

Temporal Changes in Socio-Ecological Systems and Their Impact on Ecosystem Services at Different Governance Scales: A Case Study of Heathlands

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ABSTRACT

Heathlands are considered biodiversity hotspots of high conservation interest. However, they are at risk of degradation and disappearance in most parts of Europe mainly due to land abandonment, degradation, and conversion to other land uses. Heathlands are semi-natural systems: their maintenance and survival depends on specific practices such as extensive grazing or burning. Traditionally they provide a wide range of goods and services to societies. In this study we used the ecosystem services (ES) framework to analyze the changes in the demand for and delivery of ES for the heathland landscapes of the Cantabrian Mountains (NW Spain), since the 1950s. Particularly, we analyzed how the social changes since the 1950s have determined changes in stakeholders' demand for provisioning, cultural and regulating services and how these changes have influenced the vegetation dynamics and conservation status of these systems. We identified a general shift from the provisioning

of grazing facilities and local products for the local-regional market to the provisioning of conservation services to satisfy national–international demand. For the present situation we found a clear mismatch between the conservation demand, management practices, and land-use forms. This mismatch threatens to lead to further landscape changes and loss of biodiversity. The results of our multi-scale and -services study can help to increase awareness of the value of currently obtainable benefits from heathlands among stakeholders and managers. The ES approach can improve understanding of the functioning of the socio-ecological heathland system, and inform the development of new management strategies for heathland protection.

Key words: conservation; ecosystem services; heathlands; governance scales; management; socio-economical systems; transhumance; temporal scales.

Received 7 April 2012; accepted 17 January 2013;
published online 5 March 2013

Author Contributions: AMO: conceived and designed the study, performed the research, the literature review and wrote the manuscript. RB: contributed new methods, literature review and wrote the paper. SSS, EL, and LC: conceived and designed the study and wrote the paper.

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INTRODUCTION

European heathland landscapes (open mosaics of grasslands and heathlands) are considered biodiversity hotspots due to their high richness in plants,

invertebrates, and birds (de Bello and others 2010). Differences in geology, soils, and climate have generated a wide diversity of heathlands across Europe, which can only be preserved by safeguarding a wide range of local varieties of heathland habitat-types (Leite 2004). This is reflected by the fact that nine different types of heathlands are taken up in Annex I of the Habitats Directive (92/43/EEC; Anon 1992).

Heathlands are semi-natural systems: their maintenance and survival depends on their exploitation through specific practices such as extensive grazing or burning (Ostermann 1998). If these practices cease, succession will proceed and the heathlands will eventually disappear. Heathlands' disappearance will cause losing unique combinations of plants and animals (Gimingham 1992) that are adapted to the variety of habitats created by these management practices (e.g., bare soil; Cameron and Leather 2012). For example, heathlands held great diversity of invertebrates (Webb 1989; Usher 1992; Cuesta and others 2006), and also rare species exclusively related to heathlands, such as the endangered heath tiger beetle (*Cicindela sylvatica*) (Cameron and Leather 2012).

The reason heathlands were maintained traditionally was that they in return provided important goods and services to local communities (Wessel and others 2004; Harrison and others 2010), generally within subsistence farming systems, where benefits from livestock grazing were complemented with other activities such as fishing or peat extraction (Kvamme and others 2004; Leite 2004). As the goods and services of the heathlands were an indispensable part of the local communities' livelihoods, they exploited them to the limits of the system but not beyond them, keeping and closely guarding the balance between degradation and vegetation succession.

Historically, heathlands underwent a large expansion process in Europe until the end of the eighteenth century, as a consequence of centuries of deforestation aimed at creating grazing areas for extensive livestock (Pinto-Correia and others 2005). Due to socio-economic changes, grazing requirements gradually lost their importance at the beginning of the nineteenth century and heathlands began to be considered as unproductive wastelands (de Blust 2007). This caused their abandonment and replacement by shrub or forest through secondary succession (Moen and others 2006), their degradation and cover by sifting sandy dunes (de Blust 2007), or their gradual conversion to other land covers (for example, arable fields and urban areas; Webb 2005). The greatest changes occurred within

the second part of the twentieth century (Webb 2005; de Bello and others 2010; Harrison and others 2010). As a consequence, in some European countries only 10% or less of the original heathland landscapes remain (de Blust 2007).

Despite this general trend, there are exceptions. In the Cantabrian Mountains (NW Spain), the decline of grazing activities in heathland landscapes, traditionally linked to sheep transhumance, is a relatively recent process which has become increasingly marked since the 1950s (Rodríguez 2004). This decline has caused a large increase in the area covered by later successional state heathlands and shrublands encroaching grasslands (Celaya and others 2010; Morán-Ordóñez and others 2011). The recovery of grazing practices in these mountain systems is unlikely due to their low profitability and competitiveness compared to lowland systems (McDonald and others 2000). Without them, or another way of maintenance to replace them, heathlands in this area will be replaced by grasslands or shrublands (Calvo and others 2007). It is difficult to infer whether this will imply an evolution to a new equilibrium or a return to pre-anthropogenic conditions, given the lack of appropriate long-term studies in this regard. A return to previous conditions appears unlikely given the long history of disturbance, and the possibility of interactions with other aspects of ongoing or future environmental change (e.g., nitrogen depositions; Calvo and others 2007). This presents a conservation challenge which is in its base a socio-economic one: to stop the decline, a new financial as well as practical balance for exploitation and maintenance has to be found.

The relatively novel field of research on ecosystem services (ES) can help in achieving this by providing a framework for linking conservation interest to local economy through the identification, description, and assessment of both current and potential benefits provided by heathlands. Its implementation can add value to strategies for species/habitat conservation in human-dominated regions (Luck and others 2009; Haslett and others 2010). ES are the conditions and processes through which ecosystems sustain and fulfil human life (Costanza and others 1997; Daily 1997). Although ecosystems support both biodiversity and human activities, the concept of ecosystem services is mainly anthropocentric, because it implies that the supply of a service depends on the human demand for it. Each service is provided by the "service providing" unit (Luck and others 2009), which can correspond to different levels of ecological organization: single species, populations, functional groups, ecosystems, or even landscapes.

Several studies have tried to identify, classify, and evaluate the services provided by the main ecosystems worldwide, across all levels of ecological organization and using different methodologies (see Wallace 2007 for a review of classification methods). However, there is still insufficient information on the dynamics of service provisioning at a local or regional scale (MEA 2003), which often represent the practical scales at which management strategies are designed and implemented. For instance, at a local scale there is limited knowledge of the consequences of land-use and vegetation cover change on ecosystem services and human well-being (Reyers and others 2009), although these consequences have been more widely explored at large scales (for example, Metzger and others 2006). A few studies on ecosystem services have focused on the analysis of multiple services, considering the trade-offs between the costs and benefits of conflicting services (Rodríguez and others 2006). Most studies on ES have ignored the interactions between social and ecological components of the system at different spatio-temporal scales (Nicholson and others 2009), despite the fact that temporal dynamics should be considered an important component of the ecosystem service approach, because ecosystem responses occur over large periods of time (Rounsevell and others 2010).

In this study we summarized existing knowledge regarding historical and current management, exploitation, and conservation values of the Cantabrian Mountains' heathlands and used it to identify and characterize the ecosystem services delivered by these semi-natural landscapes and describe their interactions with the social systems over time. In particular, we investigated how social changes in the second half of the twentieth century have driven both the landscape dynamics and the changes in stakeholders' perception of the provision of services by these landscapes and the justification for the management needed to obtain them. We provide insight in the changes in service delivery patterns, their causes and their impacts on heathlands conservation. We discuss how our results can be used to raise awareness of the value of currently obtainable benefits among stakeholders and managers and to develop new management strategies to help protect heathlands.

SOCIO-ECOLOGICAL CHANGES IN THE CANTABRIAN MOUNTAINS

Study Area

The study area is located at the southern slope of the Cantabrian Mountains in the León province

(NW Spain). The site is a biodiversity hotspot (Worboys and others 2010), on the boundary between the Mediterranean and Atlantic/Eurosiberian regions. Due to its high conservation value, several protected areas, including Natura 2000 sites, are located inside its borders. These include at least 30 habitats of community interest listed in Annex I of the Habitats Directive (92/43/EEC; Anon 1992), four of which are heathland types. The area also forms the south-western distribution limit of many Eurosiberian communities (for example, *Calluna vulgaris* dominated heathlands), and therefore is an important location for long-term conservation of genetic diversity and evolutionary potential (*sensu* Hampe and Petit 2005).

Transhumance has been one of the main factors shaping the landscape of this area over centuries. It consists of seasonal movements of sheep flocks across the Iberian Peninsula, to take advantage of the availability of complementary grazing resources (south-Iberian "dehesa" systems in winter and north-Iberian mountain pastures in summer mountain passes). In mountain passes, shepherds traditionally used burning to increase the availability and quality of pastures, where the landscape consisted of an open mosaic of heathlands and grasslands. This activity has maintained open heathlands at an early successional/building state over centuries due to their fire-prone character (Calvo and others 2002a, b, 2005). Actually, the occurrence of heath-dominated habitats in this area is directly associated with transhumant activities (Bunce and others 2004) and their current geographic distribution follows that of the mountain passes (see Figure 1 based on results of Morán-Ordóñez and others 2012). Therefore, we focus our analysis and discussion on mountain passes because these comprise most of the current conservation values linked to heathland landscapes in our area.

Changes in Socio-Ecological System and Landscape

Heathlands are maintained by human activities, and therefore we use the term socio-ecological system to refer to the interaction between heathland ecology and human society in this study. We analyzed changes in the study area by comparing two different time periods: the 1950s and the 2010s. The first period represents a pre-rural abandonment situation. The rural population in mountain areas was organized in nuclei located in the valleys with a small private stretch of land near the villages used as orchards. Larger areas on the

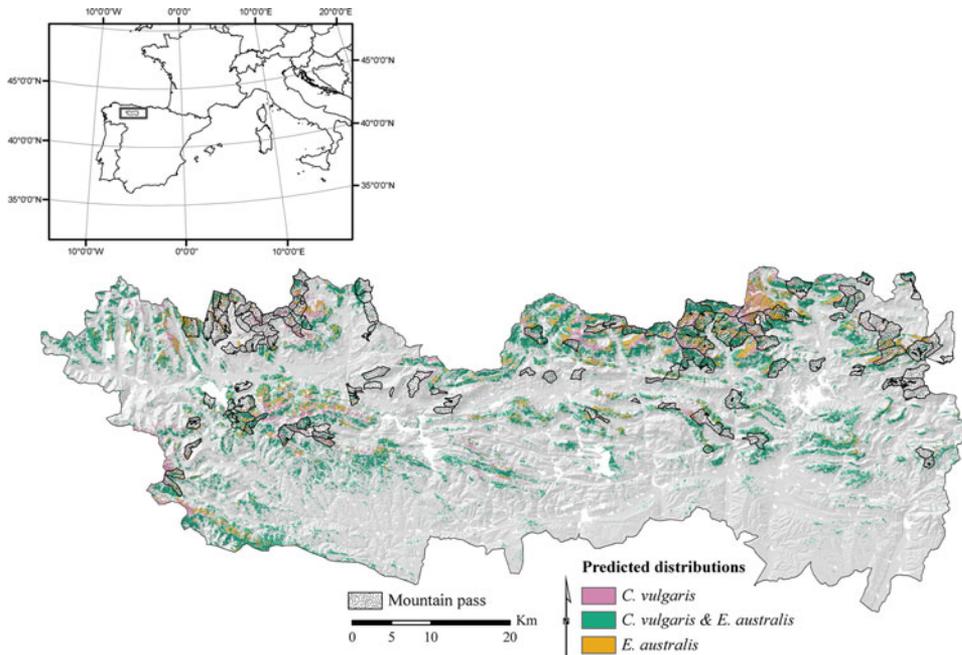


Figure 1. Location of the study area (NW Spain). Mountain passes traditionally used for sheep grazing are shown in *dotted* areas. Predicted distribution of heath formations dominated by *C. vulgaris* and *Erica australis* based on the results of Morán-Ordóñez and others (2012) are represented with colors: pink (*C. vulgaris*), yellow (*E. australis*), and green (areas where the distribution of both species overlaps).

nearest slopes were used for subsistence crops (for example, potatoes) and hay meadows for the winter subsistence of the villages' livestock (Mayor 2002). Historically, forests and pasturelands located near the villages were common property of villagers, with their use strictly regulated to avoid over-exploitation (Rodríguez 2004). The high mountain passes were also community property, rented annually to transhumance flocks owned by farmers from lower valleys or the south of Spain. Management of the mountain passes was thus the responsibility of the villages who owned them and directly benefited from the rental income (Rodríguez 2004).

The current landscape situation (2010s) results from the changes caused by: (i) the decline of the transhumance system, which from the 1960s was unable to compete with the upcoming industrial systems leading to emigration towards cities (Rodríguez 2004; Figure 2); (ii) changes in properties and management rights and in the protection status of the territory. All these factors led to rural abandonment and the ensuing loss of traditional management in the valleys and nearby slopes, which in turn caused the conversion of croplands and meadows to different types of grassland or shrublands (Gomez-Sal and others 1993; Rescia and others 2008; Morán-Ordóñez and others 2011). These areas were now considered unproductive (in the sense that they did not contribute to the local economy anymore) and a large proportion of them, including some heathlands, was ploughed and planted with coniferous trees in order to make

them profitable at the short to medium term (Gomez-Sal and others 1993; Calvo and others 2002a). Most common lands (for example, mountain passes) were declared lands of public utility interest and management was transferred from villages to national and regional administrations, which currently regulate their uses (Technosylva 2004). After the 1950s, the low profitability of transhumance compared to lowland intensive sheep-rearing reduced livestock pressure on the mountain passes. This boosted secondary succession processes favoring the spread of later successional state heath and shrub and resulting in a homogenization of the landscape (Rescia and others 2008; Morán-Ordóñez and others 2011). These land use and cover changes match the general trends of landscape evolution due to land abandonment that occurred in other mountain ranges in Europe during the same period (McDonald and others 2000; Lasanta and others 2009). Management of mountain passes in the area was transferred to the regional administration, but the villages and local councils have kept their ownership (Rodríguez 2004). Currently, 85% of the income obtained from mountain passes' leasing belongs to local councils and villages whereas the remaining 15% is retained by the regional administration. This 15% is invested in management actions such as building infrastructures (for example, improvement of accessibility to mountain passes by creating forest paths) and vegetation management (Technosylva 2004). Although land-use on the mountain passes is mainly oriented to extensive

livestock grazing, multiple land-use forms coexist in these areas; some mountain passes are for example included in hunting reserves and in ski resorts. Since the 1990s, most mountain passes fall under some category of land protection (for example, National Parks and Natura 200 sites), and therefore land-use and management of these sites is regulated by regional, national and international legislation (for example, Habitats Directive, Anon 1992).

IDENTIFICATION OF ECOSYSTEM SERVICES

We characterized the ES supplied by the heathland landscapes in the study area following the Framework for Ecosystem Service Provision (FESP) proposed by Rounsevell and others (2010). To obtain information about ecosystem services, we extensively sourced the existing scientific, technical, and popular literature regarding heathlands' conservation values and management, transhumance systems, and land-use change dynamics in the Cantabrian Mountains, Spain, and Europe. In particular, Gómez-Sal and Rodríguez (1992) and Rodríguez (2004) provided valuable sources of information to analyze the provision of ES of both current and past socio-ecological systems linked to heath–pasture landscapes within the study area.

Another important data source was a technical report on the use of mountain passes (Tecnosylva 2004). Historical data on livestock and game reserves were provided by the regional administration (Junta de Castilla y León).

We classified the services into provisioning, regulating and cultural services (Tables 1, 2) following the Millennium Ecosystem Assessment (MEA 2003). Supporting services are background ecosystem functions allowing for maintenance of other services. These were not considered in this study due to the high complexity of their assessment: their removal also helped minimize double counting of ES, because their value is reflected in the other three types of services (*sensu* Hein and others 2006). For example, increases in soil nitrogen (the nitrogen cycle being the supporting service) will determine increases in flowering and vegetation species richness on *C. vulgaris* heathlands (Calvo and others 2007) which are already valued as provisioning services through the production of honey and the maintenance of genetic diversity.

We identified the different ecosystem services in each class, defining the following aspects for each service: (1) ecosystem service providers (ESPs) or the ecological level of organization (landscape, species, etc.) contributing to the ES provision; (2) ecosystem service beneficiaries (ESBs) or those

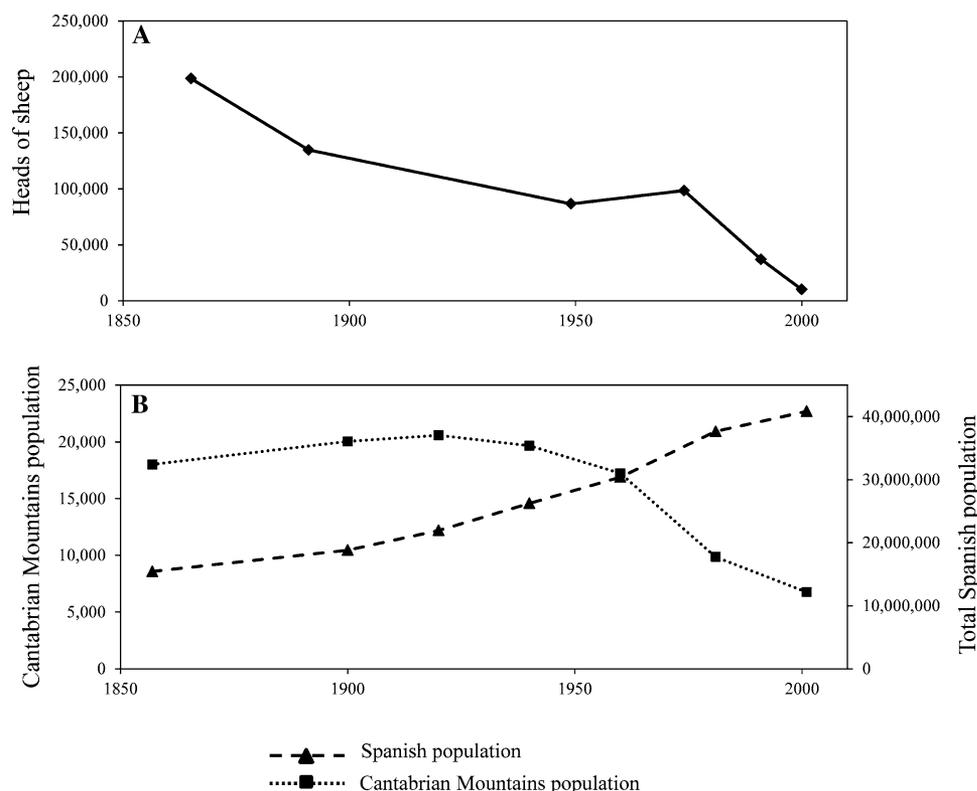


Figure 2. **A** Evolution of the transhumance in León province, since the second half of the nineteenth century (number of sheep using mountain passes). The *break* in the decline observed in the 1960s was caused by the relatively late decline of transhumance in the Cantabrian Mountains. Source of data: Rodríguez (2004). **B** Population changes in the municipalities of the Cantabrian Mountains of León owning mountain passes, compared with changes in the total Spanish population. Source INE population census (Spanish National Institute of Statistics).

sectors of society (stakeholders) who actually or potentially benefit from the ES; (3) benefits obtained from the service and their value (when possible); (4) service providing unit (SPU) or the minimum attributes that the ESP should fulfil to guarantee the delivery of a service at the desired level; (5) threats and impacts and (6) current or potential responses aimed at preserving the provision of the service. For example, for the service “provision of honey”, the ESPs (1) are the pollinator communities and the flowered Ericaceous shrubs and the ESBs (2) are the beekeepers and the honey consumers who benefit from this service through direct incomes and health benefits of honey consumption, respectively (3). The SPUs (4) are the amount of hectares of flowered Ericaceous shrubs and the number of pollinators per ha needed to produce 1,000 Kg of honey. Current main threats to the provision of the service (5) are the aging of Ericaceous communities (late successional stages produce lower amounts of flowers) and the disappearance of pollinator communities. Therefore responses (6) should focus on maintaining Ericaceous shrubs in a building state to ensure honey production. In this study, ESBs and benefits (2 and 3) were analyzed separately for each of the two socio-ecological systems described above.

Hein and others (2006) defined “the hierarchically organized institutional/administrative levels at which decisions on the utilization of capital, labor and natural resources are taken” as governance scales. We followed their approach to identify the governance scales demanding or valuing the ES supplied by heathland landscapes for both socio-ecological systems (1950 and 2010s). These were the local (municipality), regional, national, and international scales. We also constructed comparative diagrams showing how the ES previously identified within the FESP framework distribute across governance scales in each socio-ecological system.

CHANGES IN TYPES OF ECOSYSTEM SERVICES

Provisioning Services

In the Cantabrian Mountains, heathland landscapes provide and have historically provided a wide range of goods to societies (see Table 1). The subsistence system characterizing the 1950s made use of all local natural resources available: heath wood as fuel, fertilizer, livestock bedding, and thatching. The rental of mountain passes for pasture provided income and employment opportunities for local communities (Rodríguez 2004). Mountain passes

that were not rented were used for local livestock feeding. Fresh food products (honey, meat, cheese) were sold in local and regional markets. Other products such as wool reached high prices on the national market (Rodríguez 2004). Game represented an additional source of food for the local population, although this was a marginal service, limited to small species, mainly partridge, and hare. Large wild mammals were rare due to either persecution (for example, wolves that attacked extensively reared livestock) or competition with the extensive livestock and unavailability of adequate habitat (case of ungulates; Sáenz de Buruaga 1985). Medicinal plants linked to heath-pasture habitats (mainly *Gentiana lutea*) were collected by locals and sold in national markets.

Nowadays most provisioning services are either marginal or have disappeared completely because demand for them dwindled (Wessel and others 2004) (Table 1). Fuel and fertilizer are more easily obtained from outside suppliers. Locally produced food faces competition from cheap mass-produced food from elsewhere. Fresh products are still produced and mainly sold in regional markets but their prices have significantly decreased. In some cases, the sale of these products is mainly oriented to tourist-consumers. The wool market associated with transhumance flocks has almost disappeared in Spain (Rodríguez 2004) due to its low competitiveness with international markets and the increasing use of synthetic fabrics. Due to the decline of the transhumance system and the socio-economic changes mentioned previously, rental demand for mountain passes has decreased in the last 40 years, reducing income for municipalities and local populations. Consequently, most mountain passes are currently abandoned or grazed by cattle and horses, which use the heath-pasture mosaic differently than sheep, feeding only on herbaceous vegetation (Osoro and others 2003; Celaya and others 2007), leading to higher levels of shrub encroachment (Calvo and others 2002a). These are mainly endangered local breeds subsidized by the Common Agricultural Policy (CAP; Anon 2005). The decrease in livestock pressure also led to the increase of wild herbivorous populations (mainly roe deer *Capreolus capreolus*, red deer *Cervus elaphus* and chamois *Rupicapra rupicapra*; see Figure 3). Two game reserves have been created within the area since 1960 (covering approx. 110,000 ha). Thus, as in other parts of Spain, game has evolved from its marginal role as a provisioning service to an extensive recreational service (Wessel and others 2004). The harvesting of *Gentiana lutea* is now regulated by law (after being banned due to

Table 1. Provisioning Services Supplied by Heathland Landscapes in the Cantabrian Mountains

Service	ESPs	SPU	1950s ESBS	1950s Benefits	2010s ESBS	2010s Benefits	Threats and impacts	Response
(1) Direct goods: Honey	Heath (<i>C. vulgaris</i> and <i>Erica australis</i>) Flowering plants	Heath communities containing plants at pioneer states of development	Local population	Food supply	Small producers. Tourism	Price of the honey in local/regional markets	Low profitability and low demand of high quality organic products	Policies aimed to promote the market of high quality goods produced with environmental-friendly techniques
(2) Indirect goods: meat, wool, cheese, etc.	Livestock feeding within these landscapes	Herds of sheep, cattle and horses grazing these areas	Owners of sheep herds Buyers of the products (local and regional market mainly) Local population	Income related to the sale of these products in local, regional and national markets.	Owners of cattle and horses	Benefits related to sale of these products mainly in local and regional markets	Higher profitability of intensive livestock feeding vs. extensive systems Low market value of some of these products (e.g., wool)	Policies aimed to promote the market of high quality goods produced with environmental-friendly techniques
(3) Game (hunting and shooting)	Populations of game species <i>Alceatoris rufa</i> <i>Perdix perdix</i> subsp. <i>hispaniensis</i> <i>Lepus castroviejoi</i> <i>Lepus granatensis</i> <i>Stus serrofa</i> <i>Capreolus capreolus</i> <i>Cervus elaphus</i> <i>Rupicapra rupicapra</i>	Populations of hunting and shooting species at a desirable level	Local population	Food supply	(4) Hunters Local/regional population (restaurants, rural hostels, etc.)	Two game reserves declared in 1966 covering approx. 110,000 ha 2010 benefits reported by these game reserves: 335,370€ ¹	Overexploitation of certain species (e.g., <i>Perdix perdix hispaniensis</i> ; <i>Lepus castroviejoi</i>) whose populations are nowadays considered at a vulnerable conservation status	Control of the demand as a recreational service
(5) Grazing	Heath-pasture landscape at the highest parts of the mountains	Open heath-pasture landscape mosaic.	Local councils Local population Owners of herds who rented the summer pastures	Employment for local people The rental of mountain passes represented the main annual income for mountain municipalities. Grazing resources	Local councils Owners of herds who rented the summer pastures	Biodiversity shelter. Income for the rental of summer pastures. 2007: 247,500€ ¹ Grazing resources	Decline of the traditional sheep transhumance system, favouring scrub encroachment and homogenization of the landscape	Shrub cutting management. Control burning of small health patches
(6) Fuel (wood)	Heaths (<i>Erica</i> sp. and <i>C. vulgaris</i>) and Shrubs (<i>Cytisus</i> sp. and <i>Genista</i> sp.)	Heath and shrub cover	Local population	Availability of fuel for cooking and heating Branches were also used to thatch houses and for livestock bedding	-	-	The use of other sources of energy for heating and cooking (e.g., electric)	Promoting the use of heath and shrub biomass removed in shrub-cutting management activities for production of pellets and their sale in local markets

Table 1. continued

Service	ESPs	SPU	1950s ESBS	1950s Benefits	2010s ESBS	2010s Benefits	Threats and impacts	Response
(7) Fertilizers	Heathlands & Livestock	Heath branches used for livestock bedding mixed with manure	Local population	Low cost fertilizers (when mixed with manure), for application in crops and orchards	–	–	Rural depopulation and abandonment of the subsistence crops Cheap price and easy access to chemical fertilizers	Regulatory legislation in relation to the exploitation and management of this natural resource
(8) Medicines	<i>Gentiana lutea</i>	Presence <i>Gentiana lutea</i> populations associated to heathlands	Local population National companies	Local income for harvesters who sell the product to local companies	Pharmaceutical and cosmetic industry Local councils who receive money for the exploitation of the resource	Related to the selling of cosmetic products in the national and international market	Over-exploitation Poaching	Regulatory legislation in relation to the exploitation and management of this natural resource
(9) Protecting genetic variability of heathland species	<i>C. vulgaris</i> heathlands	Maintenance of healthy communities of <i>C. vulgaris</i> heathlands	–	–	European Union (Natura 2000 network) Natural heritage National programs of biodiversity conservation	Conservation of natural heritage and biodiversity values	Senescence and loss of these communities due to the loss of traditional management Reforestation with coniferous species Land use change Shrub encroachment and landscape homogenization	Declaration of sites of community importance including heath and pasture habitats Specific habitat-oriented management
(10) Provisioning of habitat	Heath–pasture landscape mosaic	Maintenance of healthy communities of <i>C. vulgaris</i> heathlands	–	–	Heath specialist species Species-dependent of the heath pasture landscape mosaic (some of them present in the Annex I of the Birds Directive; Anon. 2009: <i>Luscinia svecica</i> <i>Perdix perdix hispanensis</i>)	Conservation of natural heritage and biodiversity values	Senescence and loss of these communities due to the loss of traditional management Reforestation with coniferous species Land use change Shrub encroachment and landscape homogenization	Declaration of sites of community importance including heath and pasture habitats Specific habitat-oriented management

For each service we detail: ecosystem service providers (ESPs); the service providing unit (SPU); ecosystem services beneficiaries (ESBs), and the benefits obtained from the service in 1950s and 2010s; and their main threats and impacts; current or potential responses aimed to preserve the service provision.

¹Source: Junta de Castilla y León (Regional Administration).

overexploitation) and mostly managed by national companies, paying fees to villages. There are, however, two provisioning services under increasing demand by current society which were not part of the socio-ecological system of the 1950s: maintenance of genetic variability and provision of habitat (numbers 9 and 10 in Table 1). They are both related to the high conservation values of these agro-sylvopastoral systems due to the endangered fauna and flora that they shelter (Gómez-Sal and Llorente 2004).

Cultural Services

Heritage related to the shepherds' culture (traditions, songs, tales, handicrafts, and constructions) and their traditional management of the heath-pasture mosaic is one of the most important cultural services of these landscapes (see service 11 in Table 2). This culture has been orally transmitted for centuries, with only few written sources documenting it (Gómez-Sal and Rodríguez 1992; Rodríguez 2004). In the 1950s these cultural values were part of the local lifestyle, whereas nowadays they are disappearing. Conversely, other cultural services valued nowadays were ignored in the 1950s, particularly those related to aesthetic and conservation values (services 12 and 13 in Table 2). The number of tourists visiting natural spaces in the León province has increased significantly in the last decade (Figure 4), leading to an increase in the number of related business activities (Lago and Sevilla 2008). This follows the general trends of other Western countries where nature tourism has become a major cultural service (Hein and others 2006).

Regulating Services

The location of heath-pasture landscapes in mountain systems make them particularly important for the provision of high-quality drinking water to valley populations, and for controlling erosion by maintaining slope stability through vegetative cover (MEA 2005; see services 14 and 15 in Table 2). The importance of these services to any society remains regardless of temporal changes. In addition, the carbon-sequestration capacity of heath-pastures, ignored in the 1950s, is increasingly valued today for its potential contribution to climate change mitigation (UKNEA 2011) (see service 16 in Table 2). Currently, information about the role of shrub and heath vegetation on carbon storage is scarce and uncertain (RUBICODE 2009): the amount of sequestered carbon will vary as a function of the proportion of grass and woody vegetation (Jackson and others 2002), and this depends on the manage-

ment of the landscape mosaic. Wessel and others (2004) and Alonso and others (2012) also showed that for similar heath-grassland equilibrium mosaics, the amount of sequestered carbon would also vary depending on temperature and rainfall conditions.

CONSEQUENCES OF SHIFTS IN SERVICE DEMAND

Analysis of ES demand by stakeholders at different scales allowed us to identify potential conflicts in environmental conservation and management, in particular between local and regional/national stakeholders (*sensu* Hein and others 2006). Figure 5 shows, for the socio-ecological systems of the 1950s and 2010s, how the demand for the ES provided by the heath-pasture landscape mosaic of the Cantabrian Mountains is distributed over governance scales (from local to international). The ES demand shifted towards a different combination of services during the studied period (as discussed in the previous section) but it also partly shifted to different governance levels. In that respect, the main difference between the 1950s and the 2010s is the introduction of a demand at international level for services (mainly cultural and regulation services), a higher demand for conservation services at regional, national, and international scales and a lower demand for provisioning services at a local scale.

Historically, and until the 1950s, the socio-ecological system of the Cantabrian Mountains relied mainly on interdependent local services (Figure 5a), the use of which was strictly controlled by local rules. Every stakeholder, at all governance levels, was interested in the maintenance of the stability of the system, particularly local villagers, who managed these landscapes for maximum sustainable service. Traditional grazing and burning management ensured the yearly maintenance of the open heath-pasture landscape patterns on which most of provisioning services depended. Benefits from products sold at regional and local markets (for example, meat) contributed to local incomes. Benefits from the rental of mountain passes had a direct effect on the social welfare state of mountain villages, funding social services such as school and health systems (Rodríguez 2004). The shepherds' culture had a strong influence on the system at a local level, because it represented the lifestyle of the population of mountain villages associated with the heath-pasture landscape mosaic (in some cases entire villages and social groups moved seasonally between regions following the grazing resources; García 2009). The regional and

Table 2. Cultural and Regulating Services Supplied by Heathland Landscape

Service	ESPs	SPU	1950s ESBs	1950s Benefits	2010s ESBs	2010s Benefits	Threats and impacts	Response
<i>Cultural services</i>								
(11) Cultural heritage	Landscape heathland mosaic, which is the result of the management that shepherds have made of these areas for centuries	Open heath-pasture landscape mosaic and all the species associated to it	Local population	Style of life, traditions, handicrafts, sense of place, shepherds' culture	Local population Tourists	Sense of place Ancestral culture Conservation values due to the high biodiversity of these cultural landscapes which are encouraged to protection by EU/National designation	Loss of traditional management (sheep grazing and control burning) Reforestation Land use change (quarries, ski resorts, etc.)	Policies aimed to protect these landscapes within the framework of the Natura 2000, and to promote the maintenance of traditional management activities
(12) Ecological values	Heathland landscape mosaic	Open heath-pasture landscape mosaic and all the species associated to it	–	–	Local population Tourists	Conservation values due to the high biodiversity of these cultural landscapes which are encouraged to protection by EU/National designation	Loss of traditional management (sheep grazing and control burning) Reforestation Land use change (quarries, ski resorts, etc.)	Policies aimed to protect these landscapes within the framework of the Natura 2000, and to promote the maintenance of traditional management activities
(13) Recreation and ecotourism	Heathland landscape mosaic	Open heath-pasture landscape mosaic and all the species associated to it	–	–	Tourists Owners of rural business (restaurants, hotels, etc.)	Development of new business in the area. Recreational values for people enjoying these landscapes	Loss of traditional management (sheep grazing and control burning) Reforestation Land use change (quarries, ski resorts, etc.)	Regional strategies to promote tourism within these areas
<i>Regulation services</i>								
(14) Prevention in soil erosion	Heathlands	Vegetation cover	Population, both at local and regional scales	Prevention of problems of erosion because heathlands develop in high slope hills; otherwise the terrain slides	Population, both at local and regional scales	Same 1950s, although current population is more concerned about the problem of soil erosion	The high shrub and heath biomass accumulated as a consequence of the loss of traditional management which can favour wild fires	Management practices oriented to reduce biomass continuity (e.g., shrub-cutting, control fires on small patches of heath)

Table 2. continued

Service	ESPs	SPU	1950s ESBs	1950s Benefits	2010s ESBs	2010s Benefits	Threats and impacts	Response
(15) Water purification	Heathlands	Vegetation cover	Population, both at local and regional scales	Availability of high quality fresh water to human supply	Population, both at local and regional scales	Availability of high quality fresh water to human supply	The high shrub and heath biomass accumulated as a consequence of the loss of traditional management which can favour wild fires	Management practices oriented to reduce biomass continuity (e.g., shrub-cutting, control fires on small patches of heath)
(16) Carbon sequestration	Heathlands	Vegetation cover	–	–	Earth population	Reduction of the greenhouse effect	The high shrub and heath biomass accumulated as a consequence of the loss of traditional management which can favour wild fires	Management practices oriented to reduce biomass continuity (e.g., shrub-cutting, control fires on small patches of heath)

For each service we detail: ecosystem service providers (ESPs); the service providing unit (SPU); ecosystem services beneficiaries (ESBs), and the benefits obtained from the service in 1950s and 2010s; and their main threats and impacts; current or potential responses aimed to preserve the service provision.

national importance of provisioning services was related to the fact that transhumance linked León province with other regions of southern Spain, so that both regions benefitted from the system (use of complementary resources yielding meat and wool production). Consequently, it was an important national activity balancing cost-benefits over all scales (for example, wool market).

By the 2010s, the balanced local system of the 1950s had developed into a multi-scale system (Figure 5b), in which the demand of provisioning services at a local scale had decreased and the demand of cultural services had increased. This fits into a general pattern described for changes in ES over the same period in Europe (MEA 2005; Harrison and others 2010). In the current system numerous mismatches between demands, costs, and benefits of ES can be identified at multiple governance scales, potentially leading to conflicting situations. Particularly, we identified mismatches and conflicts between the demand for cultural services (conservation and leisure: services 12 and

13 in Table 2), management actions and different land uses.

Spain's entrance into the European Union (1986) and the declaration of protected areas in the Cantabrian Mountains at the beginning of the 1990s imposed, from the national and international scales, new rules regarding land management, and environment conservation. Biodiversity conservation became an ES demanded by stakeholders at the national and international scale (Hein and others 2006). To insure continued service provision of conservation-related ES from heathland landscapes, their heterogeneous character should be preserved as far as possible in the face of changing environmental conditions (*sensu* Haslett and others 2010). However, and due to the collapse of the demand for grazing grounds and increasing alternative possibilities in the industry sector, the demand for provisioning services decreased. This led to a decrease in the amount of heathland management and consequently to widespread landscape homogenization. This might involve a

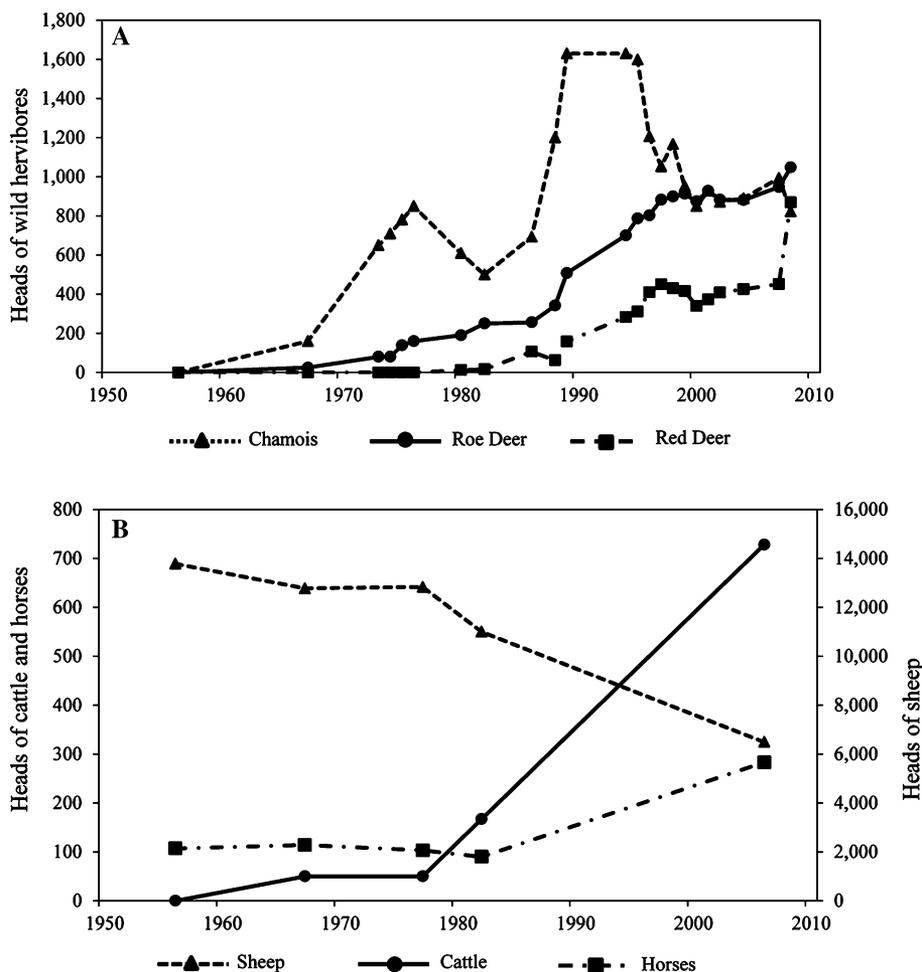


Figure 3. Evolution of populations of wild herbivores in the game reserve of Mampodre (Cantabrian Mountains) since the second half of the twentieth century (A), compared to the evolution of livestock demand on the mountain passes within the same area (B). Source Junta de Castilla y León.

reduction in biodiversity at the short-medium term (Garzón-Heydt 2004; Bartolomé and others 2005), threatening the conservation values of these areas. On the other hand, present conservation activities scarcely contribute to the welfare of people living in a protected area (Rescia and others 2008), apart from the benefits for those involved in the tourism sector and for farmers (subsidies related to endangered local breeds). There is scarce incentive for local populations to maintain an adequate level of management of these landscapes, because they tend to perceive their needs as under-represented in the regional or national administration plans, particularly as opposed to environmental issues (West and others 2006; Rescia and others 2008). Because the present use of the landscape does not sustainably provide the required ES benefits, there clearly is a mismatch between the demand of conservation values (mainly from national and international scales) and the costs (that is, the required landscape management efforts) involved in providing them at the local scale.

In our research area, we also found conflicts between the demand for leisure activities and biodiversity conservation targets (Figure 5b; cultural services 12 and 13 in Table 2). Leisure-related services, although mostly benefitting from attractive and natural landscapes, do not especially

benefit from conservation of heathlands or heathland-dependent species and are often partly in conflict with it. For example recreational hunting in game reserves in this area (service 4 in Table 1), demanded at regional, national, and international scales, is in conflict with conservation of the grey partridge *Perdix perdix* subsp. *hispaniensis* and the broom hare *Lepus castroviejoi*. These are endemic species of the Iberian Peninsula, with the main populations in the Cantabrian Mountains and the Pyrenees for the grey partridge and in the Cantabrian Mountains for the broom hare (Blanco and González 1992). The endemic grey partridge is included in the Annex I of the Birds Directive since 1979 (endangered species) (Anon 2009) implying it should be the subject of special conservation measures concerning their habitat. However, it was hunted in the game reserves of the Cantabrian Mountains until 2001. The broom hare is still hunted nowadays in some parts of the study area, although it is listed as vulnerable by the IUCN (2011).

PRESENT STATE AND OUTLOOK FOR THE STUDY AREA

Current Threats and Management

In the Cantabrian Mountains, the lack of grazing and burning management is the main threat to all services related to heathlands' ecological and aesthetic values (services 9–13 in Tables 1 and 2), cultural landscape heritage, and also some provisioning services. For example, the maintenance of protected *C. vulgaris* heath communities (Anon 1992), at an early successional state depends exclusively on fire-stimulated germination (Calvo and others 2002a, b, 2005). Burning management by local villagers (habitually still aimed at the creation of—now obsolete—pastures) was banned when these areas were protected and current management is handled by the regional administration through mechanic heath/shrub clearing. The lack of fires has led these communities to enter into a mature to degenerate state in the mountain passes (*sensu* Watt 1955), which in the short-term will result in their large scale replacement by more competitive grasses or shrubs (Calvo and others 2002b). This will lead to the loss of these heath habitats and the biodiversity they support (services 3, 8, 9, 10, and 12 in Tables 1, 2). Some other provisioning services will also be affected (e.g., heath honey production).

Abandonment of traditional management has led to the accumulation of woody above-ground bio-

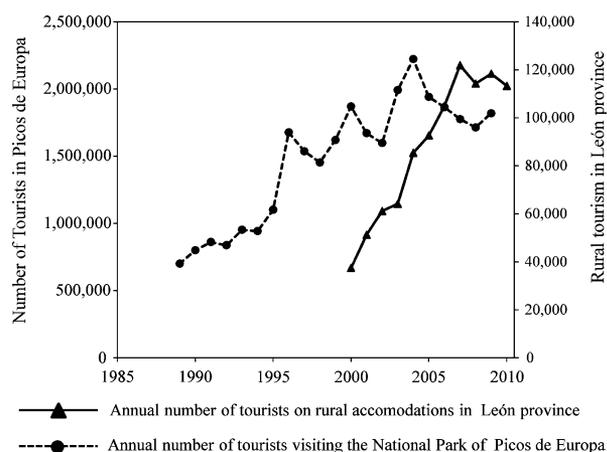


Figure 4. Annual number of visitors in the Picos de Europa National Park, placed in the Cantabrian Mountains. The southern slope of this Park (approx. 40% of its total area) belongs to the León province. Alpine mosaics of heath and pastures are one of the most important habitats present in this park and one of its most distinctive traits. The *graph* also shows the evolution in the number of tourists using rural accommodations in León province. *Source* INE (Spanish National Institute of Statistics).

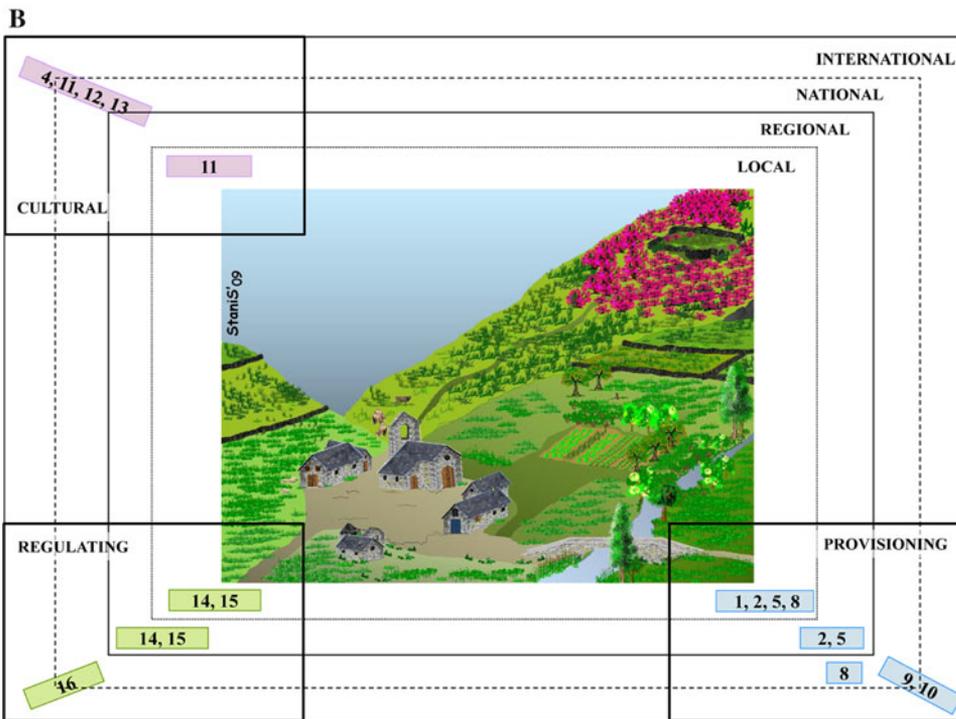
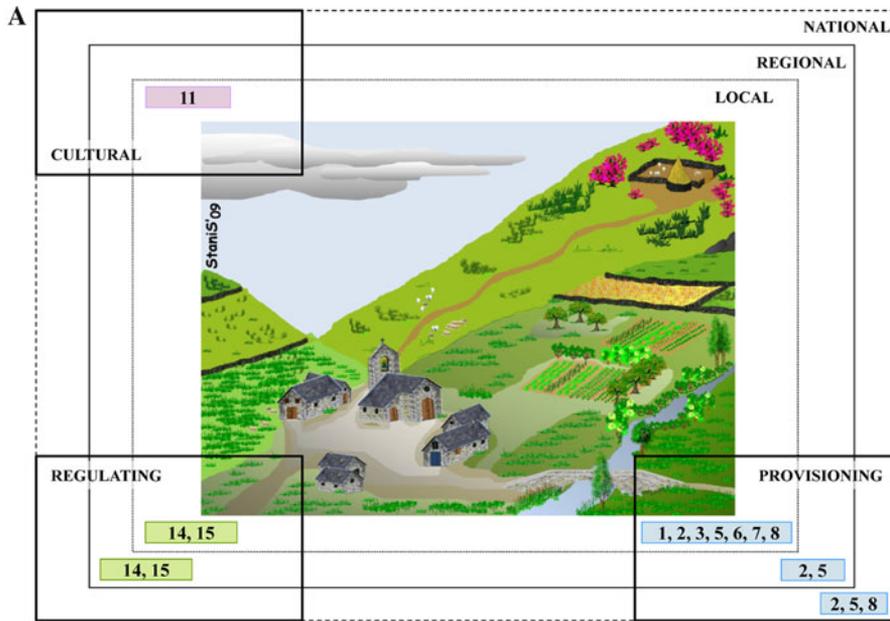


Figure 5. Demand for ES across different governance scales. Pictures represent the fifties (A) and the current (B) socio-ecological systems and the heath–pasture landscapes. Governance scales are represented in nested boxes placed around the pictures organized from local (inner box) to international scales (outer box). Provisioning, regulating, and cultural services are represented respectively in the right-bottom, left-bottom, and right-top corners of each diagram. Numbers of the services correspond to those indicated for each service in Tables 1 and 2.

mass. This in turn may increase the risk of wild fires (Celaya and others 2010), which affect biodiversity directly and reduce or damage the supply of regulation services through carbon release, increased erosion, and reduced water quality (services 14–16 in Table 2). Currently, the regional administration carries out silvicultural management aimed at facilitating the regeneration of pastures to support extensive grazing, while reducing the connectedness of the fuel and hence, decreasing both the risk

and extent of fire. These actions, mainly consisting of the heath/shrub-cutting already mentioned above, may negatively affect heathland conservation. In this area, the cutting of *C. vulgaris* stands has resulted in a shift in the community species composition (Calvo and others 2002b, c): cutting practices favor resprouters (such as *Erica australis*) over seeders (*C. vulgaris*) (Calvo and others 2002b, 2005). This may cause the loss of the less competitive heath species such as *C. vulgaris*. Controlled

fires on patches of *C. vulgaris* would help provide grazing resources in the short-term, while preserving *C. vulgaris*-dominated habitats at a building state. Between 2000 and 2005, more than 10,000 ha of shrub and heath were cut in the study area (Morán-Ordóñez and others 2011). However, biomass removed is left on site, thus increasing nutrient loads. Looking back to the socio-ecological system of the 1950s, it might be possible to recover the service related to provision of wood for fuel, currently limited to the production of pellets for local markets, as trialed in other countries such as Denmark (Gregersen, pers. comm.).

Future Perspectives

Given the influence the transhumance system had on heathlands (mainly enhancing provisioning services: 1, 2, 5–8 in Table 1), the feasibility of (partly) rebuilding it from the current condition should be investigated. To compensate for the current low profitability of the system, additional support to the remaining transhumant shepherds would be necessary. Some proposed measures are the direct payment for their ecological contribution to the conservation of ES provision and the promotion of a market of high quality goods produced with environmentally-friendly techniques (Rescia and others 2008). However, it would be difficult to re-value some of the services, such as the provisioning of fertilizers, due to the current high availability of “low-cost” chemical fertilizers (Wessel and others 2004). A useful initiative for possible rebuilding is the creation of schools for shepherds, aimed at reevaluating the profession and ensuring the generational renewal (<http://escueladepastores.es>). Moreover, such actions might help prevent the disappearance of one of Europe’s ancient and most interesting cultures (Bunce and others 2004).

The increase of landscape maintenance to preserve these landscape mosaics implies the return to a balanced, cost-effective socio-ecological system. This would require at least a partial re-involvement of the local population (scarce when compared to the 1950s) in exploitation activities. In the 1950s, heathland landscape mosaics were in fact protected against under-exploitation by the fact that it was the local community’s only source of income. They therefore maintained them for maximum delivery. Presently, most of the gains from mountain pass renting still goes to the villages, but the benefits are low compared to the 1950s (247,500€ for the entire region in 2007) and therefore they no longer represent an incentive for local management. Moreover, the lack of a local future still leads to

further depopulation and an increasingly aging local population. To preserve a local market for goods provided by heathlands and make investing in the landscape attractive for locals, the area would need to provide at least a small group of younger people with an income again.

One possible contribution to this would imply the promotion of public policies aimed at rewarding local people for carrying out actions that increase/maintain the levels of a desired ecosystem, through direct payments for ecosystem services (that is, subsidies) or incentive mechanisms (for example, tax deductions) (Jack and others 2008). Similar measures have already been implemented in some countries with varying results in ecosystem and species conservation (for example, payment for biodiversity conservation and carbon sequestration; Jack and others 2008 and references therein); however, this point remains controversial, among other reasons, because of the perceived risk that economic arguments about services might override and outweigh non-economic justifications for conservation (Redford and Adams 2009). The anthropocentric character of the ecosystem service concept could bias conservation targets towards those elements of the ecosystem with direct or indirect economic value, whereas nature conservation implies, among other factors, ethic, and cultural values which are difficult to translate into currency terms. These public policies should not be imposed on local managers from regional, national, or international institutions but should arise from consensus among all governance levels, taking into account demands from all stakeholders to avoid mismatches and conflicts in ES demand. This also implies that conservation should not be blind to other interests and certainly not in the case of heathland conservation where these influence the feasibility of adequate management. Conservation activities might not provide substantial direct income for the local population, but will contribute to an attractive landscape that can generate money from tourism (guiding, renting, providing accommodation, and selling goods). This in turn could for instance be an incentive to reinstate sheep grazing activities because the market for its products (for example, cheese, traditional clothing items made from local wool) increases and because it adds touristic value. As there are certainly trade-offs between conservation and activities like skiing, hunting and the development of tourism in general, that are necessary to give the area an economic future, a proper analysis of the costs and benefits of all services will be necessary to find the right balance.

DISCUSSION

Heathlands are cultural landscapes and hotspots of biodiversity. Despite their ecological and social relevance, these landscapes are currently at risk of degradation and loss mainly due to the disappearance of the traditional management activities on which their survival depends. The Cantabrian Mountains heathland landscapes have historically provided a wide range of ecosystem services to societies, but that ES demand has changed over the last sixty years. We have observed that stakeholder demand has changed across governance scales which resulted in a situation where there is a clear mismatch between service demand and delivery. To fulfil the new demand for conservation services landscape homogenization has to stop, but the present socio-ecological system is not able to deliver this. The question conservation faces is how to solve this problem.

The Framework on Ecosystem Service Provision used in this study, and the analysis of ES demand at different governance and temporal scales, are useful tools to identify and describe the ES provided by these landscapes and the main threats and stakeholder conflicts regarding ES demand. This information enables the incorporation of ecological knowledge about multiple ecosystem services of heathlands into decision making. Quantification and economic valuation of ES would be more useful for policy makers and land managers than qualitative analyses (Johst and others 2006). However, the knowledge gap on the importance of different services across heathland landscapes in the Cantabrian Mountains needs to be filled before a good quantification is possible (Harrison and others 2010): our study represents the first attempt to fill this gap.

As of date, most ecosystem service assessments have focused on single services, ignoring interactions between social and ecological components of the system at different spatio-temporal scales (Nicholson and others 2009). However, a multi-service and -scale approach aimed at identification and understanding of these interactions over the time, as we undertook in this study, is a key step toward developing models for an integrated quantification of ecosystem services that can illustrate the impacts of management decisions and global change on biodiversity, and hence on the provision of ecosystem services, by accounting for the feedbacks that link environmental drivers, biodiversity, ecosystem services, and socio-economic dynamics (for example, Daily and others 2009). These can be essential tools in the hands of managers and policy-makers,

allowing an evaluation of the outcomes of different management decisions for the maintenance of desired levels of ecosystem services' provision. For instance in the Cantabrian Mountains a lack of formal knowledge of the whole range of potential services that heathlands could provide has led to management decisions that worsen their conservation status (for example, cutting management of *C. vulgaris* heathlands). Providing managers with a tool that gives them a better view of services and of the effects of different management options, including trade-offs and uncertainty, would facilitate their decision-making and improve conservation of these valuable landscapes.

ACKNOWLEDGMENTS

The study was supported by the Junta de Castilla y León (project No. LE021A08) and the Ministry of Science and Education (project No. CGL2006-10998-C02-01/BOS). The Ministry of Education of Spain provided the PhD Scholarship for A. Morán-Ordóñez. The authors would like to thank the Fire Ecology Research Group of the University of León and the Landscape Centre of the Environmental Sciences Group (ESG) of Wageningen University and Research (WUR) for their support. We are also grateful to I. Alonso, S. Canessa, J. García-Fernández, P. Grogger and R.H.G. Jongman for their help and comments. We would also like to thank K. Andersson and the three anonymous reviewers who provided constructive and valuable comments on a previous version of this manuscript.

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