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Livestock management in Natura 2000: A case study in a *Quercus pyrenaica* neglected coppice forest

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ABSTRACT

Due to the European Habitats Directive, *Quercus pyrenaica* habitat has been protected within the Natura 2000 network for biodiversity conservation. Many of these habitats have been widely managed as coppice forest with silvopastoral use throughout Spain. Currently, in many of these oak coppices fuelwood extraction is neglected and grazing is the main use. Management plans required in the Directive should consider all these circumstances and offer an integrated approach to ensure a favourable conservation status of these habitats. We propose a three phase methodology to assess the ability of the habitat to support a given livestock density annually and seasonally, and to evaluate some of the physical impacts of grazing animals on the physical structure and development of the habitat. We applied the methodology to a neglected coppice forest that supports livestock at different periods. Results show that there is a possible compatibility between annual livestock food requirements and pasture production. Current grazing periods seem to fit the seasonal pasture productivity. Negative impacts were assessed on oak shrubland stands due to intense browsing and on low polewood owing to the high density of broken trees. On more developed stands, positive livestock impact was due to the control of the regrowth of coppice shoots. Acorn absence is a result of the previous coppice management. This negative impact may endanger long-term viability of *Q. pyrenaica* in the study area. We propose a process of conversion into high forest through a sequence of thinning to start sexual regeneration. In this proposal, livestock have an important role to ensure biodiversity, control the regrowth of coppice shoots and thinning low polewood stands.

Introduction

The concern regarding the conservation of biodiversity in Europe led to a series of legislation: such as the Birds Directive 79/409/EEC and the Habitats Directive 92/43/EEC (Martínez, Pagán, Palazón, & Calvo 2007). The Habitats Directive sets a framework for the conservation of natural habitats and wild fauna and flora through the Natura 2000 network. The main goal of Natura 2000 is ensuring "favourable conservation status" of natural habitats and species within these areas (EC 2005). European Member States are required to establish the necessary conservation measures and management plans (Ostermann 1998) to ensure the favourable conservation status of natural habitats (Article 1.e) and species (Article 1.i).

Quercus pyrenaica has been protected within the Natura 2000 network and listed as "9230 *Quercus robur* and *Quercus pyrenaica* forests" (Annex I). Many of these *Quercus pyrenaica* habitats have been historically used as coppice forest throughout Spain, with the main purposes of producing: fuelwood or charcoal; and, grazing-land in rural areas. Secondary uses include obtaining tannins from bark and wood for small tools (Serrada, Montero, & Reque 2008).

The traditional harvesting activity in coppices has changed dramatically in Spain since the 1970s as a consequence of the widespread use of fossil fuels (gas and oil) and also as a consequence of a strong migratory movement of people from villages to towns. Those facts resulted in a deep crisis of the coppice system (Mosquera-Losada, McAdam, & Rigueiro-Rodríguez 2005; Serrada, Allué, & San Miguel 1992). Coppices were neglected in large areas of Spain while grazing was allowed without restrictions. As a result, these stands currently show ecological constraints such as high tree density, almost no seed regeneration, stand decay, and also loss of economic and social benefits (Serrada et al. 2008).

This recent status can be considered unfavourable (Hernando, Tejera, Velazquez, & Nunez 2010). On the contrary, a favourable conservation status for 9230 habitat previously managed as coppice forests would be "mature coppice" (García and Jiménez 2009). This entails two aspects, naturalness (Peterken 1996) and successional states (Frelich 2002). On the one hand, naturalness implies

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a vital uneven aged forest with several complex covers (each of them with a large number of typical species) and some gaps. On the other hand, successional states involves acorn production and sexual regeneration which lead to different canopy layers with different age classes (Valbuena-Carabana, Gonzalez-Martinez, & Gil 2008). To achieve this scenario, silviculture resulting in conversion into high forest is mostly proposed (Ciancio & Nocentini 2004; Montoya 1982; Serrada et al. 2008). Coppices should be treated by thinning on shoots that directly compete with stems of the higher diameter classes (San Miguel 1985; Serrada-Hierro et al. 1994). Sexual regeneration may be subsequently attained.

Besides this forest use, these oak forests are also subjected to silvopastoral management (Robles et al. 2007). Silvopastoralism is an ancient way of managing forestland and a recent way of managing pastureland. It is a type of agroforestry system, fully in line with the global action plan for sustainable development of areas (UNCED 1992). When managed in a sustainable way, silvopastoralism can enhance biodiversity and contribute to the preservation of many endangered species that depend on ecotones between woodlands and open landscapes (Mosquera-Losada, Rodríguez-Barreira, López-Díaz, Fernández-Núñez, & Rigueiro-Rodríguez 2009; Tárrega, Calvo, Taboada, García-Tejero, & Marcos 2009).

Areas managed for silvopastoralism can increase pasture yield beneath the canopy (Moreno 2008), reduce fire and erosion risk in forests, creating the necessary balance between full ground cover and shrub control (Nair, Gordon, Rosa Mosquera-Losada, Sven Erik, & Brian 2008; San Miguel 2004). In this context, manipulation of the type and density of grazing animals can greatly influence the biological (Bartolome, Fehmi, Jackson, & Allen-Diaz 2004; Jackson, Allen-Diaz, Oates, & Tate 2006; Weber, Rigling, & Bugmann 2008) and socio-economic outcomes from the system (Campos, Oviedo, Caparros, Huntsinger, & Coelho 2009; Rapey, Lifran, & Valadier 2001).

In silvopastoralism, grazing capacity usually refers to "the optimal number of (a combination of) livestock (and/or wildlife) that may be maintained sustainably on a management unit as far as compatible with management objectives for that unit" (SRM 1998). Existing methods for determining grazing capacity depend more or less on trial and error (Smith 2003; Vallentine 2001), generally referring to rangeland conditions. Other models relate plant biomass and the rate of food intake of herbivore (Bosch & Booysen 1992; McLeod 1997), or the timing and duration of grazing periods (Chapman et al. 2007) and the degradation processes over a wide range of stocking rates (Schonbach et al. 2009). Lately, there is a debate between equilibrium and non-equilibrium dynamic systems to describe the dynamics of grazing systems (Derry & Boone 2010; Vetter 2005). However, for practical management application, there is a need for more practical data based approach to grazing management, instead of further development of global ecological theories (Laca 2009).

In this study we propose a methodology to evaluate interactions with livestock density. This could break down into two aims: (1) to assess the ability of 9230 habitat to support a given livestock density, annually and seasonally, and (2) to assess some of the physical impacts of grazing animals on the physical structure and development of the habitat. Several management implications are outlined based on knowledge of the traditional pastoral system and on the specific dynamic of coppice forest, in order to improve the conservation status of "9230 *Quercus pyrenaica*" habitat. Other biodiversity elements of the Natura type – e.g., ground flora communities, associate shrub species, bird populations – are not considered.

Materials and methods

Study area

The study area is included in the Natura 2000 network, with the following codes: SCI ES4110114 "Pine forests in the lower Alberche" and SPA ES0000186 "Pine forests in the lower Alberche" (Fig. 1). This forest territory is in an area of importance for black stork (*Ciconia nigra*) and is also part of a recovery plan for imperial eagle (*Aquila adalberti*).

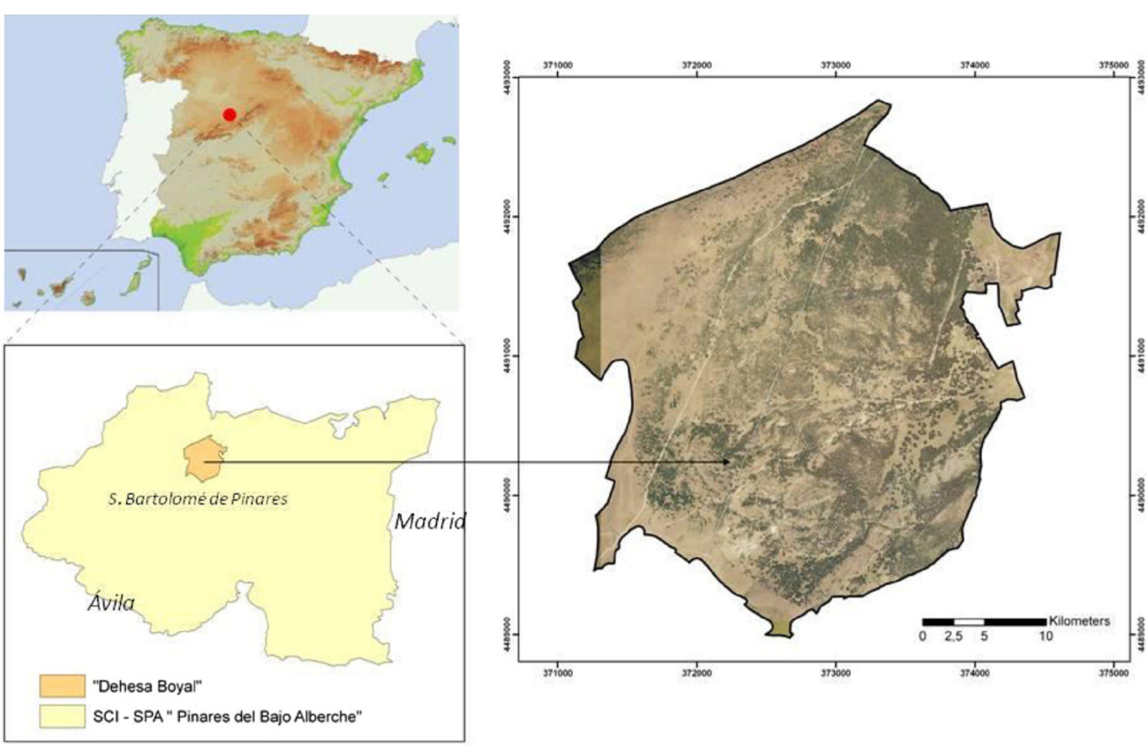

Fig. 1. Study area.

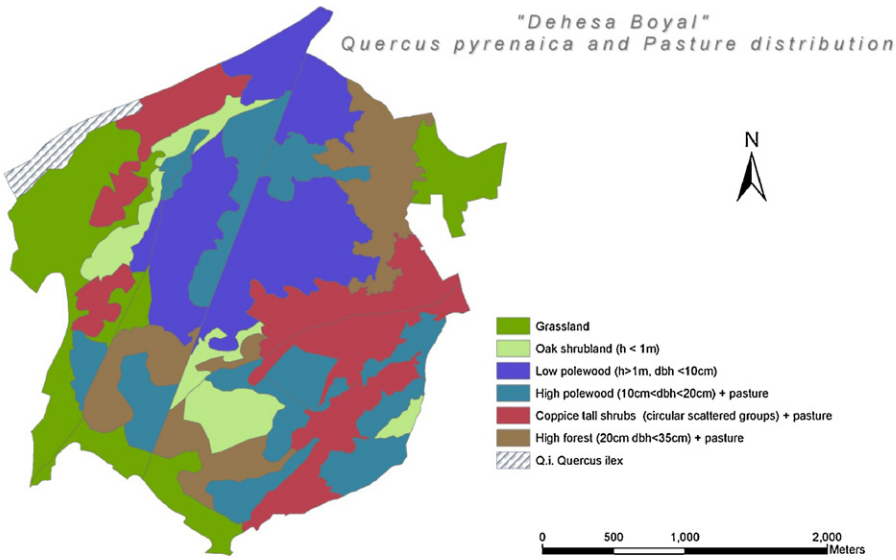

Fig. 2. *Quercus pyrenaica* and pasture distribution.

The study was carried out in "Dehesa Boyal" (815 ha), Central Spain (40°33′N, 4°30′W), located on flat or gently sloping land (altitudes 1220–1395 m, slope 5–12%), with oligotrophic acid soils. The climate is Temperate Mediterranean, with dry hot summers, cool and rainy winters, a mean annual rainfall between 600 and 2500 mm. Mean minimum daily temperature in the coldest month (January), 0 °C and mean maximum daily temperature in the warmest month (August), 28 °C. *Quercus pyrenaica* is the dominant tree species in the study area. It presents even-aged patches with different coppicing age, from oak shrubland to standards with trees over of 35 cm diameter. Different pasture types grow in grassland areas under trees (Fig. 2) (Tejera & Núñez 2007).

Since 1385 the municipality of "San Bartolomé de Pinares" has the privilege for extracting fuelwood and grazing in Dehesa Boyal. The high sprouting capability of *Quercus pyrenaica* favoured this traditional exploitation (Ruiz de la Torre 2006). In 1962 a management project of simple coppice was proposed. It included the sequential cuttings of 33 ha/year on a regular cycle of 20 years that should be preserved from livestock for three years to allow the traditional grazing activity in Dehesa Boyal (Aullo-Urech 1962). However, at the beginning of the 1980s coppice ceased to be regularly cut. Since then the main use is grazing. The current grazing regime is continuous and extensive, that is, the study area is stone-fenced around the whole perimeter and livestock movements are not restricted inside. Each year, 900 sheep and 60 horses graze in Dehesa Boyal area from November to March. They are subsequently removed in April. During this month the area is temporary restricted to livestock through the fencing gate. Later, 189 cows and 118 horses graze in the study area for six months (May–October). Finally, 1300 goats start to graze in July until 31st October.

The current forest vegetation is a neglected coppice of *Quercus pyrenaica*, with areas of high shoot density, almost no seed regeneration and stand decay. The activity of livestock rearing on native pasture and shoots has also led to a shrub encroachment of *Quercus pyrenaica*.

The current conservation status of *Quercus pyrenaica* in "Dehesa Boyal" can be considered far from the "mature coppice" (García & Jiménez 2009) adopted as favourable (Table 1). As the study area belongs to Natura 2000 Network, management plans must be established in order to avoid the decline in quality of this 9230 habitat (Cantarello & Newton 2008).

Data collection

Sampling technique

The previous delineation of stands in the study area was done using object based image analysis and field work (Hernando et al. 2010). Once we had obtained the stands map, a systematic sampling (Avery & Burkhart 2002) was then developed to characterise the stands, according to the methodology required in "General Rules for the forest management in Castilla y León" (León 1999). We sampled 158 circular plots (10 m diameter) in a square network of 200 m (p = 95%, CV = 80%, relative error = 13%). The main objective was to assess physical impacts of grazing animals on the physical structure and development of the habitat of each stand.

Table 1
Comparison of conservation status.

Favourable status "Mature coppice"	Current status "Dehesa Boyal"
Unmanaged coppice with 100–150 years' growth; well stocked with standards and some gaps (Peterken 1996)	Unmanaged coppice with only 40 years' growth
Late-successional stands (Frelich 2002) that involves acorn production and sexual regeneration	Early-successional stands that are unable to produce acorns

Table 2
Impact levels for erosion, browsing and broken trees.

Erosion	Browsing	Broken trees	Acorn presence	Impact
Level 1–2	10–25% area covered with coppice shoots <1 m tall	<2 broken trees with dbh 8–10 cm/10 m^2	Presence	Low
Level 3–4	25–75% area covered with coppice shoots <1 m tall	2–4 broken trees with dbh 8–10 cm/10 m^2	Absence	Medium
Level 5	>75% or <10% area covered with coppice shoots <1 m tall	>4 broken trees with dbh 8–10 cm/10 m^2	Absence	High

Table 3
Types of pasture resources and pasture production (kg DM year^{-1}).

Type of pasture	kg DM ha^{-1} year^{-1}	Area (ha)	Production (kg DM year^{-1})
Trifolio subterranei-Periballion	3000	294	882,000
Agrostion castellanae	3000	6	18,000
Agrostio castellanae-Stipion giganteae	3000	6	18,000
Agrostion salmanticae	1700	124	210,800
Quercus pyrenaica	300	301	90,300
		Total	1,219,100

We sampled density (stem number/ha), diameter at breast height (dbh, m), height (m) and basimetric area (m^2/ha), number of broken trees with dbh between 8 and 10 cm and presence/absence of acorn on soil or trees.

Vegetation map

We used the vegetation map developed by Velázquez, Förster, and Kleinschmit (2008) for Dehesa Boyal area, where five types of pasture resources were identified (Table 3).

Pasture productivity

We adopted the pasture productivity levels defined by San Miguel (2001) (Table 3) for Spanish Mediterranean pastures. This author describes palatability, production (quantity, quality, and seasonal distribution) and medium dry mass (DM) production for Spanish Mediterranean pastures. We describe the main characteristics of the mapped pastures to facilitate subsequent comparisons:

Trifolio subterranei-Periballion: Mediterranean pastures settled on *neutral* or slightly acid soil with high organic matter level. They are mainly composed of *Poa bulbosa* and *Trifolium subterraneum*. They present a high production level and two growing periods: autumn and spring.
Agrostion castellanae: acidophil Mediterranean pastures, tall and dense with late summer withering. They settle on annual edafic humid soils, near talwegs. They can be used as summer pasture of low bromatologic quality. They are especially suitable for horses.
Agrostio castellanae-Stipion giganteae: coarse acidophil Mediterranean pastures. They are suitable for autumn–winter livestock demands, when cattle cellulose requirements increase.
Agrostion salmanticae: temporary flooded pterophitic pasture. They represent medium production levels and low nutritive values. They can offer fresh herb in summer when other pastures are withered.
Quercus pyrenaica: this semideciduous species offers a real fodder reserve for livestock in summer. Their nutritive value is lower than green grass but higher than senescent grass. They are better suited to the requirements of cows and horses than to those of sheep.

Methodology

Controlling competition between trees and forage plants is the main objective to manage grazing in terms of grazing capacity, distribution and season of grazing (Ainalis, Platis, & Meliadis 2010; Carlson, Sharrow, Emmingham, & Lavender 1994; Doescher, Tesch, & Alejandrocastro 1987). We developed a three phase methodology to assess the pressure of livestock in terms of (i) demand and supply, (ii) seasonal balance of pasture and (iii) impacts to soil and trees (Fig. 3).

(i) Annual demand and supply balance
The medium daily livestock intake value (D) can be estimated as 2.5% of the animal live weight (LW) expressed in kg of dry mass (DM) (San Miguel 2001). The demand for the grazing period (D) can be calculated as follows:

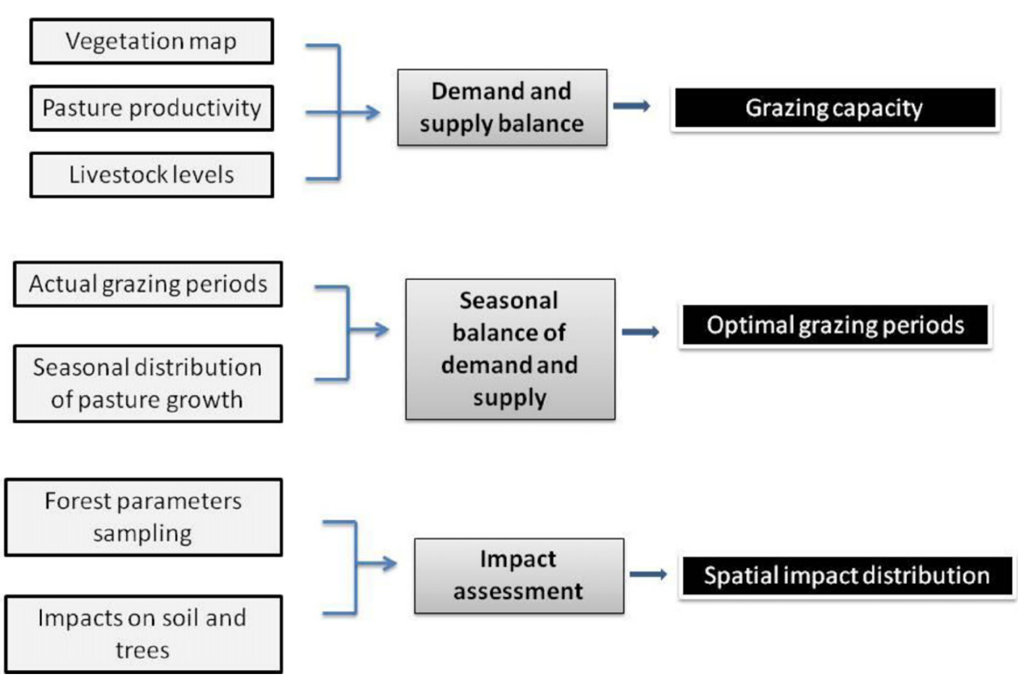

Fig. 3. General outline of the methodology.

Table 4
Annual livestock food requirements (kg DM).

Livestock (production)	Grazing period	LW_i	dli	p_i	n_i	D (kg DM)
Sheep (meat and milk)	Nov 1st–March 30th	40	1	151	900	135,900
Horse (recreation)	Nov 1st–March 30th	500	12,5	151	60	113,250
Horse (recreation)	May 1st–Oct 31st	500	12,5	184	118	271,400
Cattle (meat and milk)	May 1st–Oct 31st	500	12,5	184	189	434,700
Goat (meat and milk)	July 1st–Oct 31st	60	1,5	123	1300	239,850
					Total	1,195,100

$$D\,(\mathrm{kg\,DM}) = 0.025\sum_{i=1}^{n} \mathrm{LW}_i p_i n_i$$

where LW_i = live weight (kg) for each species in a grazing period (i) and p_i = number of days per grazing period and n_i = individuals of each species in a grazing period.

(ii) Seasonal demand and supply balance

We assessed seasonal demand and supply balance by comparing grazing periods in the study area and changes of nutritional quality of the pasture over time.

(iii) Impacts assessment and distribution on soil and trees

For each type of impact, impact level was assessed with the criteria of Table 2. Erosion was evaluated through erosion hazard (Velázquez, Tejera, Hernando, & Victoria Núñez 2010) as it takes into account slope, plant cover and lithology. Browsing was assessed as the recovery capacity (Velázquez et al. 2010) since it informs about the speed with which the habitat recovers its original situation after natural or anthropogenic disturbances. Broken trees were assessed as the number of trees between 8 and 10 cm dbh/10 m^2, broken by livestock, as these are critical diameters for *Quercus pyrenaica* to withstand cows' weight without breaking (Serrada et al. 2008). Additionally the presence of acorns on soil and trees was annotated as presence/absence, given that oak coppices of *Q. pyrenaica* usually lack acorn production due to competition for the light, water and nutrients in high shoots density areas (Serrada et al. 2008).

Impacts were mapped based on the division of the forest area into stands (Hernando et al. 2010) which identified five types of stands for 9230 habitat in "Dehesa Boyal": oak shrubland; low polewood; high polewood; high forest; and, coppice tall shrubs.

Results

(i) Demand and supply balance

Total livestock consumption requirements during grazing periods reached 1,195,100 kg DM (Table 4) and total pasture production, 1,219,100 kg DM (Table 3). Therefore we can see a possible compatibility between demand and supply.

This comparison offers a general view of the equilibrium between pasture production and livestock requirements. This result shows that there is enough forage available to sustain the current number of grazing animals. However, grazing efficiency is low in silvopastoralism because it depends greatly upon the Mediterranean climate. Summer drought and winter cold, impose severe restrictions on grass and shoots' growth and thus, on animal feeding behaviour (San Miguel 2004).

(ii) Seasonal balance of supply and demand

We compared livestock food requirements in the two main grazing periods and the quantity of pasture resources, taking into account the annual yield and the seasonal variation of yield (Table 5).

When sheep and horses graze in the study area, pasture production is low. Agrostio castellanae-Stipion-giganteae, Agrostion-salmanticae and Trifolio-subterranei-Periballion can offer only 30% of their annual production (Ortuño 2003). From November to April pasture resources and livestock requirements may be considered well-adjusted. The size of these winter pastures is very suitable for the type of livestock traditionally moved to "Dehesa Boyal": sheep and horses.

In April there is no grazing use of "Dehesa Boyal". Livestock are driven to other pastures near the town of "San Bartolomé de Pinares" with the help of some shepherds. This period allows for a good establishment of the herbaceous vegetation until cows and horses graze the area again. In May and June, and even in July, vegetation reaches the greatest growing period and offers good pasture to cattle and horses. When goats start to browse "Dehesa Boyal" pasture resources herbs are commonly withered so they hedge young shoots.

Therefore, there can be a low lack of pasture supply from May to November. 94% of livestock food requirements can be satisfied, but due to the great variations of Mediterranean climate, this can be considered a satisfactory result.

Both separate grazing periods and the exclusion of April from grazing seem to be a fitting seasonal distribution for the livestock in "Dehesa Boyal".

(iii) Impacts assessment and distribution

The spatial distribution of impacts was mapped (Fig. 4) with GIS by means of the database of impacts and the division of the area into stands (Hernando et al. 2010).

Erosion: Vegetation properly covers the surface of the soil so no significant land degradation is noticeable. The reduced slope of the area helps to avoid erosion processes, therefore, impact is low in the whole study area.

Browsing: The impact in oak shrubland stands is high. These areas show intensive browsing. They are used for livestock forage in summer when herbs are mostly withered. The oak shrubland is very palatable to livestock, so animals graze there eating the young shoots which make them shoot again (Barbour et al. 2007). This intensive regrowth of coppice shoots leads to stump decay, especially if it lasts for decades (Serrada et al. 2008). Therefore, the impact in this type of stand is also negative. This stump decay could had been avoided if these more recent clear-cut areas had been preserved from livestock. But, at least for the last 20 years,

Table 5
Pasture production and livestock food requirements in the two main grazing periods.

Period	Pasture production (kg DM)	Livestock requirements (kg DM)	Livestock
Nov 1st–Apr 30th	333,240	249,150	Sheep + horses
May 1st–Nov 30th	885,860	945,950	Cows + horses + goats

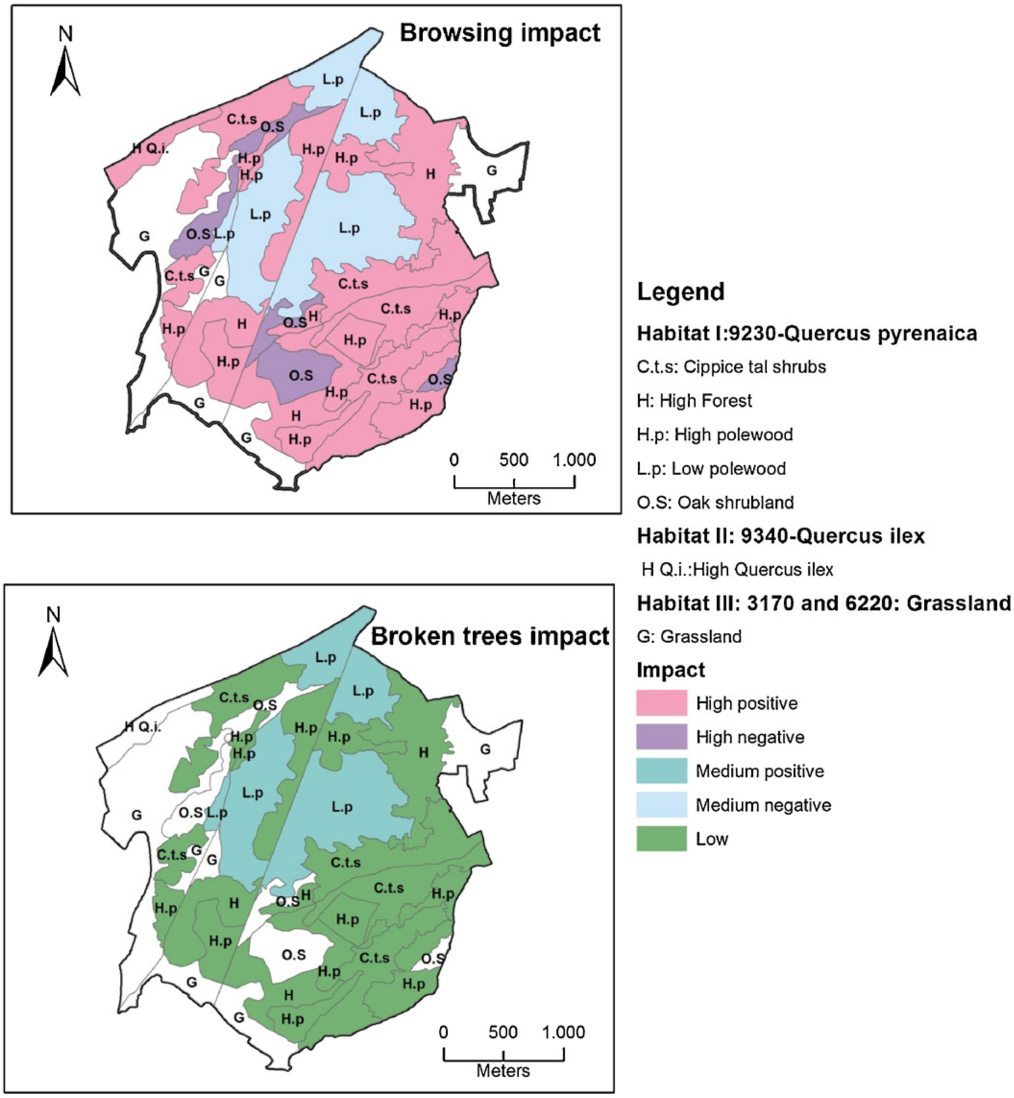

Fig. 4. Spatial distribution of impacts due to livestock.

grazing has been extensive, so now this impact may be considered irreversible. Coppices over 10 years' growth and below 2–3 m mean height are considered not capable of developing into an old growth coppice, due to the utilisation of too short cutting cycle or inadequate protection from browsing animals (Serrada et al. 2008).

The browsing impact in more developed stands, with trees above 10 cm dbh is assessed as being and positive since livestock are successfully controlling the regrowth of coppice shoots. This efficiency to control shoots was also observed by other authors (Maccherini, Marignani, Castagnini, & van den Brink 2007; Tárrega et al. 2009). As a consequence, competition for water and nutrients may decrease and tree growth increase (Serrada et al. 2008). Also an improvement on pasture quality beneath canopy may be expected (European Commission 2008).

Broken trees: The sampling showed trees below 10 cm dbh can be broken due to cattle weight. Medium density of broken trees by cattle is located in low-polewood stands (58 ha), so the impact level is medium. It is also positive since cattle are thinning with a low intensity level these stands and promoting the development of the best trees. Trees above 10 cm dbh are seldom broken by cattle. These trees are tall and wide enough to protect themselves against any possible damage from breaking. So the impact in high-polewood, coppice tall shrubs and high-forest stands is low.

Acorn presence: A small area (0.5 ha) located in high-forest stand hold some large trees (35 cm < dbh < 50 cm). This was the only place that showed acorn presence. For the rest of the area, sexual regeneration is disturbed due to the previous use of *Quercus pyrenaica* as a coppice forest and acorns are not yet produced. Oak coppices of *Q. pyrenaica* usually lack sexual regeneration and reproduction is assumed to occur asexually through root and stump suckers (Valbuena-Carabana et al. 2008; Serrada-Hierro et al. 1994). The ability of stems to regenerate coppice shoots following cutting often declines with age and some stumps may fail to produce any coppice shoots (Harmer 2003; Montoya 1989; Serrada 2005). So any solution needs to take into account acorn production to achieve sexual regeneration and promote the long-term viability of *Q. pyrenaica*.

Discussion

Results show that there is a possible compatibility between annually livestock food requirements and pasture production. Moreover, current grazing periods seem to fit the seasonal pasture productivity. However, impacts on the physical structure and development of the oak habitat were assessed. 7% of the area shows high impact due to livestock rearing on oak shrubland stands that were not properly protected after clear-cut. This impact has led to a severe stump decay and development into high forest is not expected. An area of 175 ha presents intermediate impact level because of tree breaking on low polewood. This impact has a positive effect since it contributes to low intensity thinning. For more developed stands types, livestock impact is high and positive to control the regrowth of coppice shoots.

In any case, livestock should continue in the area since it is an important part of this silvopastoral system and because of the repercussion on local economy (Hernando et al. 2010). Moreover, removal of silvopastoral use does not seem to be the most appropriate solution because moderate grazing pressure enhances species richness among herbaceous species and prevents fire hazards (Dufour-Dror 2007). Another benefit generally accepted is that low to moderate grazing intensities of large herbivores create spatially heterogeneous landscapes (Olff et al. 1999; van Oene, van Deursen, & Berendse 1999), which are driven by selective feeding behaviour and differential habitat use of the herbivores.

Nevertheless, the most important impact is the lack of acorns due to the previous coppice system management, that may prevent successful regeneration of *Q. pyrenaica*. Therefore another integrated management process needs to be introduced to make the situation more compatible with the biodiversity interests of Natura 2000.

Several studies throughout the Mediterranean area led to possible management alternatives for coppice forests such as debrushing and conversion into farming land (Montoya & Mesón 1979); other authors propose conversion into pasture land (Montoya 1983) or reforestation with conifers (San Miguel 1985). These alternatives seem incompatible with the favourable conservation of *Quercus pyrenaica* habitat.

The proposal of no intervention presumes natural evolution leads to high forest, but it may take centuries (García et al. 1997) with no control on fire hazard or on vegetation vigour, and makes this a high-risk solution in Mediterranean areas (Serrada et al. 2008).

Thinning aimed at conversion to high forest is commonly recommended (Ciancio & Nocentini 2004; Montoya 1982; San Miguel 1985; Serrada et al. 2008) as an appropriate treatment to: (1) promote tree growth of diameter, height and crown; (2) stimulate acorn production; (3) create the needed conditions for pasture improvement; (4) reduce fire hazard. These objectives are in line with the favourable status adopted in this study for the 9230 habitat (Table 1).

Coppices in the process of conversion into high forest show higher visual quality, more ecological stability and more value from a biodiversity point of view (Romagnoni, Bezzi, & Pignatti 1996). Greatest biodiversity would be obtained by preserving traditional grazing use and promoting sexual regeneration, as well as preserving some intermediate succession stages in some communities, like oak shrublands, or more mature stages of recovery represented by forest with a shrubby understory (Tárrega, Calvo, Marcos, & Taboada 2007).

Treatments of conversion into high forest based on high-intensity thinning are often used in France (Hubert 1983) and Italy (Cappelli 1991) for fast-growing species of valuable timber. Experiences in central Spain for *Quercus pyrenaica* coppices with low-intensity thinning (<35% of the pre-thinning basal area for the first 15 years) show good results for crown and diameter growth that facilitates acorn production (Canellas, Del Rio, Roig, & Montero 2004; Valbuena-Carabana et al. 2008).

Therefore, the solution that we propose is a process of conversion into high forest through a sequence of thinning to reduce stand density. These thinnings should be maintained at least until stand age and structure are suitable enough to permit sexual regeneration (Serrada et al. 1992). When acorn production starts, small areas must be preserved from livestock for some years (8–10 years) to achieve high forest (Serrada et al. 2008).

In our proposal, livestock have an valuable role to ensure biodiversity:

Oak shrubland: Our proposal consists in maintaining the current situation. Although it may increase stump decay, natural recovery is not expected. So, these stands are not included in the thinning proposal. These patches provide forage supply to livestock in dry seasons and refuge for rabbits, hares or partridges (Ceballos & Ruíz de la Torre 1979). For example Montoya (1982) suggests 5% of the coppice area is preserved from conversion due to the importance of hunting and shooting.

High forest, high polewood and coppice tall shrubs: Conversion by low-intensity thinning should be used in these stands in order to achieve natural regeneration. In the Mediterranean deciduous oak coppice forest, the conversions to high forest benefited from the moderate grazing which favoured the increase of wood stock (Ainalis et al. 2010) and controlled the resprouting vegetation (Papachristou, Platis, & Nastis 2005) favouring acorn production (Serrada et al. 2008).

Thinning can start in these stands during the first fifteen years, felling the dominated trees and those showing worse aspect. Besides, livestock will be led to these areas to control the shoots. The most appropriate moment to release cattle in these areas are June and July, when shoots present optimal nourishing quality (Serrada et al. 2008). Grazing intensity may then reach one sheep/ha/year in these areas (Serrada 2005).

During this process, to achieve sexual reproduction, it will be important for managers to find trees that produce acorns and preserve these areas from livestock with temporary fencing. Indeed, the small area with the largest trees identified in our study must be preserved.

Low polewood: These stands are allowed to grow without protection from livestock. The damaging effects of animals on small thin trees can be used as an easy no-cost way of thinning. Similar proposals for cattle in coppices were reported from Serrada et al. (1992) and Montoya (1983).

Conclusions

The habitat "9230 *Quercus robur* and *Quercus pyrenaica* forests" was protected within Natura 2000 network for biodiversity conservation. The network's main goal is ensuring the favourable conservation status of these habitats. Historically these habitats were widely managed as coppice forest with silvopastoral use. However, nowadays wood is no longer extracted and grazing is the main use. The two first proposed phases of the methodology (i) *demand and supply balance*, (ii) *seasonal balance of supply and demand* may help to identify the ability of *Quercus pyrenaica* to support a given livestock density. The third phase- (iii) *impacts assessment and distribution* assesses some of the physical impacts of grazing animals on the physical structure and development of the habitat.

Acorn absence is a result of the previous coppice management. This negative impact may endanger long-term viability of *Q. pyrenaica*. Besides, livestock browsing on oak shrubland was assessed as being high and negative. To achieve a favourable conservation status of neglected coppices forests, based on naturalness and successional states criteria, we propose a process of conversion by thinning into high forest. In this proposal, livestock have a valuable role to control the regrowth. Moderate grazing (in high forest, high polewood and coppice tall shrubs) helps the increase of wood stock, controls resprouting and favours acorn production. Additionally, grazing enhances species richness among herbaceous species.

In low polewood moderate grazing intensities of large herbivores promotes natural thinning and creates spatially heterogeneous landscapes. Moreover, oak shrubland patches provide forage supply to livestock in dry seasons and refuge for fauna. The proposed methodology enables appropriate conservation measures to be taken to maintain biodiversity.

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