

Rewilding Abandoned Landscapes in Europe

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ABSTRACT

For millennia, mankind has shaped landscapes, particularly through agriculture. In Europe, the age-old interaction between humans and ecosystems strongly influenced the cultural heritage. Yet European farmland is now being abandoned, especially in remote areas. The loss of the traditional agricultural landscapes and its consequences for biodiversity and ecosystem services is generating concerns in both the scientific community and the public. Here we ask to what extent farmland abandonment can be considered as an opportunity for rewilding ecosystems. We analyze the perceptions of traditional agriculture in Europe and their influence in land management policies. We argue that, contrary to the common perception, traditional agriculture practices were not environmentally friendly and that the standards of living of rural populations were low. We suggest that current policies to maintain extensive farming landscapes underestimate the human labor needed to

sustain these landscapes and the recent and future dynamics of the socio-economic drivers behind abandonment. We examine the potential benefits for ecosystems and people from rewilding. We identify species that could benefit from land abandonment and forest regeneration and the ecosystem services that could be provided such as carbon sequestration and recreation. Finally, we discuss the challenges associated with rewilding, including the need to maintain open areas, the fire risks, and the conflicts between people and wildlife. Despite these challenges, we argue that rewilding should be recognized by policy-makers as one of the possible land management options in Europe, particularly on marginal areas.

Key words: farmland abandonment; land-use change; passive management; ecosystem services; land sharing; land sparing.

INTRODUCTION

Deforestation and the loss of natural habitats remain major global concerns. Nonetheless, although scenarios for the next decades project the contin-

uation of these dynamics in tropical ecosystems, the projections made for much of the Northern Hemisphere are quite the opposite (Pereira and others 2010). In fact, most deforestation in Europe occurred before the industrial revolution (Kaplan and others 2009), and the amount of forests and scrubland is now increasing following the land abandonment that began in the mid-twentieth century (FAO 2011), a trend that is expected to continue over the next few decades (van Vuuren and others 2006).

Natural vegetation recovery is a complex process that occurs during the progressive alleviation of

Received 6 October 2011; accepted 15 April 2012;
published online 30 June 2012

Electronic supplementary material: The online version of this article (doi:10.1007/s10021-012-9558-7) contains supplementary material, which is available to authorized users.

Author Contributions: HMP developed the ideas for the paper. LMN conducted the research and wrote the initial draft, which was then edited by HMP.

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agricultural use (Hobbs and Cramer 2007; Stoate and others 2009). This reduction in land-use intensity, including abandonment at the extreme, is, at the local scale, explained by a combination of socio-ecological drivers (MacDonald and others 2000; Rey Benayas and others 2007) such as low productivity and aging of the population. These factors interact between them and with the ecological dynamics of succession, creating positive feedback loops, which increase the irreversibility of farmland abandonment in marginal areas, and reduce the effectiveness of subsidies awarded to farmers to halt abandonment (Figueiredo and Pereira 2011; Gellrich and others 2007). In Europe, there has been a decline of 17% of the rural population since 1961 (FAOSTAT 2010). Some parishes of Mediterranean mountain areas have lost more than half of their population in a similar period (Gortázar and others 2000; Pereira and others 2005). At the regional scale, the current farmland contraction is best explained by an increase in agricultural productivity and the slowing of population growth in Europe (Keenleyside and Tucker 2010).

Landowners and managers facing increased agricultural market competition have resorted mostly to one of three active management strategies (Figure 1): intensification, extensification, and afforestation. Intensification is often chosen on the most productive soils and where good conditions exist for mechanization (Pinto-Correia and Mascarenhas 1999). Extensification consists of obtaining higher productivity by expanding the area of the farm through land consolidation or in developing multiple uses of the land. This has happened in the Montado and Dehesa areas of Portugal and Spain, an agroforestry system that integrates animal production, cork harvesting and cereal

cultivation, while hosting high biodiversity and providing recreational and aesthetical benefits (Bugalho and others 2011). Finally, in some areas with poor farmland soils, the option has been to plant forests, often of fast growing species (Young and others 2005).

In this article, we discuss a fourth option: rewilding abandoned landscapes, by assisting natural regeneration of forests and other natural habitats through passive management approaches. Rewilding has seldom been considered as a land management policy, as often it faces resistance from both the public (Enserink and Vogel 2006; Bauer and others 2009) and the scientific communities (Conti and Fagarazzi 2005; Moreira and Russo 2007). Arguments against rewilding include the loss of the traditional agricultural landscape and negative impacts on biodiversity and ecosystem services (for example, Conti and Fagarazzi 2005). This situation has given rise to a pattern of double standards: developing countries are asked to halt deforestation while some developed countries are actively fighting forest regeneration on their own land (Meijaard and Sheil 2011).

Here, we critically examine some of the arguments used in support of the maintenance of the traditional landscapes and contrast those arguments with the potential benefits for ecosystem services and biodiversity that could accrue from rewilding. We conclude with an analysis of the main challenges associated with rewilding abandoned landscapes.

EUROPEAN LANDSCAPES: EXAMINING THE PARADIGMS

The cultural importance of traditional agriculture landscapes has been widely recognized in Europe and the world. As of 2011, 76 of the 936 UNESCO world heritage sites are in the “cultural landscapes” category (<http://whc.unesco.org>), and 29 of those because of traditional or symbolical agricultural practices. Examples include the “Causses and Cevennes Mediterranean agro-pastoral cultural landscape” in France or the “Mont Perdu” in the Pyrénées. As much as 15 to 25% of the European farmland can be classified as High Nature Value farmland (EEA 2004). Of the 231 habitat types listed in the European Habitats Directive, 41 are associated with low-intensity agricultural management, including semi-natural grasslands and hay meadows (Halada and others 2011).

This has led to a generalized push towards policies embracing the protection of extensive farming

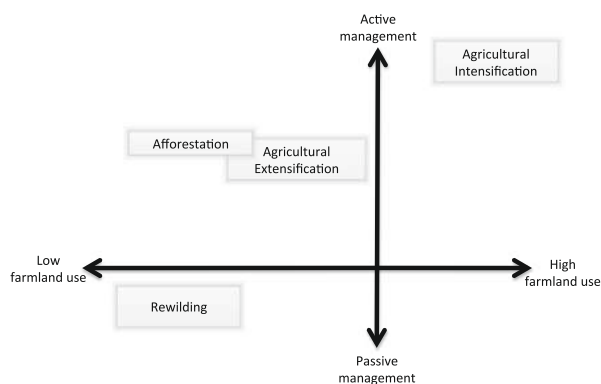


Figure 1. Landscape management strategies plotted against agricultural use intensity and level of management (from active to passive): agricultural intensification, agricultural extensification, afforestation, and rewilding.

systems with the dual-role of protecting biodiversity and ecosystem services. Here we argue that not all socio-ecological aspects of the maintenance of these landscapes have been taken into account because our perceptions of these landscapes have been biased by our own cultural experiences. We question three ideas associated with current policies: (1) the idea that traditional agriculture practices were environmentally friendly; (2) the idea that traditional rural populations lived well; (3) the idea that traditional landscapes can be kept despite the context of recent rural exodus and future socio-economic trends.

Were Traditional Agriculture Practices Environmentally Friendly?

In Europe, pre-Neolithic Holocene landscapes can most likely be described as a mosaic of old-growth forest, scrubland, and grasslands, maintained by the grazing of large herbivores and by fire (Svenning 2002; Vera 2000, Vera 2009), although the relative amount of open area is debated (for example, Hodder and others 2009). Later on, and much before the onset of modern agriculture, European inhabitants destroyed most of Europe's forests on usable land. Europe is now the continent with the least original forest cover (Kaplan and others 2009).

The process of forest clearing might be as old as human's making of tools (Williams 2000). It started in the Neolithic with the use of fire to open areas for grazing and hunting (Pereira and others in press). Forest loss was accelerated during Antiquity, when the rise of classical civilizations led to large-scale deforestation (Williams 2000; Kaplan and others 2009). After a brief interruption caused by the breakdown of the Roman society, the deforestation trend continued in the Middle Ages (interrupted only by the Black Death), with an estimated loss of 50–70% of the European forest during this period.

Hence humans amplified the disturbance regime of European ecosystems and expanded the open area considerably (Pereira and others in press), creating and maintaining "traditional" landscapes such as the alpine grasslands (Laiolo and others 2004), and the agro-silvo-pastoral systems of Mediterranean regions (Blondel 2006). These extensive farming systems have higher species diversity than intensive farming systems (Batáry and others 2012; Tschamtker and others 2005), and, at the local scale, often have higher species diversity than non-managed ecosystems and natural forests (Blondel 2006; Höchtl and others 2005;

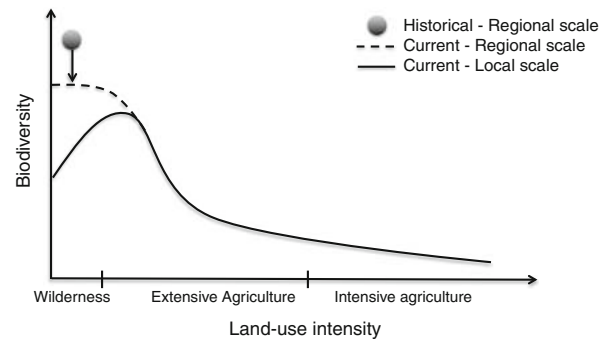


Figure 2. Conceptual representation of the response of current species diversity to land-use intensity at the local and regional scales, and of the hypothetical regional response if Holocene extinctions had not occurred. The response at the local scale is adapted from EEA (2004), whereas the current and historical responses at the regional scale are discussed in the text.

Lindborg and others 2008). Therefore, it has been suggested that biodiversity peaks for low levels of land use associated with these extensive farming systems (Figure 2), following the intermediate disturbance principle (Wilkinson, 1999).

This pattern has been used as an argument to maintain the active management of extensive farmland and halt ecological succession. However at regional scales, this relationship is likely to exhibit a different pattern (Figure 2). The habitat turnover of wild landscapes can be a mosaic of closed forest and open areas, which should accommodate many of the species that can usually be found in extensive farmland habitats. In the early Holocene, the regional diversity of wild landscapes would have been even higher (Figure 2). Several species have now disappeared due to the expansion of human activities, including the auroch (*Bos primigenius*), the Tarpan (*Equus ferus ferus*), or became extinct in most of their former ranges (for example, wisent, *Bison bonasus*).

Deforestation also had important impacts on ecosystem services. In the Mediterranean basin, deforestation is thought to have caused desiccation and soil erosion (McNeely 1994; Blondel 2006). In the Middle Ages, timber shortage is likely to have played a role on the impulse to conquer new territories (Farrell and others 2000). To build naval fleets, countries such as Portugal and Spain had to resort to importing wood from colonies from the sixteenth century on (Devy-Vareta and Alves 2007). By the end of the nineteenth century, the dimension of the erosion problems in mountain slopes and associated silting in rivers and floods

downstream led to large state sponsored afforestation programs in Portugal and Spain.

Did Traditional Rural Populations Live Well?

For centuries, populations inhabiting marginal agricultural areas organized their lives in a self-sufficient manner (Blondel 2006). The industrial revolution and the globalization of the food and labor markets brought many of these regions to an economic disadvantage with urban and peri-urban areas: increasing wages associated with economic growth and the low food prices in global markets rendered the low-productivity farmland uncompetitive.

Nowadays, marginal agricultural areas throughout the globe are classified as “poverty traps” where households suffer from scarcity of resources, low return on investment, lack of opportunities, and reduced social services (Conti and Fagarazzi 2005; Ruben and Pender 2004). For example, in mountains of Southern Europe, rural populations are constrained by the low productivity of small-scale parcels and the limited opportunities for mechanization and intensification (MacDonald and others 2000). On average, across European mountain areas, the income per hectare is about 40% lower than in other, non-disadvantaged, areas (809 €/ha vs. 1370 €/ha in EC 2009). The young have limited access to education and employment while the elders experience isolation and difficulties to access services (EC 2008a). This results in out-migration and aging of the population, leading to an inverted population pyramid. This rural exodus is driven by a “circle of decline” where low population density limits business creation, causing fewer jobs and more out-migrations which, in turn, accentuates the decrease in population density (EC 2008a).

Rural populations still value the quality of their environment and its scenic beauty (Bell and others 2009; Pereira and others 2005), but the working conditions in many of these regions have always been difficult. Terraces are some of the most admired cultural landscapes in Mediterranean areas, but locals often use the expression “slavery land” to describe the harshness of the working conditions (Pereira and others 2005).

Are Current Efforts to Maintain Traditional Landscapes Likely to Succeed?

Traditional agricultural practices were characterized by being labor intensive for relatively low agricultural yields (MacDonald and others 2000;

Gellrish and others 2007). These characteristics played a key role in the demise of many of the traditional practices when labor costs rose due to economic growth, an effect that contributed to and was exacerbated by rural exodus. Large numbers of livestock kept vegetation succession on hold for centuries, but in the past few decades livestock numbers have declined in many of these regions (Cooper and others 2006). In Europe, the number of livestock (cattle, goats and sheep) declined by 25% between 1990 and 2010 (FAOSTAT 2010).

Still, recognizing the role of European farmers in maintaining these landscapes (Daugstad and others 2006), several measures have been implemented to limit farmland depopulation. As part of the European Common Agriculture Policy, Less Favored Areas (LFAs-Regulation 1257/1999) were designated mainly to prevent rural abandonment and maintain cultural landscapes (Dax 2005; Stoate and others 2009). LFAs went from representing a third of the European Utilized Agricultural Area (UAA) in 1975 to more than half in 2005 (Dax 2005; MacDonald and others 2000). Though the LFA classification often happens to match High Nature Value farming systems and extensive agriculture, it poses no limit to intensification and overgrazing (Dax 2005).

In the Rural Development Plan for 2007–2013, the payments to farmers in LFAs totaled € 12.6 billion (DG Agriculture 2011). Though the sum of these subsidies is substantial at the European scale, at the individual level they might not be enough to maintain young farmers or attract new residents (Cooper and others 2006), especially in areas where the farm size is small. For example, when considering an average farm size of 23 ha in mountain areas (MacDonald and others 2000) and an average LFA subsidy of € 100/ha (Dax 2005), the average payment is of € 2,300 per farm/year. This value can be higher if farmers also adhere to agri-environmental schemes, but overall LFA farmers still have lower incomes (Cooper and others 2006); the Farm Net Value Added is 13,056 €/Annual Work Unit in mountain LFAs, 14,174 €/AWU in other LFAs, and 18,923 €/AWU in non-LFAs (average for the EU25 countries between 2004 and 2005 in EC 2008b).

Hence the decrease in rural populations that started in the 1960s is projected to continue into the next few decades (Figure 3). Future scenarios predict that the contribution of agriculture in regards to GDP and employment in Europe will continue decreasing (Eickhout and others 2007; Nowicki and others 2006) and the young generations will keep migrating to the cities, as long as

their life quality and income prospects are higher there (EC 2008a; Keenleyside and Tucker 2010) resulting in the non-replacement of the aging population of European farmers.

Following the decrease in the rural population, agricultural area in Europe is also expected to keep contracting (Figure 3), despite an expected increase in the global demand for agricultural goods, because enough food is obtained either directly by production on competitive land in Europe or elsewhere in the world (Keenleyside and Tucker 2010). Regionally labeled and organic products could help maintain certain forms of extensive agriculture but this market remains restricted (Strijker 2005). Projections also take into account an increasing demand in biocrops (Rounsevell and others 2006; Schröter and others 2005; Verburg and Overmars 2009), which can explain a moderate increase in the predicted agricultural area in some scenarios.

The dimension of the agricultural area abandoned or converted into production forest varies widely between scenarios (Table 1). If we use the intermediate scenarios in Verburg and Overmars (2009), between 10 and 29 million ha of land will be released from agriculture between 2000 and 2030. Areas particularly susceptible to the decline of agropastoral use include semi-natural grasslands and remote or mountainous areas with poor soil quality (Keenleyside and Tucker 2010; Pointereau and

others 2008; Stoate and others 2009). Some of these areas are located in Northern Portugal, Northwestern France, the Alps, the Apennines and Central Europe (Figure 4).

THE BENEFITS OF REWILDING

Defining Rewilding

Rewilding is the passive management of ecological succession with the goal of restoring natural ecosystem processes and reducing human control of landscapes (Gillson and others 2011). Note that although passive management emphasizes no management or low levels of management (for example, Vera 2009), intervention may be required in the early restoration stages.

In contrast, much of the biodiversity conservation efforts in Europe emphasize active management, by maintaining low-level agricultural practices (Figure 1). Active management also differs in goals, targeting the increase of the abundance of specific taxa or the maintenance of particular habitats, using approaches such as vegetation clearing and construction of artificial habitats, often working against successional processes.

Natural succession on abandoned farmland and pastures often leads to scrubland and sometimes at a later stage, to forest (Conti and Fagarazzi 2005).

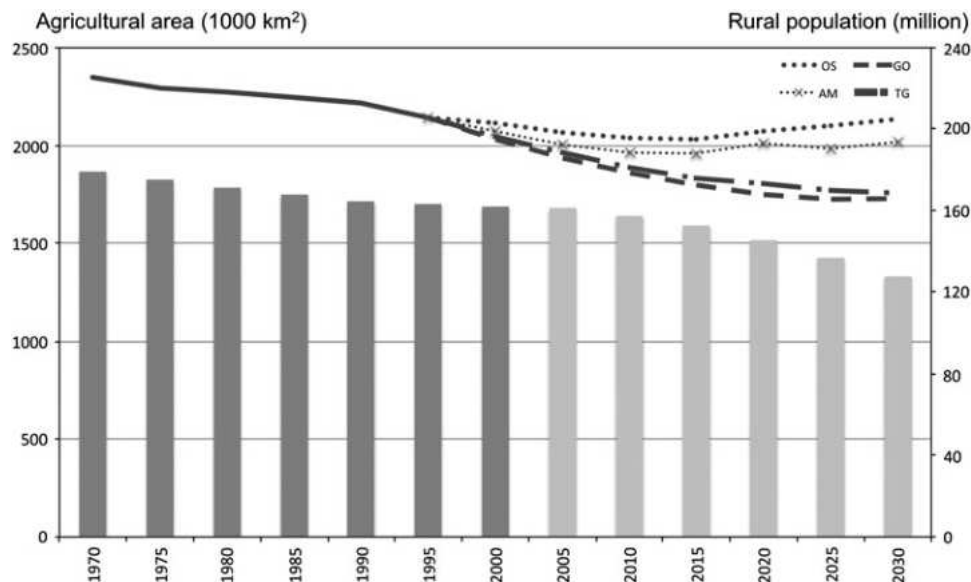


Figure 3. Past and future trends of European agricultural area and rural population. Agricultural area (*lines*): land-use change predicted in the four scenarios of the Millennium Ecosystem Assessment (van Vuuren and others 2006). The projections are based on the area of food crops, grass and fodder, and biofuels crops, between 1970 and 2030. *OS* order from strength, *AM* adapting mosaic, *GO* global orchestration, *TG* techno-garden. Rural population size (*bars*): historical values (*dark gray*) and future projections (*light gray*) (FAOSTAT 2010; past data for the Baltic countries from <http://www.nationmaster.com>).

Table 1. Projections of Future Change in the Agricultural Area (Arable Land and Pasture) from Different Studies

Region	Variation in the agricultural area	Initial agricultural area (Mha)	Period	Reference
EU15 + Norway and Switzerland ¹	−6% / −10% for cropland −1% / −10% for grassland	142.5	2000–2080	Rounsevell and others (2006)
EU15 ²	+5.5% / −15%	82.5	2000–2030	Eickhout and others (2007)
EU27	−5% / −15%	198	2000–2030	Verburg and Overmars (2009)
Europe	−5% / −24%	235	1970–2050	MA (2005)
Developed countries ³	+8% / −20%	183	2000–2050	Balmford and others (2005)

¹Initial agricultural area estimate obtained from FAOSTAT (2010).

²These values are only for arable land.

³This study looked at the 23 most important food crops worldwide, corresponding to 44% of the cropland area in developed countries.

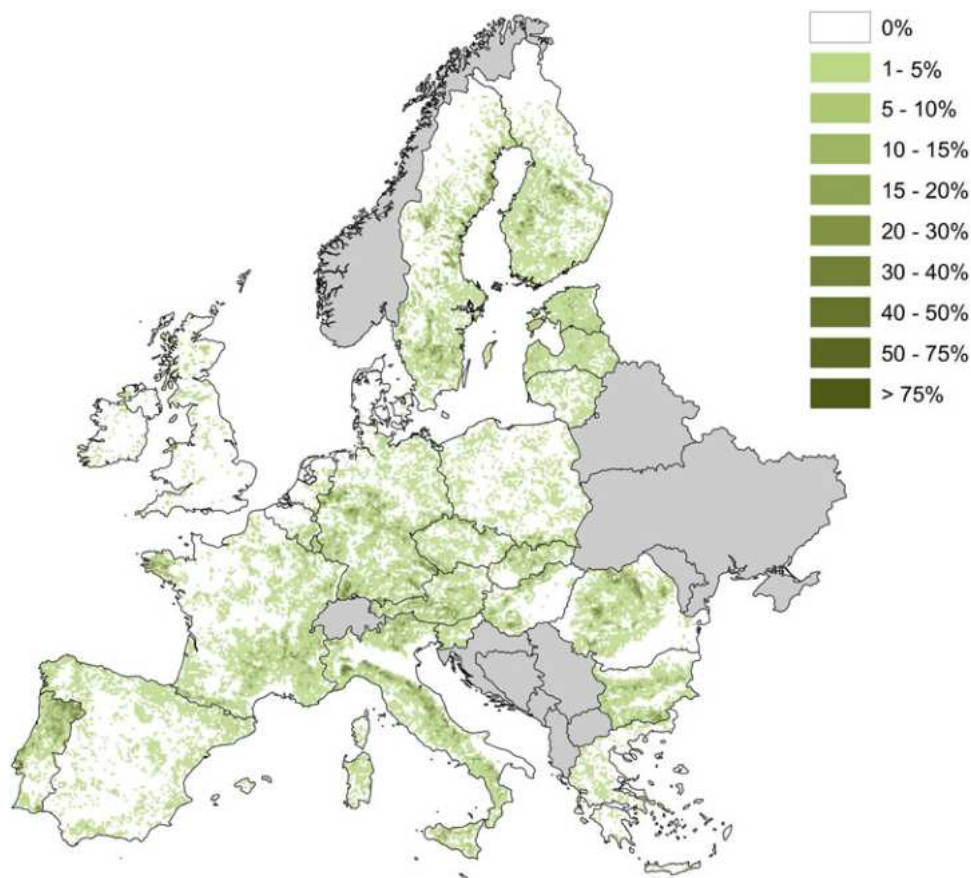


Figure 4. Localization of the hotspots of abandonment and rewilding in Europe. Those hotspots are areas categorized as “agriculture” in 2000 that are projected to become rewilded or afforested in 2030 and that are common to all four scenarios of the CLUE model (Verburg and Overmars 2009). Hotspots are expressed as a percentage of each 10-km² grid cell. Agricultural areas correspond to “arable land (non-irrigated)”, “pasture”, “irrigated arable land” and “permanent crops”. Rewilded and afforested areas correspond to “(semi)-natural vegetation”, “forest”, “recently abandoned arable land” and “recently abandoned pasture land”. Countries in *grey* have no data.

Passive forest regeneration restores almost as much forested areas globally as active tree plantation (Rey Benayas and Bullock 2012). Nonetheless, “wilder-

ness” is not a synonym of “continuous forest” (Sutherland 2002). The European megafauna played a role in maintaining open land-

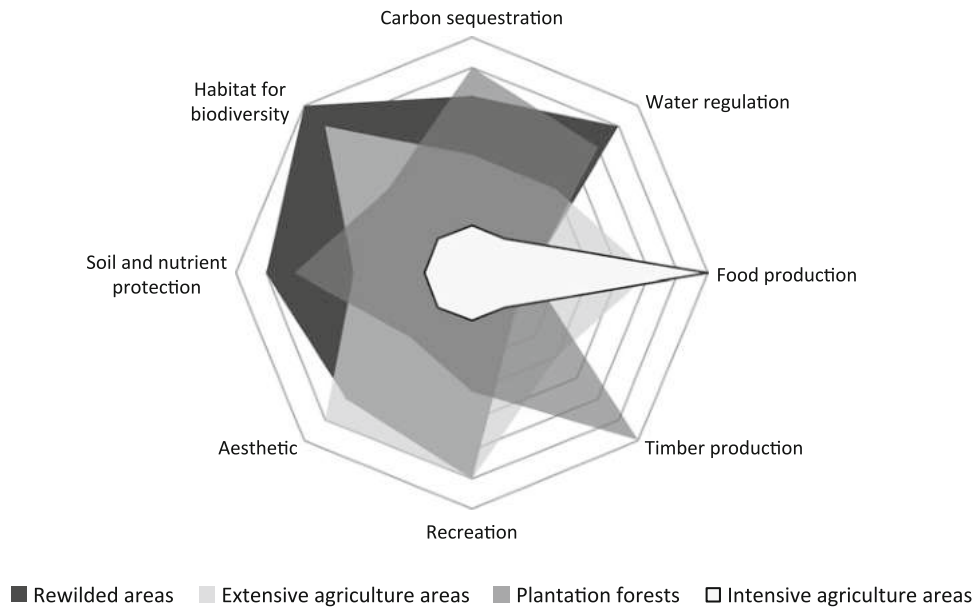


Figure 5. Qualitative assessment of the ecosystem services provided by rewilding, afforestation, extensive agriculture and intensive agriculture in Europe. The relative values given to the provision of each service by the different land management strategies are discussed in the text.

scapes, before being brought to global or local extinction by humans and replaced by domesticated grazers (Johnson 2009; Vera 2000; Bullock 2009).

This does not mean that rewilding should aim at rebuilding Pleistocene ecosystems, an approach which has been proposed elsewhere (Donlan and others 2006), but that faces many difficulties (Caro 2007), including the lack of many of the original keystone species, a different climate, and ecosystems modified locally (for example, changes in soil caused by agriculture) and regionally by humans (for example, the global nitrogen cycle). Instead, the emphasis is on the development of self-sustaining ecosystems, protecting native biodiversity and natural ecological processes and providing a range of ecosystem services (Cramer and others 2008). These novel ecosystems may be designed to be as similar as possible to some historical baseline in the recent or distant past, but they will often involve the introduction of new biotic elements (Hobbs and others 2009).

Benefits of Rewilding for Biodiversity

Rewilding will cause biodiversity changes with some species declining in abundance, that is, loser species, and other species increasing in abundance, that is, winner species (Russo 2006; Sirami and others 2008). We reviewed 23 studies identifying a positive response of species to decreasing human pressure or to restoration of their habitat following land abandonment (Supplementary Information). In total, we identified 60 species of birds, 24 species of mammals, and 26 species of invertebrates that

could benefit from farmland abandonment (Supplementary Table 1). We also identified 101 species negatively affected by land abandonment (Supplementary Table 2), but 13 of those species can be classified as both “winner” and “loser” depending on the study and the region. Much of the agrobiodiversity associated with High Nature Value Farmland will be in the “losing” category. In contrast, many of the winner species have declined or became functionally extinct in traditional agricultural landscapes, such as large carnivores. These species will benefit from forest regeneration and the connection of fragmented natural habitats (Keenleyside and Tucker 2010; Russo 2006).

Revegetation promotes the increase of the organic matter content and the water holding capacity of soils (Arbelo and others 2006). This can lead to higher biomasses and densities of earthworms (Russo 2006) and other invertebrate families (Supplementary Table 1A).

Some forest birds benefit from forest regrowth after farmland abandonment (Pointereau and others 2008), such as woodpeckers, treecreepers, and tits (Supplementary Table 1B). Some birds of prey have benefited from increases in rodent populations (Pointereau and others 2008). Perhaps more surprisingly, populations of several bird species of the Eastern European steppe have increased after agricultural activity decline (Hölzel and others 2002). Some, such as the Little Bustard (*Tetrax tetrax*), have benefited from the tall and dense grassland of the regrown steppes. This contrasts with the concerns that the decrease of open areas in Western Europe is contributing to the decline of steppe

species. Therefore the biodiversity consequences of rewilding depend on the geographical context.

Likewise, rural abandonment makes the land suitable for a comeback of large mammals (Supplementary Table 1C). Large grazers are benefiting from the lower hunting pressures that usually accompany abandonment (Breitenmoser 1998; Gortázar and others 2000). European carnivore species have been increasing since the 1960s in abundance and distribution, as stable populations of Eastern Europe are naturally recolonizing abandoned landscapes of Scandinavia, the Mediterranean, and the Alps (Enserink and Vogel 2006; Boitani 2000; Stoate and others 2009).

It is also important to consider the trophic interactions between species and the cascading effects driven by rewilding. For example, amphibians and otter (*Lutra lutra*) populations are known to benefit from the restoration of ditches by beavers (*Castor fiber*) in abandoned areas of Eastern Europe (Kull and others 2004). The presence of lynx in some parts of Switzerland reduced the roe deer and chamois browsing impact by regulating both populations (Breitenmoser 1998).

Benefits of Rewilding for People: Ecosystem Services

Abandoned farmland is often perceived negatively as it is associated with the perception of unkept land and with the decrease on the economic usability of the land, particularly by the rural populations (Hochtl and others 2005; Bauer and others 2009). However there are many ecosystem services that are provided by this type of landscapes, particularly indirect and non-use services, which are often disregarded in the process of policy-making (TEEB 2010).

Rewilded areas can, at the regional scale, provide habitat for biodiversity with conservation results as high or higher than other land management options (Figures 2, 5). This supporting service can lay the foundations for some cultural services (Figure 5), because some of the species benefiting from abandonment are linked with recreation through hunting and tourism (Gortázar and others 2000; Kaczennsky and others 2004). For instance, in the Abbruzo region of Italy, tourism has benefited from the advertisement of the presence of bears and wolves (Enserink and Vogel 2006). In addition to these direct and indirect use values, the large mammal species brought back by rewilding are amongst the species with highest existence values (Proença and others 2008).

Forest regrowth promotes carbon sequestration (Kuemmerle and others 2008). The carbon stock in

European forests has grown from 5.3 to 7.7 PgC between 1950 and 1999 (Nabuurs and others 2003). Nonetheless, active afforestation can potentially yield higher carbon sequestration rates than rewilding by using fast growing species (Figure 5). Natural regeneration allows soil recovery and nutrient availability, though erosion can increase in the first years following abandonment (Pointereau and others 2008; Rey Benayas and others 2007). Forests regulate hydrological cycles, particularly in mountain areas (Körner and others 2005) and water quality is expected to locally improve in abandoned fields (Stoate and others 2009). Nonetheless, the transition from grassland to forest, a higher water-use system, can reduce the quantity of water (Brauman and others 2007). Afforested areas managed for timber provisioning are disturbed both for plantation and management, thus providing qualitatively less water and soil related services than rewilded areas (Figure 5).

Intensive agriculture areas and planted forests are designed to focus on specific provisioning services. Extensive agriculture offers a tradeoff between food provisioning, cultural services, and habitat for biodiversity, whereas rewilding provides a wide range of supporting, regulating and cultural services (Figure 5).

The passive management associated with rewilding has much lower maintenance costs than other management options, and therefore significant returns of regulating and cultural services are obtained for limited levels of investment. Still, these services have characteristics of common goods (TEEB 2010), and therefore are rarely advantageous for the individual land-owner. Nonetheless, wilderness is linked to amenity-based growth and attracts urban individuals seeking different environments to both visit and work (Rasker and Hackman 1996): North American counties favoring wilderness showed faster growth in their employment and income level than counties in which the economy is mainly based on resource extraction.

THE CHALLENGES OF REWILDING

Rewilding as a landscape management option does involve several challenges. Our understanding of those challenges and how they can be overcome depends on the relationship between humans, the landscape and the biodiversity that it sustains.

Conflicts with Wildlife

Conflicts occur when wildlife overlaps with human activities such as hunting and farming (Gortázar

and others 2000; Linnell and others 2000; Schley and Roper 2003). Those conflicts are age-old in Europe and negative perceptions were transmitted through generations via folklore and tales (Wilson 2004; Boitani 2000). Hunting wild species, and particularly carnivores, was socially enforced (Enserink and Vogel 2006), which led in many cases to their local extinction by the nineteenth century.

Though many European countries have implemented regulations to protect large carnivores, such legislation is not understood and accepted by all (Breitenmoser 1998). In particular, they accentuate a cleavage in opinions amongst countries and between rural and urban populations (Bauer and others 2009; Wilson 2004) the latter being usually more favorable to a wildlife comeback.

The conflicts with carnivores are largely explained by the fact that they prey on domestic animals due to the scarcity of wild prey (Russo 2006) but also by the loss of traditional livestock-guarding knowledge in several countries (Fourli 1999; Kaczensky and others 2004). Nonetheless, the level of depredation of livestock by carnivores is generally low, often less than 10% of their diet (Wilson 2004). Still, the impact at the level of the livestock owner can be high (Wilson 2004). To compensate for these impacts, several countries pay for damages caused by wildlife. For bear and wolf damages, an average of € 2 million/year were compensated in Europe between 1992 and 1998 in France, Greece, Italy, Austria, Spain and Portugal (Fourli 1999) while € 2.15 million were spent in preventive measures.

Large grazers such as deer and wild boars can also cause significant damage to crops, pastures and forest plantations (Goulding and Roper 2002; Kamler and others 2010). As for the carnivores, a combination of preventive measures such as electric fencing (Honda and others 2009) with compensation payments can contribute to decrease the levels of conflict.

Fear of attacks on people also play a factor in this conflict, but this often can be improved with better information to the public as there is a correlation between the fear of an animal and a lack of knowledge of its behavior (Decker and others 2010; Kaczensky and others 2004).

Limits to Ecological Resilience

In many regions of Europe, the transition from abandoned to semi-natural land takes less than 15 years, followed by another 15–30 years before reforestation (Cramer and others 2008; Verburg and Overmars 2009). Passive regeneration can

therefore be a slow process, particularly in a dry environment such as the Mediterranean (Rey Benayas and others 2008), or when the soils have been modified by past agriculture, that is, the “cultivation legacy” (Cramer and others 2008), or the “grazing history” (Chauchard and others 2007). The revegetation also depends on the availability and quality of the native seed bank (Rey Benayas and others 2008).

If the abandoned land is too degraded assisted regeneration may be needed (Cramer and others 2008). Active restoration would involve large-scale native trees plantation and tree growth management (Rey Benayas and others 2008). An intermediate level of intervention involves the creation and management of forest regeneration sources or “woodland islets” (Rey Benayas and Bullock 2012). Another problem often requiring intervention is the vulnerability of intermediate stages of natural succession to natural perturbations, such as invasive species (Kull and others 2004; Stoate and others 2009) and fire (Pausas and others 2008). Fire is a particularly acute problem as it has impacts not only on biodiversity but also on human health (Proença and Pereira 2010b). If fire regime is not appropriately managed, frequent fires will favor fire-prone scrubland and halt succession towards forest, in a self-reinforcing feedback loop (Proença and Pereira 2010a).

One of the strategies to manage fire regimes is to maintain open spaces in the landscape, minimizing also the impacts of revegetation on species that prefer open areas (Figure 2). This strategy can be implemented by increasing the populations of large herbivores (Hodder and Bullock 2009; Sutherland 2002), including reintroduction of extinct species (Svenning 2002). In the case of species regionally extinct, it is possible to use individuals from other populations. For instance, seven European bison were recently reintroduced in northern Spain, 1,000 years after their extinction (Burton 2011). A more complex situation occurs with species that are globally extinct, such as wild relatives of some domesticated species. A possible solution is to release into the wild individuals of breeds that are most likely to be successful in replacing the ecological role of their wild ancestors. For instance, Iceland ponies have been released in the former arable fields of the Dutch-Belgian border (Kuiters and Slim 2003): their grazing favored a dense grass sward and after 27 years open grassland still represented 98% of the area.

Natural colonization of abandoned land by carnivores can also be limited by the availability of prey, as is the case for the Iberian lynx (*Lynx*

pardinus) currently negatively affected by the scarcity of rabbits, decimated by diseases (Delibes-Mateos and others 2008), or as can be expected for some populations of wolves and bears currently preying on livestock (Russo 2006).

Rewilding may be a future option in areas that are undergoing agricultural development or intensification today. There is currently a debate between land sharing and land sparing approaches to reconcile food production with biodiversity (Phalan and others 2011). In land sharing, biodiversity conservation and food production goals are met on the same land, with biodiversity friendly agricultural practices and extensive agriculture, whereas in land sparing, land is divided between areas of intensification and of exclusion of agriculture. In practice, it is difficult to determine which is the best option because species respond differently to the alteration of their habitat (Phalan and others 2011). To maintain future options for rewilding, both land sparing and land sharing are needed. On the one hand, land sharing is essential to limit land degradation and to maintain the appropriate seed bank for future passive revegetation. On the other hand, land sparing would allow for the conservation of populations of species that are currently in conflict with human activities, making “cohabitation” very difficult.

FINAL REMARKS

Most landscapes are evaluated and protected according to emotional and aesthetic values that societies attribute to them (Antrop 2005; Gobster and others 2007) and conservation programs are determined by people’s perceptions of what should be preserved (Gillson and others 2011) and depend on shifting baselines of what nature should be like (Vera 2009). Thus, the values that Europeans give to farmland and wilderness landscapes are based on tradition and history but also on socio-economic backgrounds (Van den Berg and Koole 2006). Yet, considering that landscapes result from the dynamic interaction of natural and cultural drivers (Antrop 2005), they cannot be perceived as anchored in time and we should anticipate occasional changes that will force us to reevaluate their definition.

Rewilding appears to be a viable management option for some of these transitions with important benefits for biodiversity and ecosystem services. At the local scale, some species will decline and other increase, eventually leading to local species diversity decreases in some taxa (Figure 2). We lack research studies looking at the regional scale

dynamics, but we hypothesize that no significant loss in species diversity is expected as long as mosaics of open spaces and forest are maintained, and that some dimensions of biodiversity may even improve, such as the average size of populations of wild species. At the global scale, many species have already gone extinct and it will be impossible to get them back, but the release into the wild of breeds of some domesticated species may allow recovery of some historical losses (Figure 2). In terms of ecosystem services, rewilding allows for a wide range of regulating and cultural services (Figure 5).

The extent and outcome of rewilding will be heterogeneous across Europe (Figure 4) as different regions will have different departing points of post-farmland abandonment and varying limitations to natural forest regrowth. For example, on some abandoned areas of Southern Europe, the availability of forest tree seed banks can be a limiting factor due to little natural forest left and the frequent fire regime may delay ecological succession. In contrast, the relative scarcity of open areas in much of Northern Europe may render the intensification or reestablishment of natural perturbations, such as grazing by large wild herbivores and fire (for example, prescribed burns), priority goals for management. Rewilding can also be considered on available land that does not necessarily result from farmland abandonment, such as national forests previously managed for timber production, decommissioned military areas, salt ponds and other wetlands, thus increasing the level of heterogeneity of European wild landscapes.

From a conservation standpoint, the option between rewilding and active management will depend on the goals and the local context. Active management is likely to be preferred when the goal is to restore specific species or maintain early successional habitats and other habitats associated with human activities. Passive management emphasizes dynamic ecological processes over static patterns of species or habitat occurrence and can be more sustainable in the long term or at large spatial scales.

Despite many benefits, rewilding has been disregarded as a management option until recently. Initiatives such as Rewilding Europe (<http://www.rewildingeurope.com>) and the PAN Parks Network (<http://www.panparks.org>) are now bringing rewilding to the forefront of the discussion of European conservation policies. Rewilding poses many challenges, but those are inherent to the implementation of any restoration plan. In a world wounded by biodiversity loss, farmland abandonment is an opportunity to improve biodiversity in

Europe, to study the regeneration of vegetation, and even to test ecological theories (Hobbs and Cramer 2007). In the end, the question is not whether we prefer a domesticated or a wild European landscape but rather which management options (Figure 1) at each place will be more achievable and sustainable.

ACKNOWLEDGMENTS

We thank P. Verburg for sharing data from the CLUE model and commenting on the manuscript. We also thank V. Proença, R. Beilin, J. Bullock and S. Ceausu for comments. This research was funded by the Fundação para a Ciência e a Tecnologia (FCT)-ABAFBIO (PTDC/AMB/73901/2006) and by FORMAS-Project LUPA. L.N. is supported by a grant from FCT (SFRH/BD/62547/2009).

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REFERENCES

- Antrop M. 2005. Why landscapes of the past are important for the future. *Landsc Urban Plan* 70:21–34.
- Arbelo CD, Rodríguez-Rodríguez A, Guerra JA, Mora JL, Notario JS, Fuentes F. 2006. Soil degradation processes and plant colonization in abandoned terraced fields overlying pumice tuffs. *Land Degrad Dev* 17:571–88.
- Balmford A, Green RE, Scharlemann JPW. 2005. Sparing land for nature: exploring the potential impact of changes in agricultural yield on the area needed for crop production. *Glob Change Biol* 11:1594–605.
- Batáry P, Holzschuh A, Orci KM, Samu F, Tschardt T. 2012. Responses of plant, insect and spider biodiversity to local and landscape scale management intensity in cereal crops and grasslands. *Agric Ecosyst Environ* 146(1):130–6.
- Bauer N, Wallner A, Hunziker M. 2009. The change of European landscapes: Human-nature relationships, public attitudes towards rewilding, and the implications for landscape management in Switzerland. *J Environ Manage* 90:2910–20.
- Bell S, Montarzino A, Aspinall P, Penêze Z, Nikodemus O. 2009. Rural society, social inclusion and landscape change in Central and Eastern Europe: a case study of Latvia. *Sociol Rural* 49:295–326.
- Blondel J. 2006. The “design” of mediterranean landscapes: a millennial story of humans and ecological systems during the historic period. *Hum Ecol* 34:713–29.
- Boitani L. 2000. Action plan for the conservation of the wolves (*Canis lupus*) in Europe. *Nature and Environment*, no. 113. Strasbourg: Council of Europe Publishing. 84 pp.
- Brauman KA, Daily GC, Duarte TK, Mooney HA. 2007. The nature and value of ecosystem services: an overview highlighting hydrologic services. *Annu Rev Environ Resour* 32:67–98.
- Breitenmoser U. 1998. Large predators in the Alps: the fall and rise of man’s competitors. *Biol Conserv* 83:279–89.
- Bugalho MN, Caldeira MC, Pereira JS, Aronson J, Pausas JG. 2011. Mediterranean Cork Oak Savannas require human use to sustain biodiversity and ecosystem services. *Front Ecol Environ* 9(5):278–86.
- Bullock DJ. 2009. What larger mammals did Britain have and what did they do? *Br Wildl* 20(5):16–20.
- Burton A. 2011. Where the wisents roam. *Front Ecol Environ* 9:140.
- Caro T. 2007. The Pleistocene re-wilding gambit. *Trends Ecol Evol* 22:281–3.
- Chauchard S, Carcaillet C, Guibal F. 2007. Patterns of land-use abandonment control tree-recruitment and forest dynamics in Mediterranean mountains. *Ecosystems* 10:936–48.
- Conti G, Fagarazzi L. 2005. Forest expansion in mountain ecosystems: “environmentalist’s dream” or societal nightmare? *Planum* 11:1–20.
- Cooper T, Baldock D, Rayment M, Kuhmonen T, Terluin I, Swales V, Poux X, Zakeossian D, Farmer M. 2006. An evaluation of the less favoured area measure in the 25 member states of the European Union. London: Institute for European Environmental Policy. 262 pp.
- Cramer VA, Hobbs RJ, Standish RJ. 2008. What’s new about old fields? Land abandonment and ecosystem assembly. *Trends Ecol Evol* 23:104–12.
- Daugstad K, Ronningen K, Skar B. 2006. Agriculture as an upholder of cultural heritage? Conceptualizations and value judgements—a Norwegian perspective in international context. *J Rural Stud* 22:67–81.
- Dax, T. 2005. The redefinition of Europe’s less favoured areas. In: *Rural development in Europe – 3rd annual conference – Funding European Rural Development in 2007–2013*. MPRA paper no. 711.
- Decker SE, Bath AJ, Simms A, Lindner U, Reisinger E. 2010. The return of the king or bringing snails to the garden? The human dimensions of a proposed restoration of European Bison (*Bison bonasus*) in Germany. *Restor Ecol* 18:41–51.
- Delibes-Mateos M, Delibes M, Ferreras P, Villafuerte R. 2008. Key role of European rabbits in the conservation of the Western Mediterranean basin hotspot. *Conserv Biol* 22(5):1106–17.
- Devy-Vareta N, Alves AAM. 2007. Os avanços e os recuos da floresta em Portugal-da Idade Média ao Liberalismo. In: Silva JS, Ed. *Floresta e sociedade, uma historia em comum*. Público SA e Fundação Luso-Americana: Lisboa. p 55–75.
- DG Agriculture. 2011. *Rural development in the European Union. Statistical and economic information report*. 257 pp.
- Donlan CJ, Berger J, Bock CE, Bock JH, Burney DA, Estes JA, Foreman D, Martin PS, Roemer GW, Smith FA, Soulé ME, Greene HW. 2006. Pleistocene rewilding: an optimistic agenda for twenty-first century conservation. *Am Nat* 168(5):660–81.
- EEA 2004. *High nature value farmland: characteristics, trends and policy challenges*. Copenhagen: European Environmental Agency. 31 pp.
- EC – European Commission. 2008a. *Poverty and social exclusion in rural areas*. Brussels: DG Employment Social Affairs and Equal Opportunities. 187 pp.
- EC – European Commission. 2008b. *Overview of the less favoured areas farms in the EU-25 (2004–2005)*. Brussels: DG Agriculture and Rural Development. 99 pp.

- EC – European Commission. 2009. New insights into mountain farming in the European Union. Brussels: DG Agriculture and Rural Development. 35 pp.
- Eickhout B, Van Meijl H, Tabeau A, Van Rheenen T. 2007. Economic and ecological consequences of four European land use scenarios. *Land Use Policy* 24:562–75.
- Enserink M, Vogel G. 2006. The carnivore comeback. *Science* 314:746–9.
- Farrell EP, Führer E, Ryan D, Andersson F, Hüttl R, Piussi P. 2000. European forest ecosystems: building the future on the legacy of the past. *For Ecol Manage* 132:5–20.
- FAO. 2011. State of the world's forests. Rome: FAO. 179 pp.
- FAOSTAT. 2010. Retrieved on 1 March 2011. <http://faostat.fao.org>.
- Figueiredo J, Pereira HM. 2011. Regime shifts in a socio-ecological model of farmland abandonment. *Landsc Ecol* 26(5):737–49.
- Fourli M. 1999. Compensation for damage caused by bears and wolves in the European Union. LIFE-Nature projects, European Commission-DG XI-Environment, Nuclear Safety and Civil Protection. 72 pp.
- Gellrich M, Baur P, Koch B, Zimmermann NE. 2007. Agricultural land abandonment and natural forest re-growth in the Swiss mountains: a spatially explicit economic analysis. *Agric Ecosyst Environ* 118:93–108.
- Gillson L, Ladle RJ, Araújo MB. 2011. Baselines, patterns and process. In: Ladle RJ, Whittaker RJ, Eds. *Conservation biogeography*. Oxford: Wiley-Blackwell. p 31–44.
- Gobster PH, Nassauer JI, Daniel TC, Fry G. 2007. The shared landscape: what does aesthetics have to do with ecology? *Landsc Ecol* 22:959–72.
- Gortázar C, Herrero J, Villafuerte R, Marco J. 2000. Historical examination of the status of large mammals in Aragon, Spain. *Mammalia* 64:411–22.
- Goulding MJ, Roper TJ. 2002. Press responses to the presence of free-living wild boar (*Sus scrofa*) in southern England. *Mamm Rev* 32:272–82.
- Halada L, Evans D, Romão C, Petersen J-E. 2011. Which habitats of European importance depend on agricultural practices? *Biodivers Conserv* 20(11):2365–78.
- Hobbs RJ, Higgs E, Harris JA. 2009. Novel ecosystems: implications for conservation and restoration. *Trends Ecol Evol* 24:599–605.
- Hobbs RJ, Cramer VA. 2007. Why old fields? Socioeconomic and ecological causes and consequences of land abandonment. In: Cramer VA, Hobbs RJ, Eds. *Old fields: dynamic and restoration of abandoned farmland*. Washington: Island Press. p 1–14.
- Höchtel F, Lehringer S, Konold W. 2005. “Wilderness”: what it means when it becomes a reality—a case study from the southwestern Alps. *Landsc Urban Plan* 70:85–95.
- Hodder KH, Bullock JM. 2009. Really wild? Naturalistic grazing in modern landscapes. *Br Wildl* 20:37–43.
- Hodder KH, Buckland PC, Kirby KK, Bullock JM. 2009. Can the pre-neolithic provide suitable models for re-wilding the landscape in Britain? *Br Wildl* 20(5):4–15.
- Hölzel N, Haub C, Ingelfinger MP, Otte A, Pilipenko VN. 2002. The return of the steppe – large-scale restoration of degraded land in southern Russia during the post-Soviet era. *J Nat Conserv* 10:75–85.
- Honda T, Miyagawa Y, Ueda H, Inoue M. 2009. Effectiveness of newly-designed electric fences in reducing crop damage by medium and large mammals. *Mamm Study* 34:13–17.
- Johnson CN. 2009. Ecological consequences of late quaternary extinctions of megafauna. *Proc R Soc B* 276:2509–19.
- Kaczynsky P, Blazic M, Gossow H. 2004. Public attitudes towards brown bears (*Ursus arctos*) in Slovenia. *Biol Conserv* 118:661–74.
- Kamler J, Homolka M, Barančeková M, Krojerová-Prokešová J. 2010. Reduction of herbivore density as a tool for reduction of herbivore browsing on palatable tree species. *Eur J For Res* 129:155–62.
- Kaplan JO, Krumhardt KM, Zimmermann N. 2009. The pre-historic and preindustrial deforestation of Europe. *Quat Sci Rev* 28:3016–34.
- Keenleyside C, Tucker G. 2010. *Farmland Abandonment in the EU: an assessment of trends and prospects*. London: WWF and IEEP. 97 pp.
- Körner C, Spehn E, Baron J. 2005. *Mountain systems. Millennium ecosystem assessment. Ecosystems and human well-being: current state and trends*. Washington: Island Press. p 681–716.
- Kuemmerle T, Hostert P, Radeloff VC, Linden S, Perzanowski K, Kruhlov I. 2008. Cross-border comparison of post-socialist farmland abandonment in the Carpathians. *Ecosystems* 11:614–28.
- Kuiters AT, Slim PA. 2003. Tree colonisation of abandoned arable land after 27 years of horse-grazing: the role of bramble as a facilitator of oak wood regeneration. *For Ecol Manage* 181:239–51.
- Kull T, Pencheva V, Petrovic F, Elias P, Henle K, Balčiauskas L, Kopacz M, Zajickova Z, Stoianovici V. 2004. Agricultural landscapes. In: Young J, Halada L, Kull T, Kuzniar A, Tartes U, Uzunov Y, Watt A, Eds. *Conflicts between human activities and the conservation of biodiversity in agricultural landscapes, grasslands, forests, wetlands and uplands in the acceding and candidate countries*. Wallingford: Centre for Ecology and Hydrology. p 10–20.
- Laiolo P, Dondero F, Ciliento E, Rolando A. 2004. Consequences of pastoral abandonment for the structure and diversity of the alpine avifauna. *J Appl Ecol* 41:294–304.
- Lindborg R, Bengtsson J, Berg A, Cousins SAO, Eriksson O, Gustafsson T, Hasund KP, Lenoir L, Pihlgren A, Sjödin E, Stenke M. 2008. A landscape perspective on conservation of semi-natural grasslands. *Agric Ecosyst Environ* 125(1):213–22.
- Linnell JDC, Swenson JE, Andersen R. 2000. Conservation of biodiversity in Scandinavian boreal forests: large carnivores as flagships, umbrellas, indicators, or keystones? *Biodivers Conserv* 9:857–68.
- MA – Millennium Ecosystem Assessment. 2005. *Ecosystems and human well-being: scenarios*. Washington: Island Press. 560 pp.
- MacDonald D, Crabtree JR, Wiesinger G, Dax T, Stamou N, Fleury P, Gutierrez Lazpita J, Gibon A. 2000. Agricultural abandonment in mountain areas of Europe: environmental consequences and policy response. *J Environ Manage* 59:47–69.
- McNeely JA. 1994. Lessons from the past: forests and biodiversity. *Biodivers Conserv* 3:3–20.
- Meijaard E, Sheil D. 2011. A modest proposal for wealthy countries to reforest their land for the common good. *Biotropica* 43(5):524–8.
- Moreira F, Russo D. 2007. Modelling the impact of agricultural abandonment and wildfires on vertebrate diversity in Mediterranean Europe. *Landsc Ecol* 22:1461–76.
- Nabuurs GJ, Schelhaas MJ, Mohren GMJ, Field CB. 2003. Temporal evolution of the European forest sector carbon sink from 1950 to 1999. *Glob Change Biol* 9:152–60.

- Nowicki P, Weeger C, Van Meijl H, Banse M, Helming J, Terluin I, Verhoog D, Overmars KP, Westhoek H. 2006. SCENAR 2020: scenario study on agriculture and the rural world. Brussels: European Commission-DG Agriculture and Rural Development. 236 pp.
- Pausas JG, Llovet J, Rodrigo A, Vallejo R. 2008. Are wildfires a disaster in the Mediterranean basin—a review. *Int J Wildl Fire* 17:713–23.
- Pereira E, Queiroz C, Pereira HM, Vicente L. 2005. Ecosystem services and human well-being: a participatory study in a mountain community in Portugal. *Ecol Soc* 10(2):14.
- Pereira HM, Leadley PW, Proença V, Alkemade R, Scharlemann JPW, Fernandez-Manjarrés JF, Araújo MB, Balvanera P, Biggs R, Cheung WWL, Chini L, Cooper HD, Gilman EL, Guénette S, Hurtt GC, Huntington HP, Mace GM, Oberdorff T, Revenga C, Rodrigues P, Scholes RJ, Sumaila UR, Walpole M. 2010. Scenarios for global biodiversity in the 21st century. *Science* 330:1496–501.
- Pereira HM, Navarro LM, Martins IS. in press. Global biodiversity change: the good, the bad and the unknown. *Annu Rev Environ*. doi:10.1146/annurev-environ-042911-093511.
- Phalan B, Onial M, Balmford A, Green RE. 2011. Reconciling food production and biodiversity conservation: land sharing and land sparing compared. *Science* 333(6047):1289–91.
- Pinto-Correia T, Mascarenhas J. 1999. Contribution to the extensification/ intensification debate: new trends in the Portuguese Montado. *Landsc Urban Plann* 46:125–31.
- Pointereau P, Coulon F, Lambotte M, Stuczynski T, Sanchez Ortega V, Del Rio A. 2008. Analysis of farmland abandonment and the extent and location of agricultural areas that are actually abandoned or are in risk to be abandoned. *Ispra: European Commission-JRC-Institute for Environment and Sustainability*. 204 pp.
- Proença V, Pereira HM. 2010a. Appendix 2: Mediterranean forest. In: Leadley P, Pereira HM, Alkemade R, Fernandez-Manjarrés JF, Proença V, Scharlemann JPW, Walpole MJ, Eds. *Biodiversity scenarios: projections of the 21st century change in biodiversity and associated ecosystem services*. CBD technical series no. 50. pp. 60–67.
- Proença V, Pereira HM. 2010b. Ecosystem changes, biodiversity loss and human well-being. In: Nriagu JO, Ed. *Encyclopedia of environmental health*. Burlington: Elsevier. p 215–24.
- Proença V, Pereira HM, Vicente L. 2008. Organismal complexity is an indicator of species existence value. *Front Ecol Environ* 6:298–9.
- Rasker R, Hackman A. 1996. Economic development and the conservation of large carnivores. *Conserv Biol* 10:991–1002.
- Rey Benayas J, Bullock J. 2012. Restoration of biodiversity and ecosystem services on agricultural land. *Ecosystems*. doi:10.1007/s10021-012-9552-0.
- Rey Benayas JM, Martins A, Nicolau JM, Schulz JJ. 2007. Abandonment of agricultural land: an overview of drivers and consequences. *CAB Rev* 2:1–14.
- Rey Benayas JM, Bullock JM, Newton AC. 2008. Creating woodland islets to reconcile ecological restoration, conservation, and agricultural land use. *Front Ecol Environ* 6:329–36.
- Rounsevell MDA, Reginster I, Araújo MB, Carter TR, Den-doncker N, Ewert F, House JI, Kankaanpää S, Leemans R, Metzger MJ, Schmit C, Smith P, Tuck G. 2006. A coherent set of future land use change scenarios for Europe. *Agric Ecosyst Environ* 114:57–68.
- Ruben R, Pender J. 2004. Rural diversity and heterogeneity in less-favoured areas: the quest for policy targeting. *Food Policy* 29:303–20.
- Russo D. 2006. Effects of land abandonment on animal species in Europe: conservation and management implications. *Integrated assessment of vulnerable ecosystems under global change in the EU*. Project report. 52 pp.
- Schley L, Roper TJ. 2003. Diet of wild boar *Sus scrofa* in Western Europe, with particular reference to consumption of agricultural crops. *Mamm Rev* 33:43–56.
- Schröter D, Cramer W, Leemans R, Prentice IC, Araújo MB, Arnell NW, Bondeau A, Bugmann H, Carter TR, Gracia CA. 2005. Ecosystem service supply and vulnerability to global change in Europe. *Science* 310:1333–7.
- Sirami C, Brotons L, Burfield I, Fonderflick J, Martin JL. 2008. Is land abandonment having an impact on biodiversity? A meta-analytical approach to bird distribution changes in the north-western Mediterranean. *Biol Conserv* 141:450–9.
- Stoate C, Báldi A, Beja P, Boatman ND, Herzon I, Van Doorn A, De Snoo GR, Rakosy L, Ramwell C. 2009. Ecological impacts of early 21st century agricultural change in Europe—a review. *J Environ Manage* 91:22–46.
- Strijker D. 2005. Marginal lands in Europe—causes of decline. *Basic Appl Ecol* 6:99–106.
- Sutherland WJ. 2002. Openness in management. *Nature* 418:834–5.
- Svenning JC. 2002. A review of natural vegetation openness in North-western Europe. *Biol Conserv* 104(2):133–48.
- TEEB. 2010. *The economics of ecosystems and biodiversity: mainstreaming the economics of nature: a synthesis of the approach, conclusions and recommendations of TEEB*. 39 pp.
- Tscharntke T, Klein AM, Kruess A, Steffan-Dewenter I, Thies C. 2005. Landscape perspectives on agricultural intensification and biodiversity—ecosystem service management. *Ecol Lett* 8(8):857–74.
- Van den Berg AE, Koole SL. 2006. New wilderness in the Netherlands: an investigation of visual preferences for nature development landscapes. *Landsc Urban Plan* 78:362–72.
- Van Vuuren DP, Sala OE, Pereira HM. 2006. The future of vascular plant diversity under four global scenarios. *Ecol Soc* 11(2):25.
- Vera FWM. 2000. *Grazing ecology and forest history*. New York: CABI. 527 pp.
- Vera FWM. 2009. Large-scale nature development—the Oostvaardersplassen. *Br Wildl* 20(5):28–36.
- Verburg PH, Overmars KP. 2009. Combining top-down and bottom-up dynamics in land use modeling: exploring the future of abandoned farmlands in Europe with the Dyna-CLUE model. *Landsc Ecol* 24:1167–81.
- Williams M. 2000. Dark ages and dark areas: global deforestation in the deep past. *J Hist Geogr* 26:28–46.
- Wilkinson DM. 1999. The disturbing history of intermediate disturbance. *Oikos* 84:145–7.
- Wilson CJ. 2004. Could we live with reintroduced large carnivores in the UK? *Mamm Rev* 34:211–32.
- Young J, Watt A, Nowicki P, Alard D, Clitherow J, Henle K, Johnson R, Laczko E, McCracken D, Matouch S, Niemela J, Richards C. 2005. Towards sustainable land use: identifying and managing the conflicts between human activities and biodiversity conservation in Europe. *Biodivers Conserv* 14:1641–61.