Cuadernos de Investigación Geográfica *Geographical Research Letters*	2019	Nº 45 (2)	pp. 423-440	eISSN 1697-9540

DOI: http://doi.org/10.18172/cig.3726

ACTIVE MANAGEMENT AGAINST SHRUBLAND EXPANSION: SEEKING A BALANCE BETWEEN CONSERVATION AND EXPLOITATION IN THE MOUNTAINS

T. LASANTA*

Instituto Pirenaico de Ecología, Consejo Superior de Investigaciones Científicas (IPE-CSIC), Campus de Aula Dei, Avda. Montañana, 1005, 50080 Zaragoza, Spain.

ABSTRACT. *The mountains of Europe, especially in the Mediterranean, have undergone a significant process of revegetation since the mid-20th century with the spread of shrublands and forests in succession stages. This leads to negative effects (degradation of pasture, accumulation of biomass with the subsequent increase in fire risk, loss or trivialized of cultural landscapes, etc.) and other positive ones (greater rewilding of landscapes, recovery of forest life, more CO_2 fixation, less soil erosion, etc.). Thus, two alternatives must be put forward: either allow the rewilding process to continue, or intervene in the region to reduce the negative effects of revegetation.*

*In this paper, the literature forms the base for a discussion on the main interventions in the territory: extensive livestock grazing, combined with prescribed fires and shrub clearing. Prescribed fires are found to be insufficient to control the spread of shrublands, and in some cases promotes its regrowth (*Echinospartum horridum*), as well as degrading the pasture land and increasing soil erosion. On the other hand, clearing shrubland has positive effects: a reduction in wildfires, increased livestock numbers, and improved indicators of heterogeneity and fragmentation of the landscape.*

Gestión activa frente a matorralización: buscando el equilibrio entre conservación y explotación en montaña

RESUMEN. *Las montañas europeas, especialmente las mediterráneas, experimentan un importante proceso de revegetación desde mediados del siglo XX, con el avance de matorrales y bosques de sucesión. Ello implica unos efectos negativos (degradación de pastos, acumulación de biomasa, con el incremento del riesgo de incendios, pérdida o banalización de paisajes culturales…) y positivos (mayor naturalización del paisaje, recuperación de la vida silvestre, mayor fijación de CO_2, disminución de la erosión del suelo…). De ahí, que se planteen dos alternativas: dejar que el proceso de revegetación continúe o intervenir en el territorio para disminuir los efectos negativos de la revegetación.*

*En este trabajo se discute, a partir de la literatura, sobre las principales intervenciones en el territorio: ganadería extensiva en combinación con quemas prescritas y desbroce de matorrales. Se señala que las quemas prescritas resultan insuficientes para controlar la expansión de matorrales, favoreciendo en algunos casos (*Echinospartum horridum*) su rejuvenecimiento, además de degradar la comunidad de pastos e incrementar la erosión del suelo. El desbroce de matorrales, por el contrario, muestra efectos positivos: disminución de incendios, aumento de los censos ganaderos e incremento en los índices de heterogeneidad y fragmentación del paisaje.*

Key words: land abandonment, rewilding, prescribed fires, shrub clearing, Mediterranean mountains.

Palabras clave: abandono de tierras, rewilding, quemas prescritas, desbroce de matorrales, montaña mediterránea.

Received: 31 August 2018
Accepted: 9 November 2018

*Corresponding author: Teodoro Lasanta, Instituto Pirenaico de Ecología, Consejo Superior de Investigaciones Científicas (IPE-CSIC), Campus de Aula Dei, P.O. Box 13.034, 50080 Zaragoza. E-mail address: fm@ipe.csic.es

1. Environmental effects from rewilding after land abandonment

Changes in land management, transforming both land cover and use (LCLU), have significant implications for sustainability and are included among the main causes of global climate change, since they impact biological diversity, contribute to local climate change, are the principal factors in soil degradation, and alter the ecosystems that support the needs of humans (Lambin *et al.,* 2001; Foley *et al.,* 2005).

Among the LCLU, there is a noticeable spread of vegetation, a common process in the mountain areas of developed countries (Riebsame *et al*., 1994). For some authors, higher temperatures are the main cause of the positive growth in plant biomass (Kawabata *et al.*, 2001; Lucht *et al.*, 2002). Without diminishing the role of warming, it seems to be more justifiable to attribute the main responsibility for land management and land use changes, in particular, depopulation, farmland abandonment, less pressure from livestock in the territory, and scant use of forest products (wood, firewood, etc.), all caused by an intense rewilding process (Ramankutty and Foley, 1999; MacDonald *et al.*, 2000; Kozak, 2003; Lasanta and Vicente-Serrano, 2007; García-Ruiz and Lana-Renault, 2011). In mountain areas, especially in the Mediterranean, cropland abandonment and sparse pasture land are the main reasons for enormous land cover and landscape changes, as shown by the dominance of forests, shrublands and secondary shrubs where, before, there had been crop fields and pastures (Molinillo *et al.*, 1997; Poyatos *et al.*, 2003; Metailié and Paegelow, 2004; Vicente-Serrano *et al.*, 2005; Motta *et al.*, 2006; Gellrich *et al.*, 2007; Sluiter and de Jong, 2007; Sitzia *et al.*, 2010; Komac *et al.*, 2011; Gatzia *et al.*, 2014; Sanjuán *et al.*, 2018).

The unbridled spread of vegetation, shrub succession and forest possibly constitutes a positive process on a global scale, as far it helps to compensate for the loss of large areas of forest, especially in the tropics (FAO, 2006; Austin *et al*., 2017). In fact, Song *et al*. (2018) calculate that tree cover worldwide increased by 2.24 million km^2 (+7.1%), while bare soils decreased by 1.16 million km^2 (-31%) between 1982 and 2016. However, in developed countries, rewilding can have several negative effects, among which are: i) loss of cultural landscape and the knowledge required to manage its preservation (Strijker, 2005; Arnáez *et al*., 2011; Lasanta *et al*., 2017a; García-Ruiz and Lasanta, 2018); ii) a reduction in bio-and eco-diversity in the medium- and long-term (Suárez-Seoane *et al*., 2002; Laiolo *et al*., 2004; Nikodemus *et al*., 2005; Cohen *et al*., 2011); iii) homogenization of the landscape (Meeus *et al*., 1990; Vicente-Serrano *et al*., 2000; Wood and Handley, 2001; Jongman, 2002; Van Eetvelde and Antrop, 2003; Varga *et al*., 2018); iv) loss of agricultural land and pasture resources, essential for sustainable development of mountain communities (García-Ruiz and Lasanta-Martínez, 1993; Laguna and Lasanta, 2003; García-Martínez *et al.,* 2008); v) water flow reduction in the rivers and decrease of water in river basins, due to interference and consumption by vegetation, which is especially important in Mediterranean areas where water is in short supply (López-Moreno *et al.,* 2011; García-Ruiz *et al*., 2011); vi) fewer environmental and leisure services (Benjamin *et al.,* 2007; Rescia *et al.,* 2008; Sayadi *et al*., 2009; Bernués *et al.,* 2014); and vii) an increase in natural risks, such as increased pests and diseases, but more particularly, forest fires (Westerling *et al*., 2006; Chauchard *et al*., 2007; Pausas *et al*., 2008; Varga *et al*., 2018).

However, negative effects are offset by some positive ones, such as i) rewilding of the landscape with less fragmentation, which promotes recovery of natural habitats and wild animals (Enserink and Vogel, 2006; Keenleyside and Tucker, 2010; Ceausu *et al*., 2015); ii) increased biodiversity in the initial stages of plant succession (Suárez-Seone *et al*., 2002; Höchtl *et al*., 2005); iii) reduced flooding and better regulation of the hydrological cycle (Beguería *et al*., 2003; Cosandey *et al*., 2005; Lana-Renault *et al*., 2018); iv) reduced sediment load soil erosion (Nadal-Romero *et al.,* 2012, 2013); v) increase in the useful life of reservoirs, as less sediment reaches them (López-Moreno, 2008, 2011); vi) increased carbon dioxide capture, the main cause of global warming (Paul *et al*., 2002; Maestre *et al*., 2003; Ruiz-Sinoga and Martínez-Murillo, 2009); and vii) rapid recovery of fertility, stability and biodiversity of degraded soil (Keestra *et al*., 2018).

The marginalization of farm production and revegetation therefore cause environmental, economic and social impacts that not only affect the mountains, but also the rest of society. It must not be forgotten that mountains, even today, provide resources and essential services: water, high levels of biodiversity, wood and meat, attractive countryside for recreation and leisure, carbon sequestration, prevention of natural hazards, etc. (Schmitz *et al*., 2003; Viviroli *et al*., 2007; Petanidou *et al*., 2008). Price (2004) states that, in this respect, the mountains supply goods and services to over half the world's population.

2. Two different trends: rewilding or intervention in the territory

Given that revegetation has positive and negative effects on the environment, two alternatives have been suggested for abandoned land: allow the process to continue and with it the rewilding of the landscape, or intervene in the territory in order to control the negative effects of revegetation. The issue has gained a certain importance and is under discussion between scientists and land managers (Conti and Fagarazzi, 2005; Gellrich *et al.,* 2007; Navarro and Pereira, 2012; Lasanta *et al*., 2015; Nogués-Bravo *et al*., 2016, Fernández *et al.,* 2017, among others).

The rewilding alternative first appeared in 1998 (Soulé and Noss, 1998) and is the passive management of ecological succession in order to restore the natural ecosystem and reduce human control over landscapes (Pereira and Navarro, 2015). Rewilding is based on an irrefutable fact: the widespread land abandonment in Europe throughout the 20th century (MacDonald *et al*., 2000; Keenleyside and Tucker, 2010; Lasanta *et al*., 2017b), which could be an opportunity to renaturalise and recover wildlife on a large scale (Navarro and Pereira, 2012).

In defence of renaturalising ecosystems, its supporters claim that rewilding creates a more natural landscape and greater biodiversity, by promoting the reintroduction or return of wildlife (Ceausu *et al*., 2015). In this context, more wild ungulates are proposed to fulfil the traditional role of extensive livestock grazing in maintaining a diverse and stable landscape (San Miguel-Ayanz *et al*., 2010). Navarro and Pereira (2012) point out that the Mediterranean landscape is more sustainable if the land is more renaturalised, since the erosion risk is reduced. They emphasise that forest regeneration could provide certain ecosystem services, such as carbon sequestration, and serve as a recreational element for numerous city dwellers. Lastly, they suggest that those wishing to maintain traditional uses, especially agriculture, underestimate the huge amount of human work needed to sustain them. Merckx (2015) states that intensive farming killed the moths and butterflies in Europe, while farmland abandoned has helped to halt their decline and contributed to improve biodiversity. In addition, he found that forests had a higher diversity of species than areas with shrublands or pastures.

The rewilding concept has been gradually extended, with a wide range of differing views on how to understand it, from allowing ecosystems to evolve with no human control (Schnitzler, 2014), to supporting the need for sustained intervention to minimise conflicts between humans and wildlife (Hobbs *et al*., 2015; Boitani and Linnell, 2015). The only thing these varying perspectives have in common is the wish to improve the naturalness of the landscape and wildlife, but with very different ideas on how the ecological processes and communities of species should be restored (Hobbs *et al*., 2015; Boitani and Linnell, 2015). For Deary and Warren (2017), the many-sided nature of the concept is one of the reasons why rewilding is attractive and widely accepted; because it is imprecise, the concept can be appropriated and moulded to each person's vision and particular values, while users benefit from the fact that it is widely accepted. Jørgensen (2015) points out that it has become a "plastic word" which embraces so many issues that it lacks a specific content, a claim that is refuted by Prior and Ward (2016) and by Cloyd (2016). The truth is that rewilding is being promoted internationally by NGOs,

environmental activists and owners of large farm holdings. The Rewilding Europe project aims to restore 1 million hectares of abandoned fields as a natural space. It has 5 areas of application, where the Rewilding Europe Foundation has joined up with NGOs to implement revegetation and increase biodiversity (Helmer *et al*., 2015). In addition, over the last few years, scientific publications have proliferated, and the concept habitually appears in journalism and professional activities relating to nature (Navarro and Pereira, 2015; Corlett, 2016; Svenning *et al.*, 2016). Nogués-Bravo *et al*. (2016: 87) put it, that 'the drumbeat for rewilding is getting faster and louder', although they caution that it might be 'the new Pandora's box in conservation'.

On the other hand, some authors state that the advantages of rewilding are more apparent than real (Conti and Fagarazzi, 2005). They emphasise that the landscape in Europe, especially the Mediterranean, is one that has been humanised (Grobe and Rackham, 2001; Agnoletti, 2014). Gill (2006) says that the concept of "forest" in Europe refers to places with trees and herbivores, which is more like a park or savannah than a closed space of trees. Similarly, it is argued that the most common landscape in Mediterranean regions is cultural, due to agriculture on the slopes and extensive livestock grazing (Farina, 2007; San Miguel-Ayanz *et al*., 2010; García-Ruiz and Lasanta, 2018).

Several scientists and managers advocated intervening on the land, in order to reduce the negative effects of farmland abandonment and massive revegetation. This is in a bid to break off with an over-naturalised landscape and, in some way, maintain the traits of a cultural landscape, because of its high ecological (Moreira *et al.,* 2006), productive (Quetier *et al.*, 2005; Kizos and Koulouri, 2006) and aesthetic (Vanslembrouck *et al.*, 2005; Sayadi *et al.*, 2009) value. In addition, some authors agree that, to be sustainable, landscapes must be multifunctional: they need to produce food, contribute to social structuring and maintain environmental values. Only in this way, they help in the sustainable development of the population and ensure the resources and values of the territory (Kinzing *et al*., 2006; Kizos and Koulouri, 2006; Pelorosso *et al.,* 2011).

The wide area occupied by abandoned land is an opportunity to manage it by introducing new uses (Cogliastro *et al*., 2003; Benjamin *et al*., 2008). Land managers have mainly supported two strategies: reforestation and extensive livestock grazing.

Reforestation, especially with conifers, is a very common strategy in Mediterranean areas. In Spain, approximately 5 million hectares were reforested between 1940 and 2006 (S.C.F.C., 2011). Forests are replanted for economic and environmental reasons: to generate jobs, avoid depopulation, produce wood and paper pulp, reduce soil erosion and control flooding (Ortigosa Izquierdo, 1990; Pausas *et al*., 2004). However, the economic objectives are not very successful, as hardly any jobs are created except at planting time, it does not retain the rural population, and production of wood and paper pulp is small and only in the long-term (García-Ruiz, 1976; Chauvelier, 1990). Ortigosa *et al.* (1990) point out that reforesting had a highly negative impact in the local development of the central Spanish Pyrenees: it reduced the pasture area and livestock census, which accelerated emigration of the local population. Moreover, the environmental results are very heterogeneous, depending on the location of the perimeter and technique used in reforesting. Thus, soil erosion and growth of pine trees is lower in plantations on terraces

built with bulldozers than when made by digging holes or furrows manually (Ortigosa Izquierdo, 1991). Furthermore, Nadal-Romero *et al*. (2016) found that, in abandoned fields in the Pyrenees, forest plantations did not speed up recovery of soil properties (fertility and quality) in comparison with secondary succession (natural revegetation). In addition, it must be remembered that large plantations of pines create a highly uniform, fire-prone landscape (Pausas *et al*., 2008; Martínez-Fernández *et al*., 2013).

Over the last few decades, land managers have tried to control the expansion of shrublands, and conserve cultural landscapes by supporting extensive livestock grazing, especially with economical aids to maintain it. This has been the case in the European Union since 1992 through its Common Agricultural Policy (Mottet *et al*., 2006; García-Martínez *et al*., 2008). It must be remembered that extensive grazing provides certain advantages that are supported by public policies, as it combines production (meat, milk, wool, etc.), social (maintenance of cultural landscapes, fixing the rural population) and environmental (increasing landscape diversity, reduction in wildfires) purposes (Mouillot *et al*., 2003; Calvo-Iglesias *et al*., 2006; Rescia *et al*., 2008). Gibón (2005) states that, with extensive grazing, a landscape consisting basically of shrubland can be transformed into another, characteristic of European mountains, with a mosaic of land uses, such as forests, pasture, shrub and some fields as meadows. A landscape containing huge production (pasture, wood, firewood, by-products, etc.), ecological (pollination, bio-chemical cycles, etc.), cultural (aesthetic, educational, recreational, etc.), for regulation (land conservation, hydrological control, water quality, flood control, etc.) value, and which also supports very varied habitats, the basis for maintaining biodiversity.

However, in the control of revegetation, various studies (Bartolomé *et al*., 2000; Casasús *et al*., 2007; Komac *et al*., 2013; Álvarez-Martínez *et al*., 2016) highlight the fact that, with the small number of livestock currently in mountain areas, livestock grazing will only slow down the encroachment of shrub, but not deter it from expanding. Similarly, Muñoz-Barcia *et al*. (2019) deem it crucial to establish the grazing pressure needed to keep the habitats in optimum condition so as to ensure their preservation.

3. Combining extensive livestock grazing with prescribed fires and shrubland clearing

The limited role of extensive grazing, on its own, to control the expansion of shrubland has resulted in combining grazing with other actions on the territory, especially prescribed fires and shrubland clearing.

Prescribed fires, or controlled fires, are a tool to reduce the accumulation of fuel and the risk of fire. In addition, they promote the regeneration of pastures for livestock grazing, and conserve biodiversity and cultural landscapes (Fernandes *et al*., 2013; San Emeterio *et al*., 2016). Canals (2019) justifies the environmental interest in the combination of prescribed fires–guided grazing (pyro herbivory) as a tool for handling mountain ecosystems, for which it is essential to combine traditional knowledge of shepherds with the technical and scientific knowledge. Alcasena *et al*. (2019) try to identify areas in the landscape on which to intervene to reduce wildfires spreading to

particularly sensitive areas, due to their environmental value. They start from the idea that, to lessen fire risk, fire-resistant landscapes must be created by managing fuels, with extensive grazing and prescribed burning suitable strategies for eliminating fuel and making open spaces acting as fire breaks.

Prescribed fires began experimentally in Mediterranean areas of Europe in the 1960s, although it was not definitely implemented until the 1980s (Fernandes *et al*., 2013). At present, it is used on 10,000 ha yr^{-1}, which is approximately only 3% of the burned surface in Portugal, Spain and France (Ascoli and Bovio, 2013). In Spain, prescribed burning for grazing started in 1998, when the Environment Ministry introduced forest fire prevention teams (EPRIF), to reduce farmers' uncontrolled use of fire to remove shrub and regenerate pastures (Lasanta *et al*., 2014).

However, prescribed fires proved to be insufficient in controlling the spread of shrubland. Komac *et al.* (2011), in a study carried out in sub-alpine pastures in the central Spanish Pyrenees, highlight the fact that *Echinospartum horridum* grows back two or three years following fires, and is fully revitalised and widespread after four or five years. Badía *et al.* (2017) concluded that burning *E. horridum* rejuvenates the community which, far from being eliminated, undergoes self-succession in time. Nuche *et al.* (2018) also found that burning *E. horridum* increases its germination and helps to sow seeds that were not previously present in the rich sub-alpine pastures of the Pyrenees. Ruiz Mirazo *et al.* (2011) state that the current low numbers of livestock in many mountain areas result in the failure of the fire-grazing balance. Gómez-García *et al*. (2011) analysed the effect of controlled fire and clearance combined with livestock grazing in the north-western Spanish Pyrenees. Their results show that the ideal situation is grazing and shrub clearings on gentle slopes with abundant vegetation cover, while fire-grazing is a more effective combination in areas with medium or steep slopes and sparse vegetation. In a more recent article, Gómez *et al.* (2019) recommend frequent clearance (every 1-2 years) and heavy grazing after clearing, in order to prevent the spread of unsuitable grasses for pasture, which are precursors of shrub recolonization. In turn, Alados *et al*. (2019) studied the effects of prescribed burning and shrub clearance in sub-alpine pastures in the central Pyrenees on the recovery of *E. horridum* and on *Bromion erecti* pasture, finding that clearing was better at controlling colonisation of *E. horridum* than burning, as well as degrading the soil loss. They concluded by saying that clearing is a better strategy than burning to restore sub-alpine pasture land after invasion by shrubs.

Prescribed fires also affect the land to a certain extent. San Emeterio *et al.* (2016) point out the reduction in microbial biomass in the soil for at least the first two years following fire. Fonseca *et al*. (2017) observed chemical changes in the soil. Thirty-six months after fire, values of organic material, pH and electrical conductivity had recovered, while those of potassium, assimilable phosphorus and exchangeable bases differed from those observed before fire. Moreover, notable increases in runoff coefficients and soil loss were found. In addition, prescribed fires comes up against certain factors that restrict its consolidation and expansion in the Mediterranean countries of Europe, such as concerns on fire risk, the scarcity of experts and organisations with experience, the public's view

of fire as a nuisance, and regulations prohibiting or limiting the use of fire (Fernandes *et al*., 2013; Mierauskas and Pereira, 2013).

Another action on the territory is to combine shrubland clearing and extensive grazing. In selected areas, especially abandoned fields, shrub has been removed by mechanical techniques to encourage grass to grow. The purpose is to promote livestock farming, control wildfires, maintain the cultural landscape and high rates of biodiversity. Although shrubland clearing occurs occasionally in various parts of Spain (Lasanta *et al.*, 2011, 2014), La Rioja is where the strategy has been widely implemented. Between 1986 and 2017, 33,900 ha were cleared in the mountain areas of La Rioja, representing 25.9% of shrubland, or 13.2% of the total surface area. Most of the clearing took place on former crop fields that had been abandoned after 1960 and were now in a process of plant succession (Lasanta *et al*., 2018).

After more than 30 years of taking action on the territory by shrub clearing, it can be seen that the results are very positive in controlling fires, increasing the numbers of livestock, and the structure of the landscape. Lasanta *et al*. (2018) found that the number of fires and burned area has been greatly reduced in comparison with Spain. In La Rioja, fires account for about 20% of incidents, while in Spain this rises to 30%. Similarly, in La Rioja from 2008-2017, only 7.5% of the area burned in the decade of 1978-1987 was burned, while in Spain it was 42.2%. Shrubland clearing has several positive effects in decreasing the burned area: i) it removes combustible material, which reduces the risk of fire; ii) it creates a mosaic and fragmented landscape with small patches where pasture land is interspersed with shrub and thickets of trees, which helps to control and extinguish any fires; iii) livestock farmers no longer need to burn to regenerate grazing land. It is well-known that the livestock sector is closely linked to forest fires, as a large part of these start with the use of fire as a tool in regenerating pastures. Also, Lasanta *et al.* (2019) found that, in the Leza Valley (north-western Iberian System), shrubland clearing led to an increase in livestock numbers, rising from 1,833.9 LU in 1972 to 7,207.8 LU in 2017, with the size of farms also expanding (27.6 LU in 1972 to 115.2 LU in 2017). In addition, new livestock farms are being started by people from outside the study area (41.7% in 2017), which is a clear factor in socio-economic and environmental sustainability. Lastly, Lasanta *et al*. (2016) studied the effects of clearing on the heterogeneity of the landscape and found that, in the study area, the number of patches doubled (from 26 to 52), while the average size of each patch was smaller (from 61.6 ha to 30.8 ha). This action has created a more fragmented landscape, a mosaic of land uses comprising trees, shrub and pasture, highly valued by the public and with great potential for developing tourism (Sayadi *et al*., 2009). Furthermore, rates of heterogeneity show an increase in diversity and a reduction in dominance following shrubland clearing (Lasanta *et al*., 2016), confirming that clearing creates a more complex landscape with greater ecological value (Bignal and McCracken, 2000).

This volume discusses the combined use of extensive livestock grazing with prescribed fires or shrubland clearing, strategies used over the last few decades to prevent the spread of shrubland, control fire risk and preserve pasture ecosystems, cultural landscapes and their biodiversity. The volume consists of several articles highlighting

the importance of extensive grazing for cultural landscapes if a balance is to be reached between the use of resources and preserving ecological and cultural values.

Acknowledgements

This research was supported by the ESPAS project (CGL2015-65569-R, funded by the State Research Agency-FEDER) and ECOHIPRO (1560/2015), funded by the Natural Parks-Ministry of Agriculture and Environment. The "Geomorphology and Global Change" Group was financed by the Aragón Government and the European Social Fund (ESF-FSE).

References

Agnoletti, M. 2014. Rural landscape, nature conservation and culture. Some notes on research trends and management approaches from a (southern) Europe perspective. *Landscape and Urban Planning* 126, 66-73. https://doi.org/10.1016/j.landurbplan.2014.02.012.

Alados, C.L., Saiz, H., Nuche, P., Gartzia, M., de Frutos, A., Pueyo, Y. 2019. Clearing vs. burning for restoring grasslands after shrub encroachment. *Cuadernos de Investigación Geográfica*, 45 (2), 441-468. http://doi.org/10.18172/cig.3589.

Alcasena, F.J., Vega-García, C., Ager, A.A., Salis, M., Nauslar, N.J., Mendizabal, F.J., Castell, R. 2019. Evaluación del riesgo de incendios y priorización de tratamientos en paisajes mediterráneos. *Cuadernos de Investigación Geográfica*, 45 (2), 571-600. http://doi.org/10.18172/cig.3716

Álvarez-Martínez, J., Gómez-Villar, A., Lasanta, T. 2016. The use of goats grazing to restore pastures invaded by shrubs and avoid desertification: A preliminary case study in the Spanish Cantabrian Mountains. *Land Degradation & Development* 27, 3-13. https://doi.org/10.1002/ldr.2230.

Arnáez, J., Lasanta, T., Errea, M.P., Ortigosa, L. 2011. Land abandonment, landscape evolution, and soil erosion in a Spanish Mediterranean mountain region: The case of Camero Viejo. *Land Degradation & Development* 22, 537-550. https://doi.org/10.1002/ldr.1032.

Ascoli, D., Bovio, G. 2013. Prescribed burning in Italy: a review of issues, advances and challenges. *iForest* 6, 79-89. http://www.sisef.it/iforest/contents?id=ifor0803-005.

Austin, K.G., González-Roglich, M., Schaffer-Smith, D., Schwantes, A.M., Swenson, J.J. 2017. Trends in size of tropical deforestation events signal increasing dominance of industrial-scale drivers. *Environmental Research Letters* 12 (5), 054009. https://doi.org/10.1088/1748-9326/aa7760.

Badía, D., Armas, C., Mora, J.L., Gómez, D., Montserrat, G., Palacios, S. 2017. ¿Podemos controlar la expansión del erizón mediante quemas? *Lucas Mallada* 19, 64-94.

Bartolomé, J., Franch, J., Plaixats, J., Selignan, N.G. 2000. Grazing alone is not enough to maintain landscape diversity in the Montseny Reserve. *Agriculture, Ecosystems and Environment* 77 (3), 267-273. https://doi.org/10.1016/S0167-8809(99)00086-9.

Beguería, S., López-Moreno, J.I., Llorente, A., Seeger, M., García-Ruiz, J.M. 2003. Assessing the effects of climate oscillations and land-use changes on streamflow in the Central Spanish Pyrenees. *Ambio* 32 (4), 283-286. https://doi.org/10.1579/0044-7447-32.4.283.

Benjamin, K., Bouchard, A., Domon, G. 2007. Abandoned farmlands as components of rural landscapes: an analysis of perceptions and representations. *Landscape and Urban Planning* 83, 228-244. https://doi.org/10.1016/j.landurbplan.2007.04.009.

Benjamin, K., Bouchard, A., Domon, G. 2008. Managing abandoned farmland: The need to link biological and sociological aspects. *Environmental Management* 42, 603-619. https://doi.org/10.1007/s00267-008-9176-5.

Bernués, A., Rodríguez-Ortega, T., Ripoll-Bosch, R., Alfnes, F. 2014. Socio-cultural and economic valuation of ecosystem services provided by Mediterranean agroecosystems. *PLoS ONE* 9 (7), e102479. https://doi.org/10.1371/journal.pone.0102479.

Bignal, E., McCracken, D. 2000. The nature conservation value of European traditional farming systems. *Environmental Review* 8, 149-171. https://doi.org/10.1139/a00-009.

Boitani, L., Linnell, J.D.C. 2015. Bringing large mammals back: Large carnivores in Europe. In: H.M. Pereira, L.M. Navarro (Eds.), *Rewilding European Landscapes*. Springer, Cham, pp. 67-84. https://doi.org/10.1007/978-3-319-12039-3_4.

Calvo-Iglesias, M.S., Crecente-Maseda, R., Fra-Paleo, U. 2006. Exploring farmer's knowledge as a source of information on past and present cultural landscape. A case study from NW Spain. *Landscape and Urban Planning* 78, 334-343. https://doi.org/10.1016/j.landurbplan.2005.11.003.

Canals, R.M. 2019. Landscape in motion: revisiting the role of key disturbances for the preservation of mountain ecosystems. *Cuadernos de Investigación Geográfica* 45 (2), 515-531. http://doi.org/10.18172/cig.3634

Casasús, I., Bernués, A., Sanz, A., Villalba, D., Riedel, J.L., Revilla, R. 2007. Vegetation dynamics in Mediterranean forest pastures as affected by beef cattle grazing. *Agriculture, Ecosystems and Environment* 121 (4), 365-370. https://doi.org/10.1016/j.agee.2006.11.012.

Ceausu, S., Hofmann, M., Navarro, l.H., Carver, S., Verburg, P.H., Pereira, H.M. 2015. Mapping oportunities and challenges for rewilding in Europe. *Conservation Biology* 29 (4), 1017-1027. https://doi.org/10.1111/cobi.12533.

Chauchard, S., Carcaillet, C., Guibal, F. 2007. Patterns of land-use abandonment control tree-recruitment and forest dynamics in Mediterranean mountainous. *Ecosystems* 10, 936-948. https://doi.org/10.1007/s10021-007-9065-4.

Chauvelier. F. 1990. *La repoblación forestal en la provincia de Huesca y sus impactos geográficos*. Colección de Estudios Altoaragoneses, Huesca, 164 pp. Available at: https://jolube.files.wordpress.com/2008/04/chauvalier_1995_repoblaciones_hu.pdf.

Cloyd, A.A. 2016. Reimagining rewilding: A response to JØrgensen, Prior, and Ward. *Geoforum* 76, 59-62. https://doi.org/10.1016/j.geoforum.2016.08.013.

Cogliastro, A., Gognon, D., Daigle, S., Bouchard, A. 2003. Improving hardwood afforestation success: an analysis of the effects of soil properties in southwestern Quebec. *Forest Ecology Management* 177, 347-359. https://doi.org/10.1016/S0378-1127(02)00395-X.

Cohen, M., Varga, D., Vila, J., Barrassaud, E. 2011. A multi-scale and multi-disciplinary approach to monitor landscape dynamics: a case study in the Catalan Pre-Pyrenees (Spain). *The Geographical Journal* 177 (1), 79-91. https://doi.org/10.1111/j.1475-4959.2010.00368.x.

Conti, G., Fagarazzi, L. 2005. Forest expansion in mountain ecosystems: "environmentalist's dream" or societal nightmare? Driving force, topics and impacts of one the main 20th century's environmental, territorial and landscape transformation in Italy. *Planum* 11, 1-20. Available at: http://www.planum.net/download/conti_fagarazzi_en-pdf.

Corlett, R.T. 2016. Restoration, Reintroduction and Rewilding in a changing world. *Trends in Ecology & Evolution* 31 (6), 453-462. http://doi.org/10.1016/j.tree.2016.02.017.

Cosandey, C., Andréassian, V., Martin, C., Didon-Lescot, J.F., Lavabre, J., Folton, N., Mathys, N., Richard, D. 2005. The hydrological impact of the Mediterranean forest: a review of French research. *Journal of Hydrology* 301 (1), 235-249. https://doi.org/10.1016/j.jhydrol.2004.06.040.

Deary, H., Warren C.R. 2017. Divergent visions of wildness and naturalness in a storied landscape: Practices and discourses of rewilding in Scotland's wild places. *Journal of Rural Studies* 54, 211-222. https://doi.org/10.1016/j.jrurstud.2017.06.019.

Enserink, M., Vogel, G. 2006. The carnivore comeback. *Science* 314 (5800), 7476-7749. https://doi.org/10.1126/science.314.5800.746

FAO 2006. *Evaluación de Recursos Forestales Mundiales*. FAO, Rome. Available at: http://www.fao.org/forestry.

Farina, A. 2007. *Principles and methods of landscape ecology towards a science of the landscape*. Springer Verlag.

Fernandes, P.M., Davies, G.M., Ascoli, D., Fernández, C., Moreira, F., Rigolot, E., Stroof, C.R., Vega, J.A., Molina, D. 2013. Prescribed burning in southern Europe: developing fire management in a dynamic landscape. *Frontiers in Ecology and the Environment* 11, e4-e14. https://doi.org/10.1890/120298.

Fernández, N., Navarro L.M, Pereira, H.M. 2017. Rewilding: A call for boosting ecological complexity in conservation. *Conservation Letters* 10 (3), 276-278. https://doi.org/10.1111/conl.12374.

Fonseca, F., de Figueiredo, T., Nogueira, C., Queirós, A. 2017. Effect of prescribe fire on soil properties and soil erosion in a Mediterranean mountain area. *Geoderma* 307, 172-180. https://doi.org/10.1016/j.geoderma.2017.06.018.

Foley, J.A., DeFries, R., Asner, G.P., Barford, C., Bonan, G., Carpenter, S.R., Chapin, F.S., Coe, M.T., Daily, G.C., Gibbs, H.K., Helkowski, J.H., Holloway, T., Howard, E.A., Kucharik, C.J., Monfreda, C., Patz, J.A., Prentice, I.C., Ramankutty, N., Snyder, P.K. 2005. Global consequences of land use. *Science* 309, 570-574. https://doi.org/10.1126/science.1111772.

García-Martínez, A., Olaizola, A., Bernués, A. 2008. Trajectories of evolution and drivers of change in European mountain cattle farming systems. *Animal* 3 (1), 152-165. https://doi.org/10.1017/S1751731108003297.

García-Ruiz, J.M. 1976. *Modos de vida y niveles de renta en el Prepirineo del Alto Aragón Occidental*. Monografías del Instituto de Estudios Pirenaicos, 106, Jaca, 272 pp.

García-Ruiz, J.M., Lana-Renault, N. 2011. Hydrological and erosive consequences of farmland abandonment in Europe, with special reference to the Mediterranean region – a review. *Agriculture, Ecosystems and Environment* 140, 317-338. https://doi.org/10.1016/j.agee.2011.01.003.

García-Ruiz, J.M., Lasanta-Martínez, T. 1993. Land-use conflicts as a result of land-use change in the Central Spanish Pyrenees: a Review. *Mountain Research and Development* 13 (3), 295-304. https://doi.org/10.2307/3673658.

García-Ruiz, J.M., Lasanta, T. 2018. El Pirineo aragonés como paisaje cultural. *Pirineos* 173, e038. https://doi.org/10.3989/pirineos.2018.173005.

García-Ruiz, J.M., López-Moreno, J.I., Vicente-Serrano, S., Lasanta, T., Beguería, S. 2011. Mediterranean water resources in a global change scenario. *Earth Science Reviews* 105 (3-4), 121-139. https://doi.org/10.1016/j.earscirev.2011.01.006.

Gartzia, M., Alados, C.L., Pérez-Cabello, F. 2014. Assessment of the effects of biophysical and anthropogenic factors on woody plant encroachment in dense and sparse mountain grasslands based on remote sensing data. *Progress in Physical Geography* 38, 201-217. https://doi.org/10.1177/0309133314524429.

Gellrich, M., Baur, P., Koch, B., Zimmermann, N.E. 2007. Agricultural land abandonment and natural forest re-growth in the Swiss mountains: A spatially explicit economic analysis. *Agriculture, Ecosystems and Environment* 118, 93-108. https://doi.org/10.1016/j.agee.2006.05.001.

Gibon, A. 2005. Managing grassland for production, the environment and the landscape. Challenges at the farm and the landscape level. *Livestock Production Science* 96, 11-31. https://doi.org/10.1016/j.livprodsci.2005.05.009.

Gill, R. 2006. The influence of large herbivores on tree recruitment and forest dynamics. In: K. Danell, R. Bergström, P. Duncan, J. Pastor (Eds.), *Large Herbivore Ecology, Ecosystems Dynamics and Conservation.* Conservation Biology Series, 11. Cambridge University Press, pp.170-202. https://doi.org/10.1017/CBO9780511617461.008.

Gómez, D., Aguirre, A.J., Lizaur, X., Lorda, M., Remón, J.L. 2019. Evolution of argoma shrub (*Ulex gallii* Planch) after clearing and burning treatments in the Sierra de Aralar and in Belate. *Cuadernos de Investigación Geográfica* 45 (2), 469-486. http://doi.org/10.18172/cig.3747.

Gómez-García, D., Aguirre, A.J., Lizaur-Sukia, X. 2011. Recuperación del matorral tras desbroce mecánico y quema en pastos de la Sierra de Aralar y Belate (Navarra). In: C. López-Carrasco, M.P. Rodríguez, A. San Miguel, F. Fernández, S. Roig (Eds.), *Pastos, paisajes culturales entre tradición y nuevos paradigmas del siglo XXI*. SEEP, Toledo, pp. 133-138.

Grobe, A.O., Rackham, O. 2001. *The nature of Mediterranean Europe. An Ecological History*. Yale University Press.

Helmer, W., Saavedra, D., Sylvén, M., Schepers, F. 2015. Rewilding Europe: A new strategy for an old continent. In: H.M. Pereira, L.M. Navarro (Eds.), *Rewilding European Landscapes*. Springer, Cham, pp. 171-190. https://doi.org/10.1007/978-3-319-12039-3_9.

Hobbs, R.J., Hallett, L.M., Ehrlich, P.R., Mooney, H.A. 2015. Intervention ecology: applying ecological science in the twenty-first century. *Bioscience* 61, 442-450. https://doi.org/10.1525/bio.2011.61.6.6.

Höchtl, F., Lehringer, S., Konold, W. 2005. "Wilderness": What it means when it becomes a reality – a case study from the southwestern Alps. *Landscape and Urban Planning* 70, 85-95. https://doi.org/10.1016/j.landurbplan.2003.10.006.

Jongman, R.H.G. 2002. Homogenisation and fragmentation of the European landscape: ecological consequences and solutions. *Landscape and Urban Planning* 58 (2-4), 211-221. https://doi.org/10.1016/S0169-2046(01)00222-5.

Jørgensen, D. 2015. Rethinking rewilding. *Geoforum* 65, 482-488. https://doi.org/10.1016/j.geoforum.2014.11.016

Kawataba, A., Ichii, K., Yamaguchi, Y. 2001. Global monitoring of inter-annual changes in vegetation activities using NDVI and its relationships to temperature and precipitation. *International Journal of Remote Sensing* 22 (7), 1377-1382. https://doi.org/10.1080/01431160119381.

Keenleyside, C., Tucker, G.M. 2010. *Farmland abandonment in the EU: an assessment of trends and prospects*. Report prepared for WWF. Institute for European Environmental Policy, London, 93 pp.

Keesstra, S., Nunes, J., Novara, A., Finger, D., Avelar, D., Kalantari, Z., Cerdà, A. 2018. The superior effect of nature based solutions in land management for enhancing ecosystem services. *Science of Total Environment* 610-611, 997-1009. https://doi.org/10.1016/j.scitotenv.2017.08.077.

Kinzing, A. P., Ryan, P., Etienne, M., Allison, H., Elmqvist, T., Walker, B.H. 2006. Resilience and regime shifts: assessing cascading effects. *Ecology and Society* 11 (1), 20. https://doi.org/10.5751/ES-01678-110120.

Kizos, T., Koulouri, M. 2006. Agricultural landscape dynamics in the Mediterranean: Lesvos (Greece) case study using evidence from the last three centuries. *Environmental Science & Policy* 9, 330-342. https://doi.org/10.1016/j.envsci.2006.02.002.

Komac, B., Alados, C.L., Camarero, J.J. 2011. Influence of topography on the colonization of subalpine grasslands by *Echinospartum horridum*. *Arctic, Antarctic, and Alpine Research* 43 (4), 601-611. https://doi.org/10.1657/1938-4246-43.4.601.

Komac, B., Kefi, S., Nuche, P., Escós, J., Alados, C.L. 2013. Modeling shrub encroachment in subalpine grasslands under different environmental and management scenarios. *Journal of Environmental Management* 121, 160-169. https://doi.org/10.1016/j.jenvman.2013.01.038.

Kozak, J. 2003. Forest cover change in the Western Carpathians in the past 180 years. A case study in the Orawa Region in Poland. *Mountain Research and Development* 23 (4), 369-375. https://doi.org/10.1659/0276-4741(2003)023[0369:FCCITW]2.0.CO;2.

Laiolo, P., Dondero, F., Ciliento, E., Rolando, A. 2004. Consequences of pastoral abandonment for the structure and diversity of the alpine avifauna. *Journal of Applied Ecology* 41, 294-304. https://doi.org/10.1111/j.0021-8901.2004.00893.x.

Laguna, M., Lasanta. T. 2003. Competing for meadows: A case study on tourism and livestock farming in the Spanish Pyrenees. *Mountain Research and Development* 23 (2), 169-176. https://doi.org/10.1659/0276-4741(2003)023[0169:CFM]2.0.CO;2.

Lambin, E.F., Turner, B.L., Geist, H.J., Agbola, S.B., Angelsen, A., Bruce, J.W., Coomes, O.T., Dirzo, R., Fischer, G., Folke, C., George, P.S., Homewood, K., Imbernon, J., Leemans, R., Li, X., Moran, E.F., Mortimore, M., Ramakrishman, P.S., Richards, J.F., Skanes, H., Eteffen, W., Stone, G.D., Svedin, U., Veldkamp, T.A., Vogel, C., Xu, J. 2001. The causes of land use and land cover change: moving beyond the myths. *Global Environmental Change* 11, 261-269. https://doi.org/10.1016/S0959-3780(01)00007-3.

Lana-Renault, N., López-Vicente, M., Nadal-Romero, E., Ojanguren, R., Llorente, J.A., Errea, P., Regüés, D., Ruiz-Flaño, P., Khorchani, M., Arnáez, J., Pascual, N. 2018. Catchment based hydrology under post farmland abandonment scenarios. *Cuadernos de Investigación Geográfica* 44 (2), 503-534. https://doi.org/10.18172/cig.3475.

Lasanta, T., Vicente-Serrano, S.M. 2007. Cambios en la cubierta vegetal en el Pirineo aragonés en los últimos 50 años. *Pirineos* 162, 125-154. http://doi.org/10.3989/pirineos.2007.v162.16.

Lasanta, T., Vicente-Serrano, S.M., Arnáez, J. 2011. La revegetación en las montañas españolas ¿Dejar hacer o intervenir en el territorio? *Geographicalia* 59-60, 199-211. https://doi.org/10.26754/ojs_geoph/geoph.201159-60832.

Lasanta, T., Álvarez-Martínez, J., Gómez-Villar, A. 2014. La ganadería extensiva frente a la matorralización: Actuaciones recientes en las montañas españolas. En: J. Cortizo Álvarez, J.M. Redondo Vega, M.J. Sánchez Múñoz (Eds.), *De la Geografía Rural al Desarrollo Local, Homenaje a Antonio Maya Frades.* Universidad de León, León, pp. 491-503.

Lasanta, T., Nadal-Romero, E., Arnáez, J. 2015. Managing abandoned farmland to control the impact of re-vegetation on the environment. The state of art in Europe. *Environmental Science & Policy* 52, 99-109. https://doi.org/10.1016/j.envsci.2015.05.012.

Lasanta, T., Nadal-Romero, E., Errea, M.P., Arnáez, J. 2016. The effects of landscape conservation measures in changing landscape patterns: a case study in Mediterranean mountains. *Land Degradation & Development* 27, 373-386. https://doi.org/10.1002/ldr.2359.

Lasanta, T., Errea, M.P., Nadal-Romero, E. 2017a. Traditional agrarian landscape in the Mediterranean mountains. A regional and local factor analysis in the Central Spanish Pyrenees. *Land Degradation & Development* 28 (5), 1626-1640. https://doi.org/10.1002/ldr.2695.

Lasanta, T., Arnáez, J., Pascual, N., Ruiz-Flaño, P., Errea, M.P., Lana-Renault, N. 2017b. Space-time process and drivers of land abandonment in Europe. *Catena* 149 (3), 810-823. http://dx.doi.org/10.1016/j.catena.2016.02.024.

Lasanta, T., Khorchani, M., Pérez-Cabello, F., Errea, P., Sáenz-Blanco, R., Nadal-Romero, E. 2018. Clearing shrubland and extensive livestock farming: active prevention to control wildfires in the Mediterranean mountains. *Journal of Environmental Management* 227, 256-266. https://doi.org/10.1016/j.envman.2018.08.104.

Lasanta, T., Nadal-Romero, E., García-Ruiz, J.M. 2019. Clearing shrubland as a strategy to encourage extensive livestock farming in the Mediterranean mountains. *Cuadernos de Investigación Geográfica* 45(2), 487-513. https://doi.org/10.18172/cig.3616.

López-Moreno, J.I., García-Ruiz, J.M., Beniston, M. 2008. Environmental change and water management in the Pyrenees. Facts and future perspectives for Mediterranean mountains. *Global and Planetary Change* 66 (3-4), 300-312. https://doi.org/10.1016/j.gloplacha.2007.10.004.

López-Moreno, J.I., Vicente-Serrano, S.M., Morán-Tejeda, E., Zabalza, J., Lorenzo-Lacruz, J., García-Ruiz, J.M. 2011. Impact of climate evolution and land use changes on water yield in the Ebro basin. *Hydrology and Earth System Science* 15, 311-322. https://doi.org/10.5194/hess-15-311-2011.

Lucht, W., Prentice, I.C., Myneni, R.B., Sitch, S., Friedlingstein, P., Cramer, W., Bousquet, P., Buermann, W., Smith, B. 2002. Climatic control of the high-latitude vegetation greening trend and Pinatubo effect. *Science* 296, 1867-1690. https://doi.org/10.1126/science.1071828.

MacDonald, D., Crabtree, J.R., Wiesinger, G., Dax, T., Stamou, N., Fleury, P., Gutiérrez-Lazpita, J., Gibon, A. 2000. Agricultural abandonment in mountain areas of Europe: Environmental consequences and policy response. *Journal Environmental Management* 59 (1); 47-69. https://doi.org/10.1006/jema.1999.0335.

Maestre, F.T., Cortina, J., Bautista, S., Bellot, J. 2003. Does *Pinus halepensis* facilitate the establishment of shrubs in Mediterranean semi-arid afforestations? *Forest Ecology Management* 176, 147-160. https://doi.org/10.1016/S0378-1127(02)00269-4.

Martínez-Fernández, J., Chuvieco, E., Koutsias, N. 2013. Modelling long-term fire occurrence factors in Spain by accounting for local variations with geographical weighted regression. *Natural Hazard Earth System* 13, 311-327. https://doi.org/10.5194/nhess-13-311-2013.

Merckx, T. 2015. Pitfalls and opportunities for moths and butterflies. In: H.M. Pereira, L.M. Navarro (Eds.) *Rewilding European Landscapes*. Springer, Cham, pp. 107-125. https://doi.org/10.1007/978-3-319-12039-3_6.

Metailié, J.P., Paegelow, M., 2004. Land abandonment and the spreading of the forest in the Eastern French Pyrenées in the Nineteenth to Twentieth Centuries. In: S. Mazzoleni, G. di Pasquale, M. Mulligan, P. di Martino, F. Rego (Eds.), *Recent Dynamics of the Mediterranean Vegetation and Landscape*. John Wiley & Sons, Ltd, pp. 219-236. https://doi.org/10.1002/0470093714.ch19.

Meeus, J.H.A., Wijermans, H.P., Vroom, M.J. 1990. Agricultural landscapes in Europe and their transformation. *Landscape and Urban Planning* 18 (3-4), 289-352. https://doi.org/10.1016/0169-2046(90)90016-U.

Mierauskas, P., Pereira, P. 2013. Stakeholders perception about prescribed fire use in Lithuania. First results. *Flamma* 4 (3), 156-161. Available at: https://docs.google.com/viewer?a=v&pid=sites&srcid=ZGVmYXVsdGRvbWFpbnxmbGFtbWFmZ3J8Z3g6NTdlZjVhNGUyYjhjZWU5OQ.

Molinillo, M., Lasanta, T., García-Ruiz, J.M. 1997. Managing mountainous degraded landscape after farmland abandonment in the Central Spanish Pyrenees. *Environmental Management* 21, 587-598. https://doi.org/10.1007/s002679900051.

Moreira, F., Queiroz, A.J., Aronson, J. 2006. Restoration principles applied to cultural landscapes. *Journal for Nature Conservation* 14, 217-224. https://doi.org/10.1016/j.jnc.2006.05.007.

Motta, R., Morales, M., Nola, P. 2006. Human land-use, forest dynamics and tree growth at the treeline in the Western Italian Alps. *Annals of Forest Science* 63, 739-747. https://doi.org/10.1051/forest:2006055.

Mottet, A., Ladet, S., Coqué, N., Gibon, A. 2006. Agricultural land-use change and its drivers in mountain landscapes: A case study in the Pyrenees. *Agriculture, Ecosystems and Environment* 114, 296-310. https://doi.org/10.1016/j.agee.2005.11.017.

Mouillot, F., Ratte, J.P., Joffre, R., Moreno, J.M., Rambal, S. 2003. Some determinants of the spatio-temporal fire cycle in a Mediterranean landscape (Corsica, France). *Landscape Ecology* 18, 665-674. https://doi.org/10.1023/B:LAND.0000004182.22525.a9.

Muñoz-Barcia, C.V., Lagos, L., Blanco, C., Díaz-Varela, R., Fagúndez, J. 2019. Habitat quality assessment of Atlantic wet heathlands in Serra do Xistral, NW Spain. *Cuadernos de Investigación Geográfica* 45 (2), 533-549. http://doi.org/10.18172/cig.3628.

Nadal-Romero, E., Lana-Renault, N., Serrano-Muela, P., Regüés, D., Alvera, B., García-Ruiz, J.M. 2012. Sediment balance in four catchments with different land cover in the Central Spanish Pyrenees. *Zeitschrift für Geomorphologie* 56 (3), 147-168. https://doi.org/10.1127/0372-8854/2012/S-00109.

Nadal-Romero, E., Cammeraat, E., Pérez-Cardiel, E., Lasanta, T. 2016. Effects of secondary succession and afforestation practices on soil properties after cropland abandonment in humid Mediterranean mountain areas. *Agriculture, Ecosystems and Environment* 228, 91-100. https://doi.org/10.1016/j.agee.2016.05.003.

Nadal-Romero, E., Lasanta, T., García-Ruiz, J.M. 2013. Runoff and sediment yield from under various uses in a Mediterranean mountain area. Long term results from an experimental station. *Earth Surface Processes and Landforms* 38, 346-355. https://doi.org/10.1002/esp.3281.

Navarro, L.M., Pereira, H.M. 2012. Rewilding abandoned landscapes in Europe. *Ecosystems* 15 (6), 900-912. https://doi.org/10.1007/s10021-012-9558-7

Navarro, L.M., Pereira, H.M., 2015. Rewilding abandoned landscapes in Europe. In: H.M. Pereira, L.M. Navarro (Eds.), *Rewilding European Landscapes*. Springer, Cham, pp. 3-23. https://doi.org/10.1007/978-3-319-12039-3_1.

Nikodemus, O., Bell, S., Grine, I., Liepiņš, I. 2005. The impact of economic, social and political factors on the landscape structure of the Vidzeme Uplands in Latvia. *Landscape and Urban Planning* 70 (1-2), 57-67. https://doi.org/10.1016/j.landurbplan.2003.10.005.

Nogués-Bravo, D., Simberloff, D., Rahbek, C., Sanders, N.J. 2016. Rewilding is the new Pandora's box in conservation. *Current Biology* 26, R83-R101. https://doi.org/10.1016/j.cub.2015.12.044.

Nuche, P., Komac, B., Gartzia, M., Villellas, J., Reiné, R., Alados, C.L. 2018. Assessment of prescribed fire and cutting as means controlling the invasion of sub-alpine grasslands by *Echinospartum horridum*. *Applied Vegetation Science* 21, 198-206. https://doi.org/10.1111/avsc.12354.

Ortigosa Izquierdo, L.M. 1990. Las repoblaciones forestales como estrategia pública de intervención en regiones degradadas de montaña. In: J.M. García-Ruiz (Ed.), *Geoecología de las áreas de montaña.* Geoforma Ediciones, Logroño, pp. 297-311.

Ortigosa Izquierdo, L.M. 1991. *Las repoblaciones forestales en La Rioja: resultados y efectos geomorfológicos*. Geoforma Ediciones, Logroño, 149 pp.

Ortigosa, L.M., García-Ruiz, J.M., Gil, E. 1990. Land reclamation by reforestation in the Central Pyrenees. *Mountain Research and Development* 10 (3), 281-288. https://doi.org/10.2307/3673607.

Paul, K.I., Polglase, P.J., Nyakuengama, J.G., Khanna, P.K. 2002. Change in soil carbon following afforestation. *Forest Ecology Management* 168 (1-3), 241-257. https://doi.org/10.1016/S0378-1127(01)00740-X.

Pausas, J.G, Bladé, C., Valdecantos, A., Seva, J.P., Fuentes, D., Alloza, J.A., Vilagrosa, A., Bautista, S., Cortina. J., Vallejo, R. 2004. Pines and oaks in the restoration of Mediterranean landscapes: new perspectives for an old practice - a review. *Plant Ecology* 171 (1-2), 209-220. https://doi.org/10.1023/B:VEGE.0000029381.63336.20.

Pausas, J.G., Llovet, J., Rodrigo, A., Vallejo, R. 2008. Are wildfires a disaster in the Mediterranean basin? - a review vegetation changes. *International Journal of Wildland Fire* 17 (6), 713-723. https://doi.org/10.1071/WF07151.

Pelorosso, R., Della Chiesa, S., Tappeiner, U., Leone, A., Rocchini, D. 2011. Stability analysis for defining management strategies in abandoned mountain landscapes of the Mediterranean basin. *Landscape and Urban Planning* 103, 335-346. https://doi.org/10.1016/j.landurbplan.2011.08.007.

Pereira, H.M., Navarro, L. (Eds.) 2015. *Rewilding European Landscapes*. Springer Open. Heidelberg. https://www.springer.com/gb/book/9783319120386.

Petanidou, T., Kizos, T., Soulakellis, N. 2008. Socioeconomic dimensions of changes in the agricultural landscape of the Mediterranean basin: a case of study of the abandonment of cultivation terraces on Nisyros Island, Greece. *Environmental Management* 41 (2), 250-266. https://doi.org/10.1007/s00267-007-9054-6.

Poyatos, R., Latron, J., Llorens, P. 2003. Land use and land cover change after agricultural abandonment. The case of a Mediterranean mountain area (Catalan Pre-Pyrenees). *Mountain Research and Development* 23 (4), 362-368. https://doi.org/10.1659/0276-4741(2003)023[0362:LUALCC]2.0.CO;2.

Price, M.F. (Ed.) 2004. *Conservation and Sustainable Development Mountain Areas*. IUCM, Gland, Suitzerland and Cambridge.

Prior, J., Ward, K.J. 2016. Rethinking rewilding: a response to Jorgensen. *Geoforum* 69, 132-135. https://doi.org/10.1016/j.geoforum.2015.12.003.

Quetier, F., Marty, P., Lepart, J. 2005. Farmer's management strategies and land use in an agropastoral landscape: Roquefort cheese production rules as driver of change. *Agricultural Systems* 84 (2), 171-193. https://doi.org/10.1016/j.agsy.2004.05.005.

Ramankutty, N., Foley, J.A. 1999. Estimating historical changes in global land cover: croplands from 1700 to 1992. *Global Biochemical Cycles* 13 (4), 997-1027. https://doi.org/10.1029/1999GB900046.

Rescia, A.J., Pons, A., Lomba, I., Esteban, C., Dover, J.W. 2008. Reformulating the social-ecological systems in a cultural rural mountain landscape in the Picos de Europa region (Northern Spain). *Landscape and Urban Planning* 88 (1), 23-33. https://doi.org/10.1016/j.landurbplan.2008.08.001.

Riebsame, W.E., Meyer, W.B., Turner, B.L. 1994. Modelling land use and cover as part of global environmental change. *Climatic Change* 28 (1-2), 45-64. https://doi.org/10.1007/BF01094100.

Ruiz-Mirazo, J., Robles, A.B., González-Rebollar, J.L. 2011. Two-year evaluation of fuelbreaks grazed by livestock in the wildfire prevention program in Andalusia (Spain). *Agriculture, Ecosystems and Environment* 141 (1-2), 13-22. https://doi.org/10.1016/j.agee.2011.02.002.

Ruiz-Sinoga, J.D., Martínez-Murillo, J.F. 2009. Hydrological response of abandoned agricultural soils along a climatological gradient on metamorphic parent material in southern Spain. *Earth Surface Processes and Landforms* 34 (15), 2047-2056. http://doi.org/10. 1002/esp.1890.

San Emeterio, L., Múgica, L., Ugarte, M.D., Goicoa, T., Canals, R.M. 2016. Sustainability of traditional pastoral fires in highlands under global change: effects on soil function and nutrient cycling. *Agriculture, Ecosystems and Environment* 235, 155-163. https://doi.org/10.1016/j.agee.2016.10.009.

Sanjuán, Y., Arnáez, J., Beguería, S., Lana-Renault, N., Lasanta Martínez, T., Gómez-Villar, A., Álvarez-Martínez, J., Coba-Pérez, P., García-Ruiz, J.M. 2018. Woody plant encroachment following grazing abandonment in the subalpine belt: a case study in northern Spain. *Regional Environmental Change* 18, 1103-1115. https://doi.org/10.1007/s10113-017-1245-y.

San Miguel-Ayanz, A., Perea García-Calvo, R.P., Fernández-Olalla, M. 2010. Wild ungulates vs extensive livestock. Looking back to face the future. *Options Méditerranéennes*, Série A 92, 27-34. Available at: http://wildrodopi.org/data/documents/San-Miguel-et-al-2010_San-Miguel-Ayanz-A.-Perea-Garcia-Calvo-R.-Fernandez-Olalla-M.-2010.-Wild-Ungulates-vs.-Extensive-Livestock.-Looking-Back-to-Face-the-Future.pdf.

Sayadi, S., González-Roa, M.C., Calatrava Requena, J. 2009. Public preferences for landscape features: The case of agricultural landscapes in mountainous Mediterranean areas. *Land Use Policy* 26, 334-344. https://doi.org/10.1016/j.landusepol.2008.04.003.

Schmitz, M.F., de Aranzábal, I., Aguilera, P., Rescia, A.J., Pineda, F.D. 2003. Relationship between landscape typology and socioeconomic structure: Scenarios of change in Spanish cultural landscapes. *Ecological Modelling* 168(3), 349-356. https://doi.org/10.1016/S0304-3800(03)00145-5.

Schnitzler, A. 2014. Towards a new European wilderness: embracing unmanaged forest growth and the decolonisation of nature. *Landscape and Urban Planning* 126, 74-80. https://doi.org/10.1016/j.landurbplan.2014.02.011.

S.C.F.C. 2011. *Informe 2010: Situación de los bosques y del sector forestal en España*. Sociedad Española de Ciencias Forestales, 302 pp.

Sitzia, T., Semenzato, P., Trentanovi, G. 2010. Natural reforestation is changing spatial patterns of rural mountain and hill landscapes: A global overview. *Forest Ecology and Management* 259, 1354-1362. https://doi.org/10.1016/j.foreco.2010.01.048.

Sluiter, R., de Jong, S.M. 2007. Spatial patterns of Mediterranean land abandonment and related land cover transitions. *Landscape Ecology* 22, 559-576. http://doi.org/10.1007/s10980-006-9049-3.

Song, X.P., Hansen, M.C., Stehman, S.V., Potapov, P.V., Tyukavina, A., Vermote, E.F., Townshend, J.R. 2018. Global land change from 1982 to 2016. *Nature* 560, 639-643. https://doi.org/10.1038/s41586-018-0411-0.

Soulé, M., Noss, R. 1998. Rewilding and biodiversity: complementary goals for continental conservation. *Wild Earth* 8 (3), 19-28. Available at: http://www.elkhornsloughctp.org/uploads/files/1238461834Soule_Noss_1998_Rewilding_Wild_Earth.pdf.

Strijker, D. 2005. Marginal lands in Europe - causes of decline. *Basic and Applied Ecology* 6, 99-106. https://doi.org/10.1016/j.baae.2005.01.001.

Suárez-Seoane, S., Osborne, P.E., Baudry, J. 2002. Responses of birds of different biogeographic origins and habitat requirements to agricultural land abandonment in Northern Spain. *Biological Conservation* 105, 333-344. https://doi.org/10.1016/S0006-3207(01)00213-0.

Svenning, J.-C, Pedersen, P.B.M., Donlan, C.J., Ejrnaes, R., Faurby, S., Galetti, M., Hansen, D.M., Sandel, B., Sandom, C.J., Terborgh, J.W., Vera, F.W.M. 2016. Science for a wilder Anthropocene: Synthesis and future directions for trophic rewilding research. *PNAS* 113 (4), 898-906. https://doi.org/10.1073/pnas.1502556112.

Van Eetvelde, V., Antrop, M. 2003. Analyzing structural and functional changes of traditional landscapes - two examples from Southern France. *Landscape and Urban Planning* 67, 79-95. https://doi.org/10.1016/S0169-2046(03)00030-6.

Vanslembrouck, I., Van Huylenbroeck, Van Meensel, J. 2005. Impact of agriculture on rural tourism: a hedonic pricing approach. *Journal of Agricultural Economics* 56, 17-30. https://doi.org/10.1111/j.1477-9552.2005.tb00120.x.

Varga, D., Vila Subirós, J., Barriocanal, C., Pujantell, J. 2018. Landscape transformation under global environmental change in Mediterranean mountains: Agrarian lands as a guarantee for maintaining their multifunctionality. *Forest* 9 (1), 27. https://doi.org/10.3390/f9010027.

Vicente-Serrano, S.M., Lasanta, T., Cuadrat, J.M. 2000. Transformaciones del paisaje del Pirineo como consecuencia del abandono de las actividades económicas tradicionales. *Pirineos* 155, 111-133. https://doi.org/10.3989/pirineos.2000.v155.91.

Vicente-Serrano, S.M., Lasanta, T., Romo, A. 2005. Analysis of spatial and temporal evolution of vegetation cover in the Spanish Central Pyrenees: Role of Human Management. *Environmental Management* 34 (6), 802-818. https://doi.org/10.1007/s00267-003-0022-5.

Viviroli, D., Dürr, H.H., Messerli, B., Meybeck, M., Weingartner, R. 2007. Mountains of the World –waters towers for humanity: typology, mapping and global significance. *Water Resources Research* 43 (7), W07447. https://doi.org/10.1029/2006WR005653.

Westerling, A.L., Hidalgo, H.G., Cayan, D.R., Swetnam, T.W. 2006. Warming and earlier spring increase western US forest wildfire activity. *Science* 313 (5789), 940-943. https://doi.org/10.1126/science.1128834.

Wood, R., Handley, J. 2001. Landscape dynamics and the management of change. *Landscape Research* 26 (1), 45-54. https://doi.org/10.1080/01426390120024475.