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IMPLEMENTING NATURA 2000 IN FARMED LANDSCAPES: THE SERRA DA ESTRELA, PORTUGAL

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Abstract

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In order to halt the loss of biodiversity in Europe and to implement Natura 2000, there is an urgent need to identify opportunities for striking a balance between the Natura 2000 objectives and the rapidly changing socio-economic conditions in farmed Natura 2000 sites. Taking the Serra da Estrela as an example, it is shown that, due to traditional farming, the conservation status of Natura 2000 habitats here in general remains higher than in Europe as a whole, especially concerning habitats that depend on farming. Traditional farming in the Estrela could until recently continue as a result of historic socio-economic and political administrative conditions, but finally the old economic basis of farming has virtually disappeared. Options for balancing Natura 2000 objectives and socio-economic conditions are discussed, taking into account the issue of wide-spread wildfires occurring at present.

Key words: agro-pastoral land use, biodiversity conservation, climate change, landscape change, land abandonment, socio-economic history, wildfires

Introduction

The focus of the Natura 2000 network (hereafter abbreviated to N2000) is on both biodiversity and habitats in Europe. One of its sites is the Serra da Estrela, which is considered a crossroad of the Portuguese interior ecological network (Jansen, 2002). Because of its geographic situation and its mountainous character it is also a transition zone between the Atlantic and Mediterranean biogeographic regions. In the Portuguese Mediterranean region the conservation status is favourable for 31% of the habitats and 5% of the species, while for the Portuguese Atlantic region 21% of the habitats and 6% of the species are classified 'favourable' (ETC/BD, 2008). For all Member States (EU-25), these figures are 17% for habitat and also 17% for species. These figures indicate that halting loss of biodiversity is an important issue in Europe, where many species and habitats were associated with extensive agriculture including a range of farming systems under various economic conditions (Table 1). To date, habitat types linked to extensive agriculture generally have an unfavourable conservation status in the Member States, with only 7% of the assessments being favourable, compared to 21% for 'non-agricultural' habitats (COM, 2009).

The focus in the paper is on three issues:

1) the actual conservation status of habitats compared to EU standards and the preceding evolution of biodiversity, habitats and traditional farming. This will help to answer the question to what extent has traditional farming contributed to conserve biodiversity in the Serra da Estrela;
2) an analysis of major events describing the socio-economic integrity of the territory and the prolonged role of traditional farming;
3) an overview of the unique role of traditional farming in the conservation of biodiversity and the impact of present wildfires on biodiversity, to assess the need for the continuation of farming for both biodiversity and the local economy.

Table 1. Biodiversity and farming in Europe.

Biodiversity in Europe is in most places the outcome of both natural conditions and human interference. Since the early arrival of man, new techniques have step by step increased human-induced dynamics in nature until today. After the Neolithic revolution, farming has become progressively important, triggering a sedentary way of life, and also the development of larger communities and markets. Traditional heath farming included a range of systems, from shifting cultivation for subsistence to labour and capital-intensive farming for the market. The high market demand from the cities revolutionised farming in Europe in the Middle Ages (Bieleman, 1987; Diemont, Jansen, 1998; Diemont, 2008; Diemont et al., 2008). After a long period of harvesting the surplus of the land through collecting, fishing, hunting and shifting cultivation, food security was no longer achieved by depending on the diversity of species, but rather by producing for the market cities by increasing the productivity of single crops. The numbers and distribution of wild species became only an unintended by-product of farming in due course. Livestock raising, crop domestication and infield-outfield farming systems developed, hand in hand with irrigation, drainage and import from manure from the cities. Indeed, drifting sands (Fanta, Siepel, 2010) are proof that good market conditions did not always keep in pace with the resilience of the system, but most biodiversity survived in these market-oriented traditional farming systems. The balance with biodiversity was lost in most parts of Europe in the 19th century when modern farming techniques made it possible to „improve" the land (Smout, 2000). Exactly as a result of improvement in these parts of Europe, heathlands ultimately became a scarce commodity for a society which became ever more involved in the idea that preservation may be necessary to impede loss of biological diversity. The same is true in mountainous areas such as the Estrela where improvement of the heath was rather limited, with the land being suitable only partly for plantation forest. At first the accent in nature conservation was indeed placed on preservation of wilderness, enabled by natural processes only, but the reality in Europe was that most resources had been used by man in one way or another. Now it is accepted, at least in Europe, that traditional land use may have contributed considerably to biodiversity. A large number of the European flora is associated with semi-natural habitats, and traditional farming as a vector and conditioner, assisted many species to perform at optimal distribution (Schrijver et al., 2008; Ozinga, 2008). Since the 1950's, there has been a marked decline in biodiversity across European farmland (Paracchini et al., 2008). Today, semi-natural habitats in Europe suffer from biodiversity loss more than other habitats (COM, 2009). Also compared to other heath areas not suitable for intensive farming, traditional farming in Serra da Estrela could persist (Jansen, 2008). However, with abandonment in progress the question is whether there is really a demand and a possibility to manage such agricultural landscapes. The inability to link biodiversity in managed N2000 habitats to sufficient income for the farmer or land manager constitutes a problem, and this problem is discussed in this paper.

Fig. 1. Situation of Serra da Estrela (based on data of ERM, 2008).

Methods

Site description

Serra da Estrela is the highest mountain of Continental Portugal and it is generally considered a major European biodiversity hot-spot. It is situated in the central interior part of the country and is largely covered by a Natural Park of c. 1000 km^2, including a N2000 area of about 880 km^2 (Fig. 1).

The area has a long history of agro-pastoral land use which resulted in an open cultural landscape supporting a multitude of biotopes and a high biodiversity (Jansen, Diemont, 2005).

Although Serra da Estrela covers only about 1% of the Portuguese continental territory, it comprises almost one third of the Portuguese flora and about two-third of the Portuguese bryoflora (Garcia et al., 2008; Jansen, 2002). The fauna comprises approximately 40 mammal species, about 150 bird species of which two third breeding, a rather limited number of fish species and some 30 amphibian and reptile species. In the database of CIBIO in Porto, about 2500 invertebrates have been listed (personal communication José Manuel Grosso-Silva, 2010). Both flora and fauna include about a dozen strictly endemic species, a few Lusitanian and dozens of Iberian ones. In this area, 40 habitat types and 98 plant and animal species have been reported, where habitat types are listed under Annex I (referred hereafter N2000 habitats) and the species under Annex II, IV and V (referred hereafter N2000 species).

The region has a low population density and the N2000 site with code PTCON0014 has 22.45 hab/km^2 (RCM, 2008). Recently, infrastructure improvement made both the mountain and the peripheral region easily accessible from all major Portuguese cities and as a result, globalisation impacts have increased. Within the N2000 site about 900 farm exploitations are active with a mean surface of c. 5 ha utilised agricultural area (RCM, 2008). The ownership is rather fragmented. For instance in the three municipalities which cover the northwestern part of the natural park with an intervention area of c. 850 km^2 of which c. 48 km^2 lies within the N2000 site, 85% is privately owned and 80% of the properties have less than 2 ha (URZE, 2010). Within the Natural Park about 42% is presently common land or land with jurisdiction under the Forest Institute. At altitudes over 1500 m, almost all is common land (Fig. 1). Currently, about half of the land is covered by extensive scrublands and grasslands, less than a quarter by forest and less than a fifth by agricultural land. This can be deducted from data delivered by ICNB (2009), IGP (2005), and RCM (2008).

Vegetation changes in time and major drivers

Pollen diagrams from the Serra da Estrela (Van der Knaap, Van Leeuwen, 1995, 1997) have been used to assess changes in vegetation since the Last Glacial. The identified vegetation formations correspond in the N2000 habitat classification (EC, 2007b) with the codes 9000 for natural forest, codes 4000 and 5000 for shrubland and code 6000 for grasslands. Formations related to aquatic (code 3000) and rocky habitats (code 8000) occupied relative small areas and are not included in the results. The percentages of pollen from the tree species, *Ericaceae* and *Gramineae* are used to assess the cover of natural forest, shrubland and grassland, respectively, in 4 categories of relative cover abundance: 1 = 0–25%; 2 = 25–50%; 3 = 50–75% and 4 = 75–100%. Current cover abundance estimation is based on several sources including ERM (2008), ICNB (2009), Jansen (1997), RCM (2008), and unpublished data on habitats of ICNB and the first author. It is acknowledged that the pollen diagrams are from one complete series of a former lake situated in the middle belt of the mountain. This takes into account that the assessment of the initial period until the early Holocene included interpretations of 8 other sites within a range of a few km's and also at various altitudes of the middle and upper belts. The recalculation from percentages of pollen into surfaces of vegetation formations is a rather disputed procedure, which it does not allow a claim on statistical precision (Sugita, 2007a, b). The 6 major periods of vegetation succession described by Van der Knaap, Van Leeuwen (1995, 1997) were used, and the results of this part of the study are in section *Resilience of traditional farming.* The database on socio-economic changes in section *Enabling conditions for continuous traditional farming* is from the field of social sciences to produce at least a preliminary background on the history of land use, culture and major socio-economic developments, in order to explain how long and to what extent farm systems were adapting and also contributed to economic development, while maintaining biodiversity.

The N2000 conservation status of traditionally farmed habitats

Criteria for assessing habitat quality on the local level are not mentioned in European legislation. The present paper follows the assessment method of the conservation status of the habitats in terms of "favourable at the regional level" according to the Habitat Directive (EC, 2006; EC, 2007a), but interprets regional as local, i.e. at site level, unless explicitly biogeographic region is mentioned. Information on Europe and Portugal is based on ETC/BD (2008). Specific information on the Serra da Estrela is based on Garcia et al. (2008), Jansen (1997, 1998, 2002, and unpublished data 1989–1999), Jansen, Sequeira (1999), RCM (2008), Sérgio et al. (1998), Willemsen, Thomassen (2009) and it is also based on the factsheets of N2000 habitats composed by ALFA (2004) and additional data on species on the website of ICNB (2006). The emphasis in this paper is on extensive agricultural practices. Nine habitats in the Serra da Estrela are without doubt "depending on or associated with extensive farming practices" according to the list defined by the EEA (2009). The impact of wildfires on habitats is based on Jansen (1997, 2002) and Jansen et al. (1997). The results of this part of

Table 2. Conservation status of habitats in the EU-25 Member States, Portugal, the two biogeographical regions in mainland Portugal and the Serra da Estrela. N = number of habitats; FV = favourable, U1 = unfavourable-inadequate, U2 = unfavourable-bad, ? = unknown or not assessed. Highest scores are highlighted.

Natura 2000	Numbers of habitats and percentages of conservation status				
	N	% FV	% U1	% U2	% ?
EU-25	216	17	28	37	18
Portugal mainland	99	30	51	9	10
Portugal Atlantic	39	21	63	8	8
Portugal Mediterranean	66	31	56	7	6
Serra da Estrela	40	32,5	35	17,5	15

the study can be found in the section "*The conservation status of habitats* and *The importance of traditional farming and the impact of wildfires on the N2000 conservation status*".

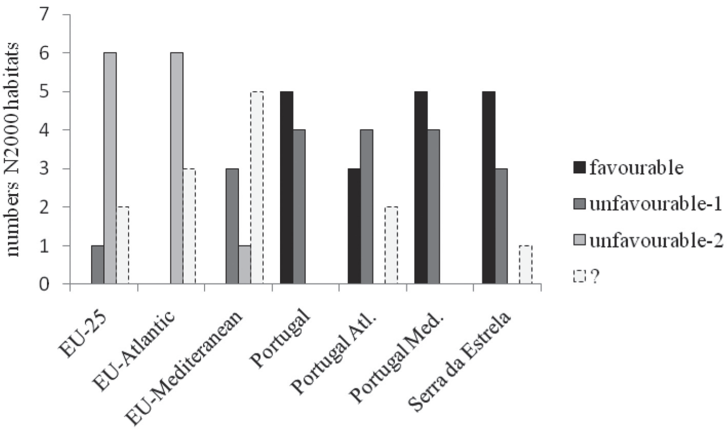

Fig. 2. Conservation status of habitats that depend on extensive agriculture in the Serra da Estrela (n = 9) in comparison to their status in the EU-25 Member States and in Portugal.

Results

The conservation status of habitats

The overall conservation status of the habitats in Portugal is relatively high compared to the EU 25 Member States (ETC/BD, 2008). The Serra da Estrela N2000 site which encompasses both the Atlantic and Mediterranean biogeographical regions is no exception (Table 2).

With regard to habitats depending on agricultural management the situation in Portugal including the Serra da Estrela is in a much more favourable situation compared to the EU, with 5 out of 9 habitats in a favourable position (Fig. 2).

Table 3. Estimated relative cover abundance of formations at milestone moments in time (in years ago) since Late Glacial. Cover of habitat groups in 4 categories varying from increasing shades of grey to black: 1 = 0–25%; 2 = 25–50%; 3 = 50–75% and 4 = 75–100%.

Formation	Milestone moments (yr ago)						
	Dominant driver: climate change			Transition	Dominant driver: human impact		
	12660	10410	8760	5730	3270	1015	0
Natural forest							
Shrubland							
Grassland							

Resilience of traditional farming

To what extent climatic changes have affected biodiversity in the Serra da Estrela in the past can only be assessed at the level of vegetation formations. It can be deduced from Table 3 that as a result of climate change, natural grasslands were replaced by forests after which human impact became stronger and forests occurred in co-dominance with shrublands and grasslands, until more than 1000 years ago both shrublands and grasslands have become a dominant feature in the landscape as a result of human impact.

More detailed information revealing changes at the habitat and species level is not available for the remote periods. But taking in account the rather favourable situation of the habitats requiring farming, as indicated in the previous section, it is clear that there have been specific enabling socio-economic and political events and conditions which made it possible to continue traditional farming. Whereas in many other places in Europe new opportunities of using fertilisers could be achieved, this was not the case in mountainous areas such as the Serra da Estrela, although orienting studies have been made (Freitas, 1918). The absence of opportunities to use fertilisers can be considered part of the explanation and taking into account that other income opportunities in the cities or through emigration existed (Alarcão, 1964), there is still a need to explain why traditional farming could continue for that long.

Table 4 provides a preliminary overview of events, i.e. agricultural innovations, which occurred in response to increased market demand. This was fueled by a higher request for food as a result of the increasing population in the 16th century, which began in tandem with development of the wool industry. The main reason that economic development and biodiversity did not frustrate each other was that farming could increase productivity without substantially changing the area of outfield shrublands and grasslands (Table 3). The terraces constructed on rather steep sloping former outfields for private intensive crop farming were important for production. However, their effective surface area was effectively was very small compared to the large outfields, where opportunities existed for less intensive rye cultivation in rotation with fallow and shrublands, in the limited appropriate conditions encountered there. This contrasted with the lowland areas, where scrub and poor grasslands were heavily reclaimed and converted into more intensively cultivated productive lands. By the 16th century, transhumance had already increased productivity and opened new markets from sheep production. The population could grow due to economic activities such as wool production and the introduction a century later of more productive crops such as maize and potatoes. These factors encouraged intensification by increasing labour input, manure availability and irrigation systems in the infields, including the terraces. The wool-based textile industry in Covilhã and elsewhere boomed at the end of the 17th century and survived in the second half of the 18th due to conversion to cotton. At this time, cheap wool had caused the collapse of the wool industry. However, transhumance decreased during the 19th century as a result of chemical fertilisers being used to improve and change former pasture areas in the lowlands of Portugal into more productive cropland.

T a b l e 4. Major events changing conditions for traditional farming in Serra da Estrela.

Major events	**Year BP**	**Impact**
Improved irrigation	800	infield-outfield systems increasing productivity (Caldas, 1991; Mattoso, 1993)
Intensified transhumance	500–300	generating a cheese industry and trade Ribeiro, Daveau (1978)
Wool industry (Monteiro, 1992)		
Maize and potatoes (Ribeiro, 1941–42; Warman, 2003)		higher population and increase food demand matched by higher labour and manure input in the infields and expansion (Ribeiro, 1940–41)
Collapse transhumance due to change of grassland in cropping land in the lowlands	120–20	in due course resulting in drastic decrease of sheep numbers in the 1930's (INE, 1934, 1940a)
Forest law 1888		transfer of common rights outfields to the state i.e. Forest Service.
Carnation revolution 1974		democratisation and redistribution of state land (previously commons) in Portugal to a growing number of local associations, involved in plantation forestry and also in agriculture and rural development, including N2000 sites (MADRP, 2010; Mendes, 2006)
		income from remittances postponing abandonment (Baganha, 1998; Santos, 1985; Ramos et al., 2004; Ratha, Zu, 2008)
		abandonment and increase wild fires (Rego, 2001)
Continuation of traditional farming		
Ageing farmers, brake-down traditional farming		
Economic agents: tourism , wind energy, water conservation,..	near future	income for land management through payments for ecosystem services and biodiversity through the new CAP?

The further collapse of infield-outfield farming in the 19th century, which occurred in many lowlands with infield-outfield farming systems in Europe, was postponed by the very moderate success of plantation forestry in the 19th century. The inflow of foreign currencies from remitting emigrants most likely prevented a collapse of the agro-pastoral system since from 1870 to1913 remittances in Portugal were about 2% of GDP, in the 1930's these mounted to 4% and in the beginning of the 1980's over 10% (Baganha, 1994). Remittances may be looked upon as a phenomenon which increased the resilience capacity of the agro-pastoral system, slowing down the process of land abandonment, but ultimately traditional farming is coming to an end (Fig. 3).

Fig. 3. Population Serra da Estrela region (period 1864–2007) based on 6 municipalities that enclose the mountain (source: Anonymous, 1864, 1878, 1890, 1900, 1911, 1920, 1930; INE 1940b, 1950, 1960, 1970, 1981, 1989, 1999, 2001a, b, 2008).

The importance of traditional farming and the impact of wildfires on the N2000 conservation status

Burnt areas are increasing (Fig. 4) and the trend line indicates that well before 2020 they will equal the total N2000 area of Serra da Estrela (88,291 ha) if wildfires continue to develop as previously.

Some decrease in plant diversity (50 to 47) and a substantial decrease of habitats (40 to 33) due to the absence of traditional farming can be depicted from Table 5 (scenario B). In the presence of wildfires (scenario D) both habitats and biodiversity would decrease from 40 to 18 habitats and from 50 plant species to 18 species, respectively.

Table 5. Number of N2000 habitats and N2000 species that actually occur in various environments or mosaics in Serra da Estrela.

Environments	N2000 habitats	N2000 plant species
A Mosaic B+C	40	50
B Natural ecosystems (no farming, no wildfires)	33	47
C Traditional farming (no forests but chestnut)	29	42
D Abandonment (natural ecosystems + wildfires)	18	18
E Production forest	12	3
F Modern farming	6	0

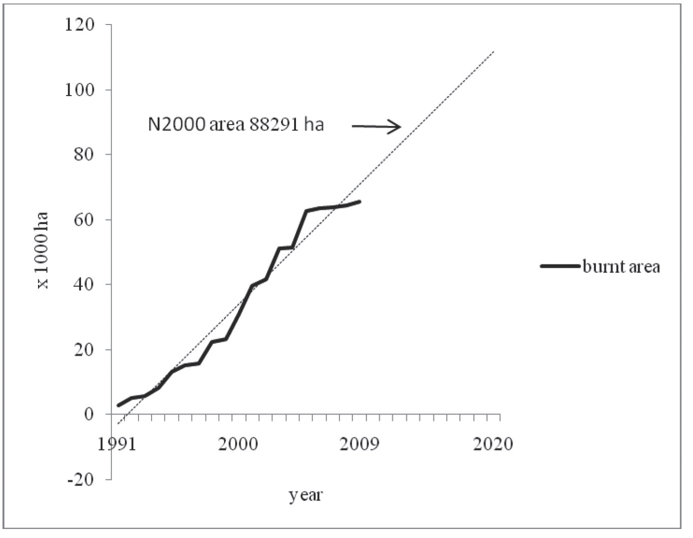

Fig. 4. Burnt areas in Serra da Estrela (1990–2009, data based on Rego, 2001; Coimbra, 2001, 2003; ICNB, 2009).

Discussion

The explanation of why semi-natural habitats and associated biodiversity in Serra da Estrela retain high conservation interest is as follows: a) the roughness of the territory makes it unsuitable for modern agriculture and area-wide forestry, b) transhumance continued until the middle of the last century, c) labour-intensive infield-outfield systems could be sustained to the present day -albeit in a moderate way- as a result of the relatively high demand of the local market, d) this area exploited additional employment supplied by the local economy largely related to the properties of this territory and e) the region also profited from relatively high payments received from emigrants. Currently traditional farming is ultimately coming to an end due to a lack of income. More than two-thirds of the active single farmers within the actual Serra da Estrela N2000 site a decade ago were older than 55 (RCM, 2008).

This discussion follows the major questions posed in the introduction; namely (1) the impact of traditional farming on achieving N2000 objectives, (2) the causes of prolonged traditional farming, and (3) achieving a new balance between biodiversity and socio-economic conditions.

Biodiversity and the conservation status of habitats

The results showed that as the overall status of Portugal, the Serra da Estrela N2000 habitats are also generally in a better condition and have higher status than those of other EU-Member States. This applies especially to habitats in Estrela which also depend on extensive agriculture as defined by the EEA (2009). Although some have been assessed as unfavourable such as the *Wet heaths* (N2000 codes 4010 and 4020), this is not directly related to farming, but rather to the fact that Estrela is located at the junction of the Mediterranean and Atlantic geographic areas. The surface of these habitats is extremely small at less than 10 ha and consequently this does not permit a favourable range status, and this is a requisite parameter for overall weighted assessment of conservation status (EC, 2006). Here, *Dry heaths* (4030) and *Pseudo-steppe grasslands* (6220*) together cover huge areas of over 10,000 ha, with the latter being a priority habitat-type. However definitions of type 6220* are rather incongruous, as far as Serra da Estrela is concerned (please see section "*The importance of traditional farming and the impact of wildfires on the N2000 conservation status*").

Additionally, we note that *Alpine and subalpine heaths* (4060) and *Mountain Cytisus purgans formations* (5120) types in Serra da Estrela are habitats which partly depend on extensive agricultural practices (see Jansen 1994a, b) and therefore these merit addition to the proposed EEA list (EEA, 2009). Currently *Molinia meadows* (6410) in Estrela are assessed as unfavourable-inadequate, whereas more than a decade ago the status of this habitat was still considered acceptable (Jansen, 1997). Although *Lowland hay meadows* (6510) also have an unfavourable conservation status, this is not an exception in Portugal nor other parts of Europe. While *Species-rich Nardus grasslands* (*6230) have been assessed favourable in Estrela, the status of this type in Portugal is deemed to be unfavourable-inadequate.

It is therefore safe to conclude from the above that the conservation status in Serra da Estrela of N2000 habitats is still high compared to Europe, and especially that habitats associated with extensive agriculture are in much better conditions than those in Europe.

We were unable to estimate the conservation status of N2000 species, since important information concerning the numbers and range in Portugal is not available (ETC/BD, 2008). However, we assume that all 96 N2000 species reported for Serra da Estrela, including both flora and fauna, have existed in natural ecosystems whether *in situ* or in other regions from which they could migrate. Therefore, it is presumed that, although some of the species are only occurring in farmed habitats, that these will not become extinct in the absence of traditional farming (Table 5). Forests declined dramatically in the past, and there was an increase especially in shrublands and grasslands in early periods which has remained relatively constant during the last five millennia (Table 3). In that anthropogenic environment, some plant species may have invaded alternative niches in vegetation formations and rural environments which evolved from the interaction between humans and natural resources. These species had previously been mainly associated with forests, forest gaps, forest fringes, rocky outcrops, river banks and open ecosystems around and above the tree line. Population numbers of species and their ranges are expected to have increased or decreased and existing habitats may have also changed and extended species' composition. Moreover, a number of plant and animal species were deliberately introduced, and this may have induced substantial change in population numbers, and the ranges and the species composition of habitats. It is possible to argue that biodiversity would not have decreased if farming had ceased, but population numbers of species and their range, however, were expected to change. We do know that almost 1000 plant species occur, and about three quarter of these can be regarded as characteristic for six broad habitat groups (Jansen, 2002). Obviously, many plant species have found niches in the mosaic-like landscape patterns. The ratios of these groups are approximately; forest: 6, scrub: 3, grassland: 10, aquatic: 3, rocky: 2 and anthropogenic: 6. All N2000 habitats and N2000 plant species in Serra da Estrela can be found mainly in a mosaic-like pattern of habitats in which natural ecosystems are combined with traditional farming practices (Table 5: Environment A). In other situations, these figures are lower. Therefore, the impact of farming may possibly have had a positive influence on biodiversity, since most of the typical species are optimally found in habitats that have been clearly changed by man. Additionally, at least half of the characteristic forest species are not found deep in the forests, but they optimally occupy fringe and gap areas (Jansen, 2002). In Serra da Estrela, the majority of forest patches have an open translucent crown structure. Indeed, species can compensate changes in conditions by selecting micro-sites, a phenomenon which is known as 'the relative law of site constancy' (Walter, 1953). In the past, climate changes radically changed the landscape (Table 3) and recently there are indications that weather conditions have become drier and warmer (Santos, Miranda, 2006). In this situation, all species can change their positions in the ecosystem. Whether species can freely migrate in the present circumstances is uncertain, due to the changed infrastructure around this rather isolated mountain range. The question of what will happen to biodiversity if farming stops is interesting, but this is beyond the scope of this paper. The urgent question we address is whether it is possible to stop the threat of the increasing impacts of wildfires which can radically change or even destroy habitats (Fig. 3, Table 5). Farming maintains an open landscape and diminishes fire hazards, as discussed in section 4.3.

Alternative options to counteract scrub encroachment and to prevent wildfires, such as re-wilding with herbivores, has not been analysed, because it is difficult to predict the effects on habitats, species, and existing live-stock in an environment resulting from centuries-old grazing regimes (Caro, 2007). Exotic diseases can affect live-stock and short-term changes can adversely affect biodiversity. Consequences from the introduction of Gredos ibex (*Capra pyrenaica victoriae*), which is a species that lives in the eastern part of the Sistema Central, have recently been discussed by Estrela's stakeholders. Information on the likely effects of grazing is minimal (Acevedo, Cassinello, 2009) .

Temporarily we conclude that traditional farming in combination with natural ecosystems have the highest possible scores supporting all N2000 habitats and N2000 plant species (Table 5: Environment A).

Resilience capacity of Estrelean mountain farming in a socio-economic context

The introduction of fertilisers in Europe did not provide the opportunity to improve the productivity of extensive outfields such as heath areas in mountainous areas. This explains why heathlands did not decrease here as they did in the lowlands of Europe. But also, as in the lowland areas, the collapse of transhumance in Serra da Estrela was at least partly the result of the transformation of traditional grazing areas or outfields into cropland, thus frustrating the continuation of the transhumance. However, the infield-outfield system was able to survive so long in economic terms because these systems with irrigated infields and high labour and manure input formed part of the market economy. The question however remains, how could these systems survive from an economic point of view when the heathland economy in the lowlands of Europe not longer provide income during most of the 19th century. Although the database presented in the section "Vegetation changes in time and major drivers" is still far from complete and requires more profound treatment, there is sufficient evidence to conclude that infield-outfield systems could stay competitive in the market place. This was due to a combination of local market demand, highly productive infields following irrigation, and most likely also because of the good prices for livestock. While these factors are covered in the section on "Resilience of traditional farming", remittances also contributed a positive effect. As already noted, the database is still poor and not yet supported by detailed accounts of the farm economy of infield-outfield systems. It is clear, however, that there was an economic basis for continuing this system, but this is now collapsing. Under these circumstances, the lack of an economic basis is a direct threat for the implementation of N2000 objectives, especially when wide-spread wildfires are considered. One solution may be the introduction of agri-environmental payments. Therefore, the new Common Agricultural Policy may be able to provide sufficient payments for biodiversity and ecosystem services such as water conservation and wildfire protection. This may also form principles for a new developing economy including tourism and other sectors, so that public payments for ecosystem services may be considered an investment in the current rural economy.

Wildfires

Assuming that succession leads to natural ecosystems, theoretically at first glance it can be concluded that abandonment has opportunities to increase the total amount of habitats from 29 to 33 and plant species from 42 to 47, which is the aim of N2000 (Table 5: Environment B). However, the actual situation reveals that the amounts would drop, of habitats from 40 to 33 and of species from 50 to 47 (Table 5: Environment A + B). Additionally, the repeated occurrence of wildfires also leads to the conclusion that wilderness *persé* is not an option for N2000 management under a regime of recurrent wildfires (Table 5: Environment D). Since wildfires have a disastrous effect on N2000 habitats and plant species, and also possibly on most fauna, it can be argued that most animal species will suffer when some habitats disappear and that all N2000 habitats and other biotopes will deteriorate. If wildfires continue to spread with the same speed as has occurred during the last twenty years, then only 18 N2000 habitat types and 18 N2000 species will remain in the foreseeable future (Table 5). This result will most likely lead to an unfavourable conservation status for all or nearly all habitats and species.

The impact of wildfires in Portugal in the past occurred on a much smaller scale than today with burnt areas of a few thousand ha per year from the late 1940's until the early 1970's. However, since then burnt areas have increased ten-fold in size consuming significant areas of plantations which were planted years before (Mendes, da Silva Dias, 2002; Rego, 2001). For Serra da Estrela, the available data on plantation regimes from 1900 until 2001, revealed 41,500 ha planted forest (ICNB, 2009; Rego, 2001). Comparative figures for wildfires from 1990 until 2009 showed that burnt areas outnumbered plantations (Fig. 4). Figures for the total territory of the 6 municipalities (*c*. 240000 ha) which cover the Estrela show that large areas had already been consumed by flames in the 1980's and that the numbers of fires increased (Lourenço, 1994).

Currently, uncontrolled fires have a very strong landscape shaping impact, triggering erosion, landslides, the loss of various mature soil types, and an increase in non-native invasive species. Over 65,000 ha were destroyed by fire between 1990 and 2009, and this is more than half of the total Estrelean park area (Fig. 4). However, it is likely that most of the burnt vegetation was uncultivated land (*incultos*), including shrublands, grasslands and other herbaceous vegetation. These *incultos* include most of the former outfields, which have now become increasingly abandoned, resulting in the accumulation of biomass and therefore increased fire hazard. The available data (ICNB, 2009) show that in the period 2001–2008 about 33,700 ha burned down, including 24% forest plantation, 70% *incultos* and 6% agricultural land. Applying this breakdown to the distribution of categories over the past 19 years gives approximately 15,600, 45,500, and 3,900 ha burnt forest, *incultos*, and agricultural land respectively. This indicates that most burnt areas were most likely extensive scrub and grasslands in contrast to the national level where burnt forests areas are larger than burnt pasture areas (Mendes, da Silva Dias, 2002), but this anomaly may be explained by the relative larger area of *incultos* in Serra da Estrela. Indeed burning favours therophytes, grasses and bulbous species and the range of grasslands. The first author with continuous fieldwork in the 1990's has contributed miscellaneous observations of post-fire dynamics. He noted amongst other things that especially grasslands rich in therophytes and bulbous species resembling vegetation, grouped by ICNB (2006) under the habitat code of *Pseudosteppe grasslands* 6220*, extended as a result of wildfires (see also Jansen et al., 1997). This priority N2000 habitat type presently covers very large areas (ICNB, 2008) and needs further study since stands differ remarkedly from the description given by the EC (2007a, b). Information was collected on the basis of some 40 relevés, showing that such grasslands are frequently dominated by tall xerophytic grasses such as *Avenula sulcata*, *Festuca livida* and *Arrhenatherum* species with a large number of therophytes in the lower layer (Jansen, 1997). However, our knowledge is insufficient to interpret such plant assemblages (see also Jansen, 2002). Controlled fires may indeed favour a N2000 habitat priority type, but frequently repeated wildfires develop high temperatures and they can penetrate very deeply into the soil, destroying the organic matter and eventually stripping the soils. In the past, *Erica arborea,* which prefers rather deep and humid soils, has been abundant in periods of deforestation growing on former forest soils, but their percentages declined in concentration diagrams for the period from *c.* 550 years ago until recently (Van der Knaap, Van Leeuwen, 1995). Currently, other scrub species are abundant in the heathlands of Serra da Estrela. Since these species can grow on shallower soils, this leads to the hypothesis that such heath types can be interpreted as the next step in soil degradation, eventually leading to shallow litho-soils.

Wildfires are not only indirectly favoured by afforestation but also by biomass accumulation in the outfields. This is a result of the declining agro-pastoral system and of dry climatic conditions which have now increased in Portugal, and further increase is expected in the future (Santos, Miranda, 2006).

While controlled burning was part of the traditional farming system for managing pastures, wildfires now accompany land abandonment and afforestation. This rather recent development is a radical change in a history of more than five millennia of human intervention and these consequences have not fully been acknowledged (Table 3). Nevertheless, wildfires have become the dominant driver of landscape changes which can adversely affect the socio-economic system.

Conclusion

For specific reasons, which are partly related to socio-economic and political-administrative conditions, the conservation status of N2000 habitats in Serra da Estrela in general remains higher than in Europe as a whole, especially concerning habitats that depend on farming. This Serra da Estrela example clearly demonstrates that both N2000 habitats and N2000 plant species are now becoming very much at risk through abandonment and wildfires, in the absence of traditional farming activities, which have lost their economic basis. While, because of scarcity, farmed habitats such as heath and extensive grassland are already being restored in some parts of Europe such as The Netherlands, and in other parts of Europe spontaneous forest development occurs as a result of abandonment such as Slovakia, afforestation still seems to remain more profitable for local Portuguese and Italian landowners (Agnoletti, 2006; Mendes, 2006; Mendes, da Silva Dias, 2002). However, at least in Serra da Estrela, continuation of traditional farming appears the best option both from the viewpoint of nature conservation and fire prevention. This requires the availability of agri-environmental payments, but these can also be considered an investment in sustainable rural development, taking into account the costs to the local economy caused by wildfires and the increasing importance of income related to ecosystem services such as tourism, water conservation, and renewable energies.

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