and Bullock, 2012); it is also, above, all a compromise of rural and urban societies with nature conservation and sustainable management.

#### **4. The Leza Valley, Iberian Range (Northern Spain), as an example of landscape restoration vs. rewilding**

As an example, we present some major management strategies applied for restoring one valley in the Iberian Range (the Leza Valley), strongly affected by depopulation and ageing, and by farmland abandonment. These strategies try to maintain a light extensive livestock pressure to ensure the presence of humans, the complexity of human-induced (cultural) landscapes, the reduction of soil erosion, and the sustainability of ecosystem services.

Farmland abandonment has affected most of the old cultivated fields in the mountainous sector of the Leza Valley, a tributary of the Ebro River in northern Spain. This abandonment arose from a dramatic depopulation that occurred when many local residents migrated to urban cities; this was followed by aging of the remaining population, loss of initiative and a general collapse of human activity (Lasanta Martínez, 2014; García-Ruiz et al., 2017a). From an ecological and geographical point of view, the main consequences of this collapse were the colonization of old fields with shrubs (*Genista scorpius*, *Rosmarinus officinalis* and *Buxus sempervirens* on carbonatic soils, and *Cistus laurifolius* on siliceous soils), the establishment of young forests of *Quercus rotundifolia* and *Q. pyrenaica*, and intentional reforestation with *Pinus nigra*

and *P. sylvestris*, which occurred mainly during the 1960s (Ortigosa Izquierdo, 1991). At the end of the 20th century, only a few fields were covered with grasslands in which shrubs were controlled by livestock. At that time, the regional government surveyed the stockbreeders, who indicated that the most important challenge in maintaining or increasing their livestock numbers was the progressive decline of grazing areas due to woody encroachment (Lasanta Martínez et al., 2013). At the same time, agronomists and forest engineers warned that the fire risks were increasing in the Leza Valley, which was almost fully covered with dense forests and shrublands (Lasanta et al., 2019). In 1986, the regional government responded to these concerns by initiating a plan to clear the best of the old, abandoned fields in order to improve and enlarge the grazing area. The objective was not only to support stockbreeding but also to reduce the fire risk and create a more diverse landscape that should improve biodiversity. The cost of clearing was (and is continuing to be) financed by the Spanish government, the regional (La Rioja) government and the European Union. The old fields chosen for clearing were located at distinct altitudes, in order to enlarge the grazing period, and comprised a mixture of cleared and uncleared areas with small forest patches and hedgerows. The steeper areas and the margins between the old fields were not cleared, and trees and shrubs over 1.5 m in height were left in the fields to favor biodiversity. The final result is a complex mosaic that includes contemporary cleared fields, small patches of forest and shrubs and large forest masses interrupted by the recovered abandoned fields (Lasanta et al., 2018) (Fig. 3). The most relevant effects of this plan are as follows:

(i) A total of 5390 ha were cleared in the Leza Valley between 1986 and 2016. This represents 29.5% of the area occupied by shrublands in the Leza Valley and 18.1% of the total area of the valley.

(ii) The cleared old fields has shown remarkable increases in productivity, with a more than twofold increase seen in old fields colonized with *G. scorpius* and a more than threefold increase seen in old fields colonized with *C. laurifolius*.

(iv) The evolution of the livestock census has been impressive: The number of cows and sheep clearly declined between 1950 and 1972. Since then, the number of cows has increased sixfold (983 in 1972 vs. 5412 in 2017); the number of sheep has increased slightly, particularly between 1993 (2826) and 2017 (6568); the number of goats multiplied by 2.5 between 2007 (413) and 2017 (1040); and the number of horses has remained stable (approximately 1050).

(v) The size of the stockbreeding farms in the Leza Valley increased more than twofold between 1993 and 2017. In parallel, the mean age of stockbreeders decreased, due largely to the incorporation of new managers who have returned to the valley in the last two decades.

(vi) The landscape complexity has increased. There are more patches and these are more irregular in shape and size (Lasanta Martínez et al., 2013), and we see many shrub-covered field borders and small forest patches within the old fields (Figs. 4 and 5). Landscape fragmentation appears to have contributed to diversity, although we currently lack empirical data regarding its specific effects on flora and fauna.

(vii) Since 1986, there has been a progressive decline in the number of fires and the number of hectares burnt per year. Between 1983 and 1985 (the only years prior to 1986 for which information is available) nine fires were recorded in the Leza Valley, with 329.5 ha burnt. In contrast, only three fires affecting 16.8 ha were recorded between 1986 and 2017.

## **5. Concluding remarks**

The construction of cultural landscapes in the Mediterranean mountains has been a slow, complex process of deforestation and adaptation to major environmental limitations (particularly climate, gradient and water flows). The first cultivated fields, which occupied small areas scattered within large forests, progressively grew since Prehistoric times in parallel with the population. Meanwhile, deforestation of the subalpine belt has been recorded since Neolithic times, when humans began to use cleared grasslands to feed their livestock in the summer. Political decisions, wars and changes in the population growth rate have contributed to transforming and enlarging the original landscapes and progressively reducing the forest areas. During the 19th century, most of the Mediterranean mountains recorded their maximum population densities, and all possible areas were cultivated, including very steep slopes. This resulted in severe erosion problems and the development of torrential, braided rivers. During the 20th century, widespread farmland abandonment in the mountain areas caused the expansion of shrublands and forests at the expense of the old cultivated fields. The consequences of such a woody encroachment are relatively well known: landscape homogenization, abrupt declines in grassland productivity that reduce the stockbreeding potential, decreased streamflow, reduced erosion rates and the loss of invaluable cultural landscapes. These cultural landscapes have been examples of the

integration of agro-silvo-pastoral activity within a heterogeneous topography characterized by extremely diverse soils, water flows and topographic (local) climates. The construction of bench-terraced fields is an extreme example of an adaptation that was undertaken to preserve the soil and adequately manage overland flow. The abandonment of these fields has most often been followed by the collapse of the terrace systems, with the occurrence of small landslides that contribute to soil erosion and landscape degradation.

Once the process of farmland abandonment is almost complete, the big question is: What can we do with the abandoned landscapes? Some ecologists speak about rewilding as a natural, passive land management strategy and hold that woody encroachment should be considered the optimum strategy for preserving the soil and water quality and re-establishing the native flora and fauna species. Conversely, other scientists would like to partially reverse the actual trend of woody encroachment by clearing the old fields that have the best topographic conditions (i.e., deep soil and very low erosion risks). The latter point of view sees clearing as an opportunity to partially restore cultural landscapes, recover traditional extensive stockbreeding, emphasize the complexity that was introduced historically by human activity, and help improve biodiversity and runoff production without increasing the risk for soil erosion. The purpose of this alternative concept (included in the so-called “ecological restoration strategy”) is to (i) construct a more complex and heterogeneous landscape, (ii) recover part of the cultural landscape, (iii) increase biodiversity, (iv) reduce the probability of large wildfires, and (v) enhance the survival of extensive stockbreeding systems that also contribute to biodiversity. Here, we present an example of this strategy, as seen in the Leza Valley, La Rioja, Northern Spain, where greater landscape complexity and quality have been recorded in parallel with the establishment of new extensive stockbreeding farms run by younger farmers.

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Figure 1. Schematic representation of landscape changes in Mediterranean mountain areas, and their ecogeological/environmental impacts.

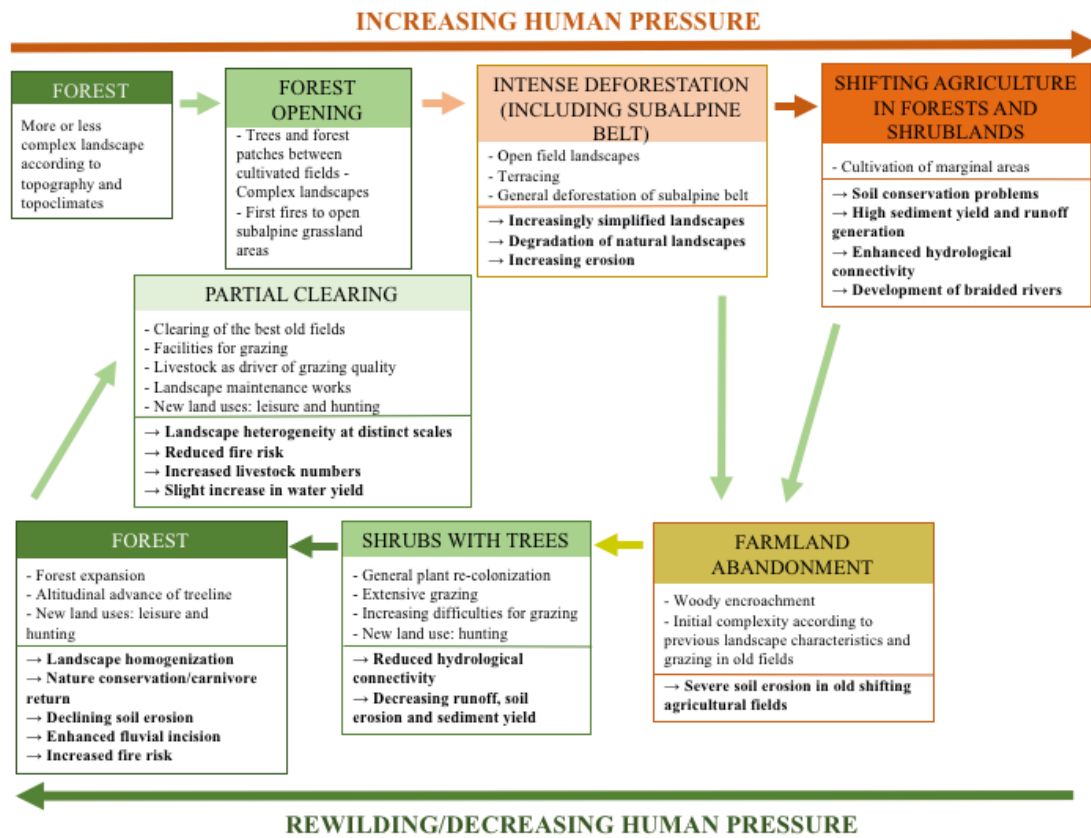


Figure 2. Land abandonment, rewilding and restoration strategies: European Common Agricultural Policy (CAP) impacts and environmental, landscape and socioeconomic issues.

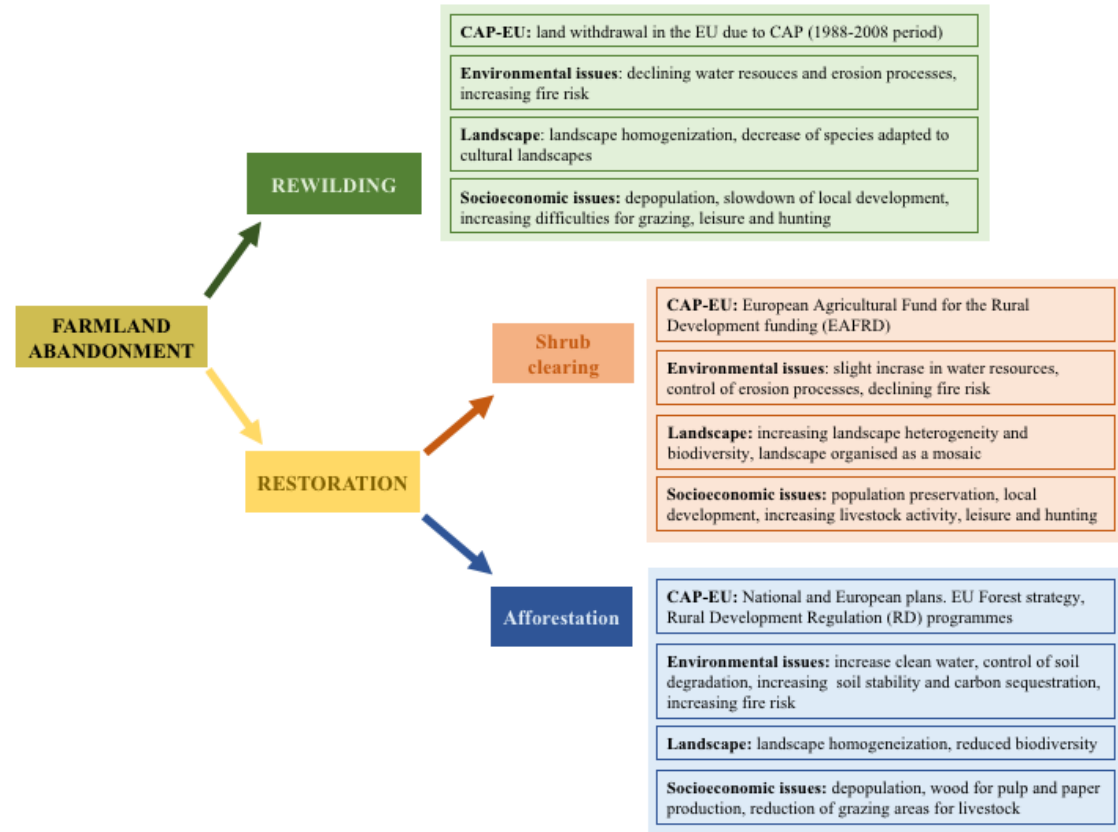


Figure 3. Satellite image of part of the Leza Valley, showing the changes that occurred between 2012 and 2014. The image from 2012 shows the typical features of old cultivated fields after more than 40 years of abandonment. Only a few of the limits

between fields are still visible, and colonization with shrubs and trees has occurred in most of the formerly agricultural landscape. The image from 2015 shows the effects of a selective clearing in which the steepest areas have been left with a dense shrub cover and trees; the old, almost flat terraced fields have been cleared; and the steps between terraces remain covered with shrubs. Some isolated trees and shrubs are also present in the middle of the fields.



Figure 4. Slope in the Leza Valley showing alternation of old fields that have been cleared, steep sectors where shrubs and trees have been preserved, and the steps between fields, where shrubs have been retained to protect against landsliding. In the



foreground, we see an uncleared old field that is partially colonized with *Cistus laurifolius*. Photo: T. Lasanta.



Figure 5. A general view of cleared and uncleared slopes in the Leza Valley. A large proportion of the landscape appears to be covered with the dense shrubs that are typically seen after decades of farmland abandonment. The slope in the foreground has been partially cleared; note the gentler gradient of the old fields and the preservation of

shrubs in the steepest sectors and in the steps between fields. The opposition between cleared and uncleared areas is highly significant, with the former exhibiting increases in complexity, heterogeneity and the number of ecotones. The observed changes have increased the richness of grasslands for livestock and favored the presence of new stockbreeders. Note that only a small part of the total landscape (exclusively the old cultivated areas) has been cleared. Photo: T. Lasanta.

