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Impact of land cover change on ecosystem service supply in mountain systems: a case study in the Cantabrian Mountains (NW of Spain)

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Abstract

Land abandonment and the loss of traditional farming practices are thought to control land cover dynamics, and hence the ecosystem service supply in traditionally managed mountain landscapes. We evaluate the impact of land cover changes in Cantabrian Mountains (NW Spain), over 1990–2012, on the potential supply capacity of ecosystem services (regulating, provisioning, and cultural) at both regional and local scales. We also analyze trends in the use of ecosystem services at the local scale. Land cover changes were estimated from CORINE Land Cover database. Patterns of potential ecosystem service supply were assessed by applying an ecosystem service supply capacity matrix and trends in their actual use by using field data. Main trajectories of land cover change encompassed woody vegetation spread in semi-natural open systems and agricultural expansion in the most suitable areas. The capacity of landscape to provide ecosystem services improved during 1990–2012 at both scales. We detected trade-offs between the potential supply of ecosystem services associated to natural systems and those linked to traditional land uses, at both regional and local scales. Changes in the potential supply of ecosystem services matched trends in ecosystem service use. This study could help develop future scenarios to address upcoming challenges in ecosystem service supply.

Keywords CORINE land cover · Provision of services · Capacity matrix · Cultural services · Regulation services · Semi-natural landscapes

Introduction

Mountain systems are key centers of ecological and cultural diversity. They cover 24% of the Earth's land surface and hold 12% of the world's population, providing half of humanity with vital goods and services. They also support 25% of terrestrial biodiversity, with almost half of the world's biodiversity hot spots (Körner et al. 2005). However, mountains are

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highly vulnerable to socioeconomic (Balthazar et al. 2015) and environmental changes (Zlatanov et al. 2017). In European mountains, the landscape has been shaped since historical times through human interventions associated with low intensive agro-silvopastoral activities (Lasanta et al. 2006; Daugstad et al. 2014). Thereby, the combination of traditional farming practices, livestock grazing, and forest management has resulted in highly heterogeneous and spatially structured cultural landscape mosaics (Farina 2000). During the twentieth century, the mountains of southern Europe have experienced a progressive socioeconomic marginalization process associated to rural depopulation, land abandonment, and a decrease in extensive livestock rearing (Conti and Fagarazzi 2005; Gracia et al. 2011). A particularly relevant change has been the decrease in transhumance practices, associated with seasonal movements of flocks of sheep to exploit natural vegetation growth in summer mountain pastures (Vicente-Serrano et al. 2004; Morán-Ordóñez 2012). As a consequence of these factors, the landscape has undergone major transformations leading to the expansion of forests and shrublands in the most marginal areas and the intensification of agricultural practices in the most fertile and accessible lands (Sidiropoulou et al. 2015; Álvarez-Martínez et al. 2016).

Managed mountainous landscapes have traditionally been an important source of ecosystem services (Kozak et al. 2017). In fact, they provide many ecological, sociocultural, and economic benefits for society that include the following: regulating services, such as water cycling regulation or control and mitigation of extreme climatic events; provisioning services, such as grazing, wood-fuel or medicinal plants; and cultural services, zsuch as traditional knowledge or cultural identity (Körner et al. 2005; Foggin 2016). Over time, ecosystem processes that support ecosystem services may be affected by land use changes and the associated land cover changes (Reyers et al. 2009) ultimately impacting on benefits for society and human well-being (Ciftcioglu 2017; Hou et al. 2017; Sonter et al. 2017). Each particular land cover change might lead to a variation in the potential supply (i.e., the hypothetical maximum yield of a service that can be provided by natural components of the ecosystem without the intervention of stakeholders; Geijzendorffer et al. 2015) of multiple ecosystem services (Vallet et al. 2016). However, it is important to consider that the supply of ecosystem services not only can change over time, but also their value and use (i.e., the quantity and type of an ecosystem service which is consumed or utilized by stakeholders; Geijzendorffer et al. 2015) for society. For instance, ecosystem services of high relevance for past traditional lifestyles, such as provisioning services like wool or fuels, have become marginal nowadays; while others less appreciated in the past, such as cultural services including the esthetic aspect or recreation, are increasing in value for current society (Morán-Ordóñez et al. 2013a; de Lima et al. 2016; van der Zanden et al. 2018).

The implications of land cover change for the capacity of mountain systems to provide ecosystem services remains however a controversial issue (Pereira et al. 2005). This controversy lies on the spatiotemporal variability of the effects of land cover changes on ecosystem services and on the existence of trade-offs among different ecosystems services derived from these land cover changes (de Lima et al. 2016; Locatelli et al. 2017). Further, although previous studies (e.g., Tasser et al. 2005; Zlatanov et al. 2017) have assessed the impacts of land cover changes on the supply of particular ecosystem services in European mountains to date, there is limited empirical evidence on the relationship between historical trajectories of land cover change and trajectories of multiple ecosystem services in mountain landscapes (Lavorel et al. 2017). Thereby, enhanced knowledge of the past spatial and temporal patterns of land cover change is required to assess mountain landscape dynamics in relation to multiple ecosystem services (regulation, provisioning, cultural) (Mottet et al. 2006). Information on these temporal and spatial patterns can help land managers develop strategies and policies to improve the inclusion of novel socioecological connections (MacDonald et al. 2000) and ensure the future continuity of benefits to human well-being (Cabel and Oelofse 2012). Box 1 indicates the key concepts used in this study.

The objective of this paper was to analyze the impact of historical land cover changes on the potential supply and use of ecosystem services in mountain landscapes, using the Cantabrian Mountains (NW Spain) as a case study. Specifically, we aimed to (i) detect the main trajectories of land cover change that occurred during the last two decades (1990–2012) considering short time fluctuations (1990–2000, 2000–2006, 2006–2012) and estimate the potential impact on the supply of multiple ecosystem services (regulating, provisioning, and cultural services) at both regional and local scales; (ii) analyze trends in the use of ecosystem services

Box 1 Ecosystem service definitions. Source Geijzendorffer et al. (2015)

Potential supply: the hypothetical maximum quantity of a service that can be provided by natural components of the ecosystem without stakeholders interventions, in a particular area and over a particular time period (eg. density of species in a game reserve)

Actual potential supply: the hypothetical maximum quantity of a service that can be provided by combination of the potential supply and the effect of interventions (e.g., management) by stakeholders, in a particular area and over a particular period of time (density of hunting species in game reserves)

Actual supply: the current amount of an ecosystem services that are provided by the combination of the potential supply and the effect of operations by stakeholders, in a particular are and within a given time period (e.g. number of hunting permits)

Actual use: The quantity and type of an ecosystem service which is consumed or utilized by stakeholders in a particular area and over a particular time period (e.g. number of hunted animal) and compare them with potential supply estimates at a local scale, using a subset of ecosystem services. Finally, we provided recommendations for the long-term supply of ecosystem services in traditionally managed mountain landscapes. We hypothesized that land cover changes associated to landscape homogenization would be associated with a loss of capacity of mountain landscapes to supply multiple ecosystem services. Further, we hypothesized that temporal trends in ecosystem service use would be consistent with temporal trends in potential supply.

Study area: definition of two scales of analysis

The study was conducted in the Cantabrian Mountains (NW Spain) where two spatial scales of analysis were considered: (i) a regional scale, which includes the whole area of the Cantabrian Mountains, covering 31,494 km^2; and (ii) a local scale, which includes the Cantabrian Mountains in León province (one of the nine provinces that encompass this mountain system) covering 7151 km^2 (23% of the surface of the Cantabrian Mountains) (Fig. 1).

The Cantabrian Mountains are located at the transition between the Eurosiberian and Mediterranean biogeographic regions (Rivas-Martínez et al. 1987). Annual rainfall varies between 700 and 2200 mm and mean annual temperature between −2.5 and 15 °C. Altitude ranges from sea level up to 2650 m.a.s.l. In this mountain range, the main land covers are crop fields and grazed meadows along valley bottoms, and heathlands, shrublands, and deciduous forests, dominated by beech (*Fagus sylvatica*), birch (*Betula* spp.), and different oak species (*Quercus petraea* and *Q. robur* on northern slopes, *Q. pyrenaica* and *Q. ilex* subsp. *rotundifolia* on southern slopes) in the uplands (Morán-Ordóñez 2012). These woody habitats can spatially intersperse with grazing systems (i.e., open semi-natural habitats mainly comprising pastures,

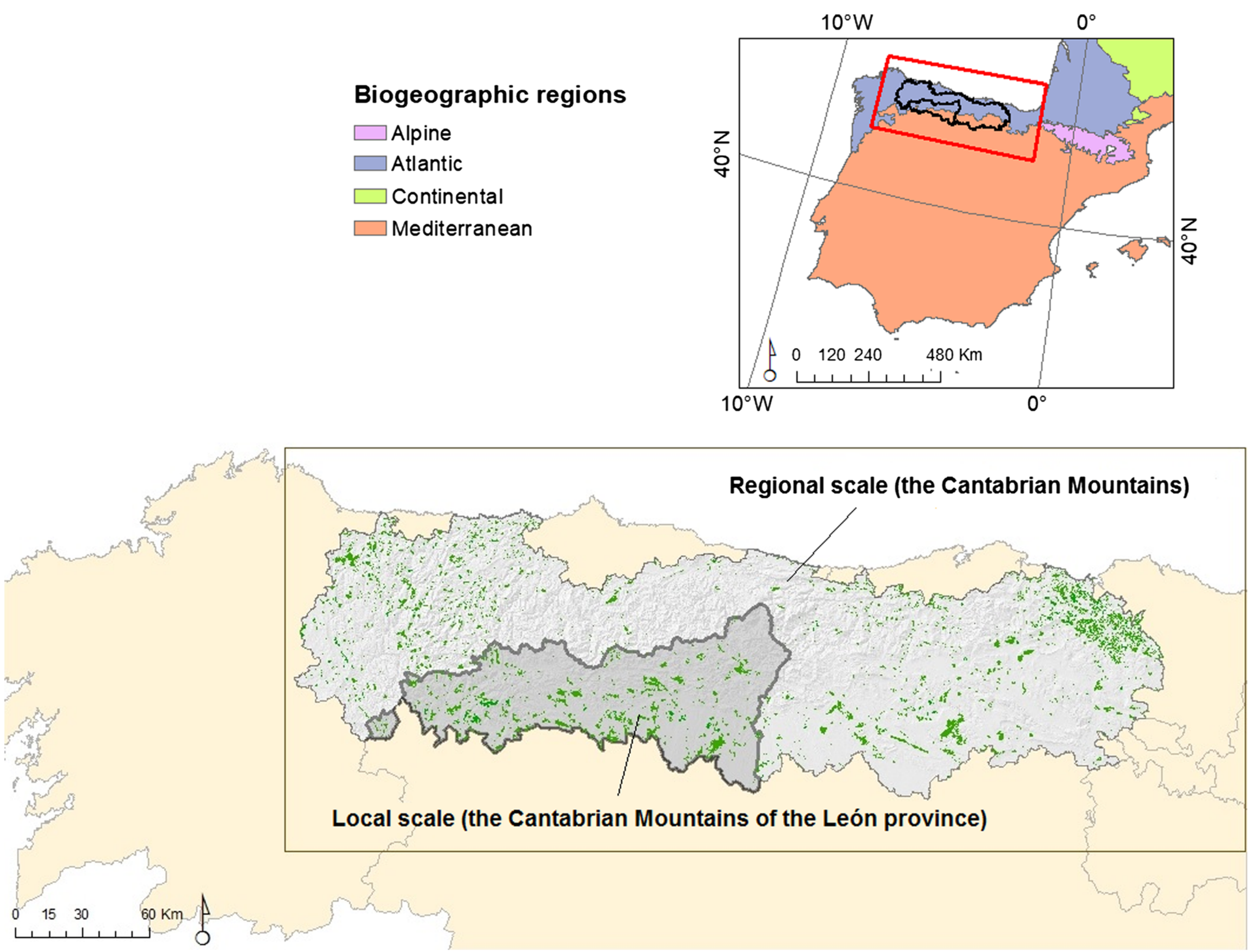

Fig. 1 Location of the study area in NW Spain and analytical scales regional (Cantabrian Mountains) and local (Cantabrian Mountains of León). Information on biogeographic regions was obtained from the Spanish Ministry of Agriculture Food and Environment (http://www.magrama.gob.es/). Spots corresponding to land cover changes during period 1990–2012 are in green, and were obtained from the CORINE Land Cover change layers (http://dataservice.eea.europa.eu)

grasslands, or open scrublands with very few or no trees) at middle slope levels (Rescia et al. 2008). The tops of the mountains are dominated by rocky formations and natural grasslands. Furthermore, plantations of pines (*Pinus pinaster*, *P. radiata*) and eucalyptus (*Eucalyptus globulus*) cover medium-to-low slopes (García-Llamas et al. 2016).

The Cantabrian Mountains of León are located on the southern slope of this mountain system. Annual rainfall ranges from 700 to 1800 mm and mean annual temperatures are between − 2.5 and 12.5 °C. The altitudinal gradient is 391–2650 m.a.s.l. Land cover pattern is similar to that described for the whole Cantabrian Mountains, with croplands and pasturelands along valley bottoms and heathlands and shrublands of *Cytisus multiflorus*, *C. scoparius*, *Calluna vulgaris*, *Erica australis*, *Genista obtusiramea*, *G. florida* subsp. *polygaliphylla*, *G. hispanica* subsp. *occidentalis*, and *Vaccinium myrtillus* at uplands. Forest formations vary with elevation and appearance. Beech forests dominate at low altitude in northern slopes, with marked xericity and warm temperature, while they also cover southern humid slopes at higher altitudes. Forest dominated by oak species (*Q. pyrenaica* and *Q. ilex* subsp. *rotundifolia*) are common in southern slopes at low altitudes, whereas the highest altitudes are covered by birch groves (*Betula celtiberica*). The tops of the mountains are dominated by rocky formations and natural grasslands.

The main driving forces historically shaping the landscape across the Cantabrian Mountains have been extensive livestock (sheep, cattle, and horses) grazing, uneven topography, and diverse climatic conditions (Morán-Ordóñez 2012). As a result of interactions among these factors, traditionally managed landscapes, consisting of a mosaic of open habitats, forests, and shrubs, have originated, those being important suppliers of multiple and high valuable cultural, regulating, and provisioning services (Rescia et al. 2010; Morán-Ordoñez et al. 2013a). Within the study area, particularly transhumance sheep activity has played a major role as a driver of landscape change in the León Mountains (MAGRAMA 2013), creating cultural landscapes consisting of an open heath-pasture mosaic (Morán-Ordóñez et al. 2013a). These particular cultural landscapes, associated to the transhumance activity, gave ground to selecting the mountains of León province as our local scale approximation. Nowadays, although livestock rearing (mainly cattle and horses) continues to represent an important economic resource, other activities such as hunting (Morán-Ordóñez 2012), forestry (Delgado-Viñas 2015), or tourism (Álvarez and Pérez 2016) have increased their importance.

The Cantabrian Mountains has suffered notable rural depopulation in the last decades (overall rates of 16% and 66% between 1990 and 2012 in the whole Cantabrian Mountains and the Cantabrian Mountains of León province respectively; Online Resource Table A1), with a population of about 1 million and 33,834 inhabitants, respectively, in the Cantabrian Mountains and the Cantabrian Mountains of Leon in 2011 (http://www.ine.es). Nevertheless, this population is unevenly distributed. In northern provinces, it is concentrated in several main urban centers and relatively close small settlements, with a density of 32 inhabitants/km^2. By contrast, southern provinces have a population density of just 3 inhabitants/km^2 and it is mainly concentrated in small settlements rather isolated from main urban centers. This rural depopulation and the loss of profitability and competitiveness of traditional agro-silvopastoral systems in the last decades have resulted in land abandonment and a loss of traditional management that have undermined landscape patterns and their related multiple bundle of ecosystem services (Morán-Ordóñez et al. 2013a).

Methods

Temporal patterns of land cover change

We identified land cover changes that have occurred in the Cantabrian Mountains during 1990–2012, at both regional and local scales, on the basis of the change layers available in the CORINE land cover inventory (CLC) (http://dataservice.eea.europa.eu). This database provides a unique and consistent land cover dataset for Europe, comprising 44 land cover classes grouped in three hierarchical levels, of which 37 are present in our study area (Online Resource Table A2) (Bossard et al. 2000). This database was first available for 1990 and was subsequently updated in 2000, 2006, and 2012. CLC change data reveal changes in land cover with a minimum mapping unit of 5 ha (Nunes de Lima 2005). Despite possible drawbacks to the CLC database, such as the existence of classification errors and uncertainties (García-Llamas et al. 2016), its accessibility and pan-European comparability and availability at different time spans offer considerable advantages for studying land cover changes (Kroll et al. 2012).

Land cover changes were reported as the net overall change for the whole study period (1990–2012) and also for the three subperiods 1990–2000, 2000–2006, and 2006–2012 (corresponding with the availability of CLC data) to account for short-term temporal fluctuations. Land cover changes were estimated as the variation in the area (ΔA) occupied by each CLC class for a given time period (Eq. 1) and expressed in per mille, in relation to the study area.

$$\Delta A_i = \frac{A_{it1} - A_{it2}}{SA} \times 1000 \quad (1)$$

Where A is the area in ha of each CLC class i, and t_1 and t_2 are the years of study, and SA is the overall area of the study region.

Additionally, we applied transition matrixes of change to identify the main land cover transitions during land cover changes. This is the most conventional method to identify significant transitions between different land covers for a given period (Martínez-Fernández et al. 2015), being widely used in several studies (e.g., Mottet et al. 2006; Morán-Ordóñez 2012; Avalos-Jiménez et al. 2018). In the transition matrix, rows display the classes at an initial time t_1 and columns display the classes at a final time t_2. Entries off the diagonal represent the proportion of landscape that undergoes a transition between land cover classes (Martínez-Fernández et al. 2015).

Trends of change in the potential supply of ecosystem services

The impact of land cover changes on ecosystem service supply was estimated independently at both regional and local scales through a semi-quantitative approach, namely the "ecosystem services capacity matrix method." This method was originally developed by Burkhard et al. (2009) for a German region and further adapted by Stoll et al. (2015) for the whole of Europe. From here on, we will refer to this method as the "Stoll matrix." This matrix provides estimates of the capacity of individual CLC classes (displayed in the x-axis) to supply 31 specific ecosystem services (displayed in the y-matrix) for the whole of Europe (Online Resource Fig. A1). The estimates in the matrix are based on averages of scores assigned by expert knowledge on a scale from "0" (no capacity to provide a particular ecosystem service) to "5" (very high capacity to provide a particular ecosystem service). The scoring of supply capacities was collected from 28 expert teams, belonging to the European Long-Term Ecological Research network (LTER-Europe), from 11 countries covering a north–south gradient and a west–east gradient in Europe. To this purpose, subsets of the original Stoll matrix including only CLC classes presented at experts' regions were defined, and the original supply scores were updated by the experts based on their knowledge on the ecosystem service provision in the CLC classes at their regions. An updated Stoll matrix was subsequently developed by averaging experts' scores. Only CLC classes that obtained at least three experts' assessments were updated. See Stoll et al. (2015) for further details on definition of the Stoll matrix. Although the method has limitations, such as various degrees of generalization and poor capacity to capture spatial variability (Jacobs et al. 2015), it constitutes a timely and cost-saving tool to evaluate the potential of ecosystems to supply services in changing environments (Balthazar et al. 2015), which has been applied in several studies (Kroll et al. 2012; Nedkov and Burkhard 2012; Sohel et al. 2015). Therefore, using the values of supply capacity of the CLC classes provided in the Stoll matrix, we have estimated the potential supply capacity (PSC) of 31 ecosystem services (i.e., regulating, provisioning, and cultural services) for the 37 CLC classes presented in the study area. PSC values were normalized between 0 and 1. Subsequently, the variation in the potential supply capacity (ΔPSC) for each ecosystem service, time period, and analytical scale was computed as follows:

$$\Delta PSC_j = \mathrm{sPSC_{ji}} \times \Delta A_i \qquad (2)$$

where sPSC is the normalized potential supply capacity value, and ΔA represents the variation in the area occupied by each land cover at each time period. j corresponds to each ecosystem service and i to each CLC class.

Trends in the use of ecosystem services

In order to assess temporal trends in the actual use of ecosystem services, we selected a subset of provisioning (timber, wild food, and livestock) and cultural (recreation/tourism) services, due to the lack of available information on actual use for the 31 ecosystem services described in the Stoll matrix. This subset was selected aiming to include services highly valued by traditional society, but also others of increasing value nowadays (Herruzo and Martinez-Jauregui 2013; Morán-Ordóñez et al. 2013a; Schulp et al. 2014; Delgado-Viñas 2015). Indicators of actual use of ecosystem services were defined on the basis of the available data (Table 1) provided by both the regional administration and Rodríguez (2004), for 1990, 2000, 2006, and 2012 (or nearest years). For timber, we used information on wood harvested in public forests. The indicator of wild food was built from hunting data collected in game reserves. Additionally, we also included information on the actual potential supply of this service, which was derived from census of game species (*Capreolus capreolus*, *Cervus elaphus*, and *Rupicapra rupicapra*). For livestock, we used information on the number of cows and transhumant sheep, which were transformed into livestock units (LSU; 1 sheep = 1LSU, 1 cow = 5LSU; Olea and Mateo-Tomás 2009). For recreation/tourism, we employed data on visitor flow to natural parks. We also included data on recreation/tourism actual supply (i.e., the current amount of an ecosystem service that is provided by the combination of the potential supply and the effect of operations by stakeholders in a particular area and within a given time period Geijzendorffer et al. 2015) measured as the amount of available rural accommodation.

Results

Temporal patterns of land cover change

Land cover dynamics followed similar trends at both regional and local scales. However, changes were particularly pronounced at local scale (Fig. 2). Land cover changes were mainly dominated by an expansion of woody vegetation,

Table. 1 Indicators of ecosystem service use, actual potential supply, and actual supply at local scale for the Cantabrian Mountains of León

Ecosystem service		Definition	Indicator	Data source and years
Provisioning	Timber	Wood production	Use: tons of wood/ha of public utility forests	Junta de Castilla y León; years from 1992 to 2012
	Wild food	Harvest of mushrooms, berries, animal hunting, and fish catch	Use: number of hunted animals in game reserves/1000 ha Actual potential supply: density of hunting species in game reserves (number of animals/1000 ha)	Junta de Castilla y León; years 2000, 2006 and 2012
	Livestock	Production and utilization of domestic animals	Use: number of livestock units per hectare of pastureland	Junta de Castilla y León and Rodríguez (2004); sheep years 1990, 2003, and 2012; cows years 1990 and 2012
Cultural	Recreation/tourism	Recreational activities including tourism associated with local environment or landscape	Use: number of tourists visiting natural parks Actual supply: amount of rural accommodation	Junta de Castilla y León; Amount of rural accommodation: from 2000 to 2012; number of tourists visiting national parks: from 1990 to 2009

particularly during the subperiod 1990–2000, but with few changes beyond 2000 (Fig. 2a, b). This expansion was primarily associated to a net increase in forests and a loss of open habitats, specifically patches of natural grasslands, moors-heathlands, and sclerophyllous vegetation (Table 2; Online Resource Table A3).

To a lesser extent, the period 1990–2012 was characterized by an expansion and geographic aggregation of agricultural lands in the most suitable areas. This change was associated with a noticeable increase in non-irrigated arable lands at the expense of smallholding agricultural lands (i.e., natural grasslands and areas of complex cultivation patterns). Further, smallholding agriculture also decreased due to land abandonment (mainly of complex cultivation patterns and pasturelands) in marginal areas, and to urban expansion (Fig. 2c, d; Table 2 and Online Resource Table A3). At regional scale, agricultural expansion and aggregation were mainly detected during 1990–2000 and, to a lesser extent, throughout 2006–2012. Conversely, the decrease in agricultural land was mostly observed over the period 2000–2006 (Fig. 2c). At local scale, the increase in non-irrigated arable lands was constant over time, but agricultural land abandonment peaked between 1990 and 2000 (Fig. 2d).

The expansion of artificial surfaces was a general trend in the whole area of the Cantabrian Mountains throughout all the reporting periods at both scales (Fig. 2, e, f), mainly in forest areas and moors and heathlands (Table 2 and Online Resource Table A3).

Trends of change in the potential supply of ecosystem services

As a result of the linear relationship between ecosystem service supply and land cover changes, there was a direct correspondence between trends of change in the potential supply of ecosystem services and trends in land cover change previously described. Overall, trends of change in the potential supply of ecosystem services (see Fig. 3) were similar at both scales, albeit changes were relatively larger at local scale and particularly remarkable for the subperiod 1990–2000. Beyond that moment, only slight changes were detected, which suggest stabilization. We found a net increase in the potential supply of all categories of ecosystem services (regulating, provisioning, and cultural) during the whole study period (1990–2012), although some differences should be highlighted. The potential supply of regulating services strongly increased, especially air quality regulation, pest and disease control, erosion regulation, and local climate regulation. Similarly, there was a substantial improvement in the potential supply of provisioning services related to the presence of trees or woodland, such as timber, wood fuel, biochemicals, and wild food. Nevertheless, there was a marked reduction in the potential supply of livestock. At the same time, there were fewer changes in the potential supply of cultural services than regulating or provisioning ones. The greatest increase was estimated for recreation and tourism, landscape esthetics, and natural heritage, showing only a decrease in service knowledge systems, understanding knowledge system as the use of a landscape for environmental knowledge arising from living in this specific environment.

Trends in the use of ecosystem services

Actual use of the assessed subset of ecosystem services at local scale showed similar temporal patterns to potential supply estimates (see Table 3 and Fig. 3). We found an increasing trend in the tons of timber extracted from public forests from 1990 to 2012, which was analogous to trends in the potential

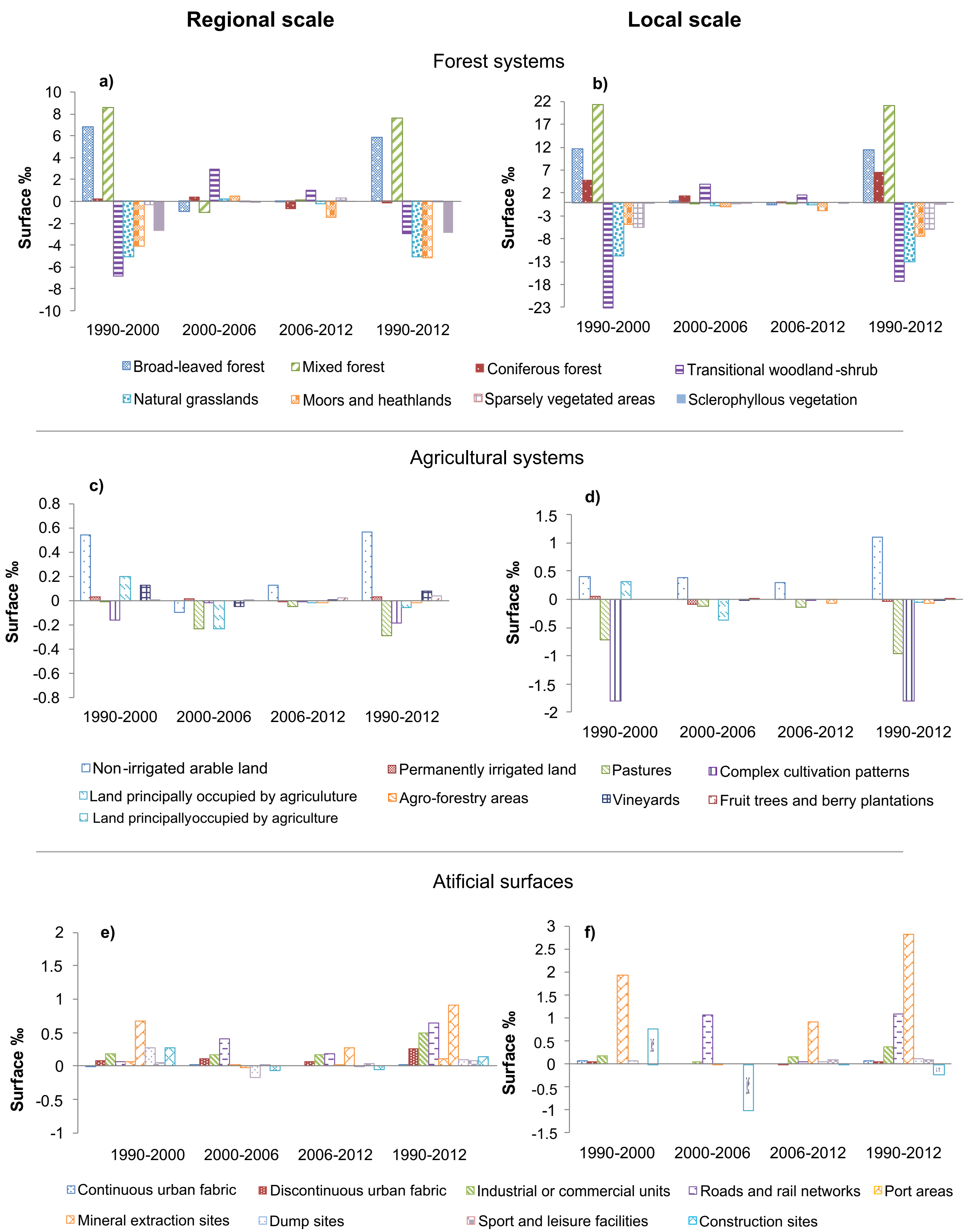

Fig. 2 Land cover changes for the overall study period 1990–2012 and the subperiods 1990–2000, 2000–2006, and 2006–2012 at both regional and local scales, representing **a**, **b** forest systems; **c**, **d** agricultural systems; **e**, **f** artificial surfaces. Source: CORINE Land Cover database. Charts corresponding to land cover changes at regional and local scales present different scales for a better display

Table. 2 Transition matrix showing changes in land cover (in ‰) between 1990 (rows) and 2000 (columns) at regional scale (Cantabrian Mountains). The largest changes for each land cover type are in italics. Only 1990–2000 is shown as the most representative period

		Land cover 2000																	
		ArtiS	NI	Pirriga	V	Fruit	Past	CCP	LPA	Forest	NG	Twood	Moor	SclV	SparV	Rock	Burnt	WatS	Total area
Land cover 1990	ArtiS						0.051	0.055		0.015	0.014	*0.163*	0.074	0.006				0.018	0.395
	NI	*0.079*		0.050			0.011	0.002		0.022		0.030		0.055					0.249
	Pirrigate	*0.012*							0.002				0.004			0.008			0.026
	Past	*0.233*						0.134	0.011	*0.204*		0.127					0.010	0.044	0.763
	CCP	0.180	*0.183*						*0.260*	0.061		0.017	0.002					0.171	0.811
	LPA	0.131	0.080	0.005	0.125		0.006	*0.189*		*0.189*	0.005	0.066	0.006	0.006			0.034		0.841
	Forest	0.371	0.033			0.007	0.098	0.099	0.122		0.047	*7.806*	0.125	0.023	0.003		0.243	0.064	9.040
	NG	0.253	*0.367*				0.035	0.144	0.261	*3.467*		*0.689*		0.036			0.142	0.139	5.543
	Moor	0.470					0.380		0.117	*1.070*	0.328	*1.544*			0.116		*1.140*	0.204	5.370
	SclV	0.018	0.063	0.010				0.005	0.133	*1.202*	0.011	*1.505*					0.139		3.088
	Twood	0.2.36	0.062				0.159	0.021	0.120	*18.184*	0.059		0.070	0.241			0.474		19.626
	Rock								0.003			0.009							0.013
	SparV	0.046										0.068	*0.274*				0.061	0.005	0.455
	Burnt							0.001	0.010	0.195		*0.732*	*0.669*		0.021				1.628
	WatS	0.067																	0.067
	Total area	1.967	0.789	0.065	0.125	0.007	0.740	0.649	1.039	24.619	0.465	12.757	1.225	0.367	0.139	0.008	2.242	0.645	

ArtiS (continuous urban fabric, discontinuous urban fabric, industrial or commercial units, road and rail networks, port areas, mineral extraction sites, dump sites, construction sites, green urban areas, sport and leisure facilities); *NI* (non-irrigated arable land); *Pirrigate* (permanently irrigated lands); *V* (vineyards); *Fruit* (fruit trees); *Past* (pasturelands); *CCP* (complex cultivation patterns); *LAP* (land principally occupied by agriculture, with significant areas of natural vegetation); *Forest* (broadleaf forest, mixed forest, and coniferous forest); *NG* (natural grasslands); *Moor* (moors and heathlands); *SclV* (sclerophyllous vegetation); *Twood* (transitional woodlands-shrub); *Rock* (bare rocks); *SparV* (sparsely vegetated areas); *Burnt* (burnt areas); *WatS* (water bodies, water courses, estuaries, sea, and oceans)

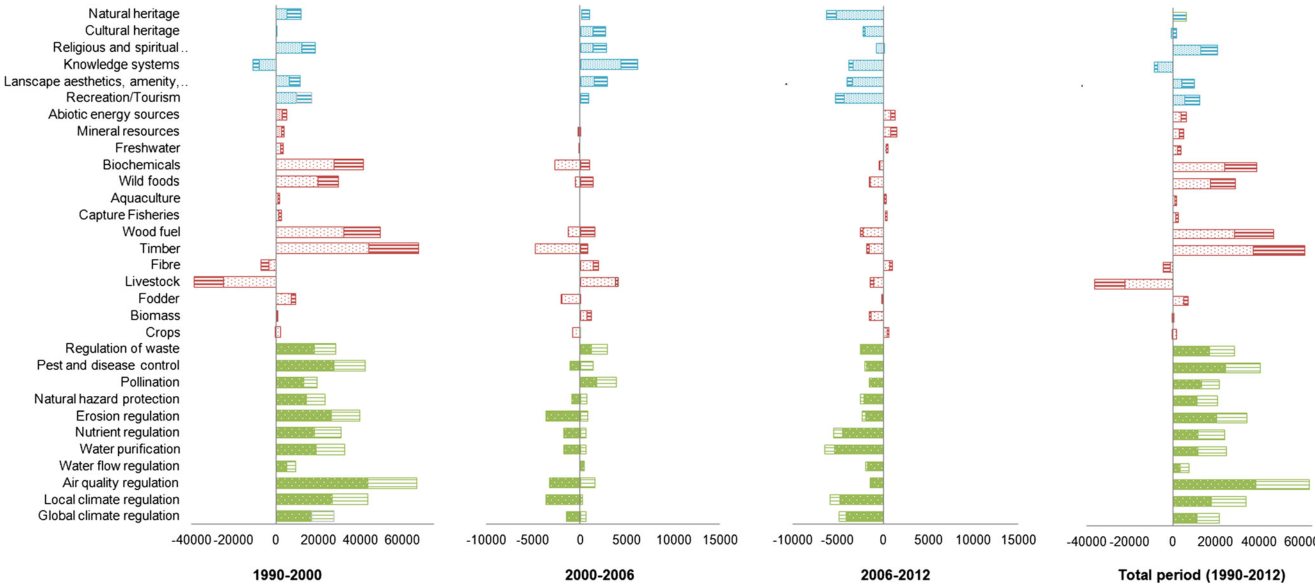

Fig. 3 Changes in the ecosystem service potential supply capacity (cultural, blue; provisioning, pink; and regulating services, green) through subperiods 1990–2000, 2000–2006, and 2006–2012 and all of 1990–2012. Spots refer to the regional scale and stripes the local one. Charts corresponding to changes in ecosystem service supply at regional and local scales present different scales for a better display

supply of timber. The increasing density of game species in hunting reserves between 1990 and 2012 indicated an increase in the actual hunting potential supply, similar to the increasing trends of estimated wild food potential supply. Currently, the number of hunted animals (hunting use) declined from 2000 onwards. Similarly, the number of livestock units decreased over the whole study period, in line with estimates of livestock potential supply. However, analyzing independently the trends of change associated to different livestock species from 1990 to 2012, we did not find a common pattern, as the number of sheep drastically decreased (70%; from 123,380 to 37,922 sheep), while the number of beef cattle increased (65%; from 3569 to 9996 heads of cattle) over this time period. Furthermore, the use/supply of recreation and tourism services showed an important increase between 1990 and 2012. More than 300 new rural tourism establishments were created in 12 years, tripling from 2000, and the number of visitors to natural parks almost doubled in 20 years. These results were consistent with trends of estimations in tourism/recreation potential supply.

Discussion

Temporal patterns of land cover change

The temporal analysis of the land cover changes that have occurred in the Cantabrian Mountains revealed landscape

Table. 3 Changes in actual use of ecosystem services at local scale, including timber, hunting, livestock, and recreation/tourism, along with changes in potential supply estimates of these services, for the subperiods 1990–2000, 2000–2006, 2006–2012, and for the whole study period 1990–2012. Information on the actual potential hunting supply and on the actual recreation/tourism supply are also shown. Negative values indicate a decrease

Ecosystem service	1990–2000	2000–2006	2006–2012	*1990–2012*
Timber use (Tn/ha public forest)	458	16	− 59	415
Potential timber l supply	23,452.07	817.26	− 287.80	23,981.53
Hunting use (no. of hunted animals/ 1000 ha)	–	− 0.1	− 1.27	−1.37
Potential wild food supply	10,068.84	1339.66	− 134.96	11,270.15
Actual potential hunting supply (no. of huntable animals/1000 ha)	44.18	− 18.98	10.66	35.86
Livestock use (livestock units/ha pastureland)	–	–	–	− 1.85
Potential livestock supply	–	–	–	− 14,090.38
Tourism use (no. of tourists visiting natural parks)	1,070,000	250,000	0	1,070,000
Potential tourism supply	7387.62	799.93	− 287.79	23,981.52
Actual recreation/tourism supply	–	103	93	196

homogenization at both regional and local scales, which is consistent with the results of other studies carried out across other European mountains (Conti and Fagarazzi 2005; Gracia et al. 2011). We have found two main trends of change: (i) a woody vegetation (shrub and forest) expansion and a loss of open habitats linked to extensification and land abandonment in marginal zones; (ii) to a lesser extent, an expansion and geographic aggregation of agricultural fields in the most suitable areas. These land cover changes have been particularly relevant during the subperiod 1990–2000, which might be attributable to the inclusion of Spain in the European Union market in 1985 and the subsequent implementation of the Common Agricultural Policy (CAP), as identified in other studies (Bernués et al. 2011; Vidal-Legaz et al. 2013). These policies prompted farm specialization and more productive and competitive agricultural systems, at the expense of small farming holdings and traditional practices (Donald et al. 2002; Casas and Manzano 2007). Transformations in farming and agricultural production drove to alterations in the equilibrium between low intensive agricultural lands, grazing and woody systems (Mottet et al. 2006; Rescia et al. 2008), typical of traditionally managed mountain landscapes, and favored secondary succession in different ranges, from grazing areas to transitional stands. Likewise, forest plantation subsidies within the CAP also favored the afforestation of abandoned lands (Rey-Benayas et al. 2007), thus contributing to forest expansion. Notwithstanding, few changes in land cover from 2000 might indicate a new state of equilibrium in the landscape. This reduction in land cover change rates represents a balance between current human and natural forces of change occurring in abandoned or less intensively used land patches (Pelorosso et al. 2011).

In addition to the aforementioned factors, the pronounced trends in land cover change at local scale may be partially related to a historical major role of transhumance in shaping the landscape in this area, in comparison with other areas in the Cantabrian Mountains (MAGRAMA 2013). The socioeconomic crisis greatly affecting transhumance during the twentieth century has caused an increase mainly in beef cattle, requiring less human handling, at the expense of the traditionally migratory sheep flocks (Morán-Ordóñez et al. 2013b). Cattle make a different use of grasslands, being less effective in controlling woody species than sheep (Calvo et al. 2002). At the same time, the traditional transhumance model has been replaced by short movements from nearby lowlands where shepherds spend shorter and shorter periods of time in mountain areas (Olea and Mateo-Tomás 2009). Further, they involve a lower number of animals, thus decreasing pressure on woody systems. Therefore, the important woody vegetation expansion and the loss of open habitats observed during the 1990s at local scale is likely the continuation of trends in land cover change occurring as a result of the decline of the transhumance systems during the twentieth century (Morán-Ordoñez et al. 2011). This process continued until 2000, when changes tended to stabilized. Additionally, particular socioeconomic factors occurring in the Cantabrian Mountains of León, such as the small size and isolation of villages, loss of facilities, and lack of economic opportunities, have encouraged depopulation. This fact, along with population aging, further explains the abandonment of small holding agriculture and traditional landscape management, inducing pronounced land cover trends at local scale (Morán-Ordóñez 2012).

Impact of land cover changes in ecosystem service supply and trends in ecosystem service use

According to our results, land cover changes linked to socioeconomic transformations and agricultural policies, mainly occurring during the subperiod 1990–2000, were identified as an important driver of ecosystem service change in traditionally managed landscapes in the Cantabrian Mountains. Our hypothesis that land cover changes associated to landscape homogenization would affect the mountain landscapes' multifunctionality as suppliers of multiple ecosystem services was confirmed. While the potential supply of ecosystem services associated with natural systems increased, that linked to traditional land uses was notably altered, at both regional and local scales, which is in line with other studies carried out in other European mountains, such as the Italian Alps (Conti and Fagarazzi 2005). The consideration of these trade-offs is key to understanding the evolution of traditionally managed landscapes as suppliers of ecosystems services, thus allowing for sustainable policies to be designed. The expansion of woody vegetation positively influenced regulating services in the Cantabrian Mountains, in line with the findings of other studies, including the rise of air quality regulation (Chaparro and Terrasdas 2009), reduction in erosion (Anaya-Romero et al. 2016), improvement in water quality (Navas et al. 2009), and the runoff regulation (Schulz et al. 2010). Additionally, it also benefited the potential supply of timber, wood fuel, wild foods, and biochemicals enhancing the use of some services, such as timber (Maes et al. 2015), consistent with our results at local scale. This further confirms our hypothesis that temporal trends of change in potential supply would meet trends in the use of ecosystem services. At the same time, the increasing density of game species at local scale evidenced how the expansion of woody vegetation, associated to a reduction of livestock pressure, is also likely to favor wildlife species, generally those associated with forested areas (Conti and Fagarazzi 2005). This fact contributes to natural heritage, which might also benefit tourism (Navarro and Pereira 2012). This increase in density of game species was consistent with the increase in potential wild food supply with land cover changes, but it was not corroborated by the hunting use, as opposed to our hypothesis. However, the decline in the number of hunted animals (i.e., hunting use) might not be directly connected with land cover changes, but with other factors such as differences in the male to female ratio, pests, weather events, and socioeconomic factors, such as increasing hunting costs and the decrease in hunting tourism. Beyond this, hunting represents an ecosystem service of increasing use at national scale (Herruzo and Martinez-Jauregui 2013), although it might be in conflict with biodiversity conservation (Morán-Ordóñez et al. 2013a), generating opposing interests among stakeholders demanding different ecosystem services. Benefits from the expansion of woody vegetation have been identified as an opportunity for the regeneration of native ecosystems and present rewilding as a potential cost-saving alternative approach to active conservation strategies (Regos et al. 2016).

Notwithstanding, in the Cantabrian Mountains, the importance of preserving traditionally managed landscapes, related to acceptable levels of livestock production and traditional farming practices, as valuable sources of ecosystem services has been stated in previous studies (Rescia et al. 2010; Morán-Ordóñez et al. 2013b). However, the expansion of shrublands and forests into semi-natural grazing systems mainly occurred during 1990–2000 at both local and regional scales, and the decrease in actual use drove a strong impact on the potential supply of livestock, consistent with other studies (Oteros-Rozas et al. 2012). At the same time, these changes in land cover and livestock use might compromise these landscapes and their capacity as suppliers of ecosystem services. In this way, the existence of open habitats and pasture activity has been recognized as crucial in reducing the vulnerability of landscape against natural perturbations, like wildfires, being associated to a reduction in fuel accumulation and its continuity (Zumbrunnen et al. 2012). Additionally, the conservation of high-quality semi-natural grazing systems has benefits for the socioeconomic welfare of mountain villagers derived from the rental of mountain passes (Rodríguez 2004). Further, despite the observed general increase in the potential cultural service supply, mainly associated to woody vegetation expansion, traditionally managed landscapes are important cultural service suppliers. Beyond economic benefits, cultural heritage related to pastoralism and traditional landscape management is a valuable cultural service which may be endangered by the loss of traditional practices (Calvo-Iglesias et al. 2009; Morán-Ordóñez et al. 2013a). Similarly, the mosaic of semi-natural open habitats, forests, and shrubs, jeopardized by the current landscape homogenization trend, is usually perceived as more esthetically attractive (Schirpke et al. 2016) than transitory degraded stages of forest (Pardini et al. 2002). In parallel, traditionally managed landscapes might also contribute to natural heritage. Many flora and fauna species of high conservation value (e.g., *Potentilla fruticosa* or *Luscinia svecica*) depend on these habitats and could thus be threatened by their detriment (Levin and Nainggolan 2016; Snell et al. 2017).

The observed enhancement of the potential supply of cultural services from 1990 to 2012, despite the loss of cultural services associated with traditional managed landscapes in the Cantabrian Mountains, might suggest potential limitations of the Stoll matrix to depict local and regional peculiarities in different European regions (Burkhard et al. 2009; Stoll et al. 2015). These limitations may be explained by the challenge of generalizing cultural ecosystem services, whose value is highly site and context dependent (Locatelli et al. 2017; Tolessa et al. 2017). Further, it might highlight an overstatement of the relative role of forest to supply particular services by matrix methods (Maes et al. 2015). In this way, the assessment of cultural services based on methods that attribute values of supply capacity to individual land cover classes might be relatively challenging because each individual might have different value systems based on its experiences, habits, or behavioral traditions (Burkhard et al. 2012; Rodríguez-Loinaz et al. 2015). Limitations of the Stoll matrix would suggest therefore the advisability of using capacity matrixes adapted to different regional socioecological contexts in future studies.

Safeguarding cultural values of traditional managed landscapes offers possibilities for the development of new services of increasing use in the Cantabrian Mountains, such as tourism (Rey-Benayas et al. 2007). Further, the increasing use of tourism could potentially serve as an instrument to diversify the economy and revitalize mountainous rural areas. Such a purpose would require greater engagement of rural society (Cánoves et al. 2004) and a diversified concept of land use planning, which contributes to ecologically sustainably tourism (Höchtl et al. 2005) while maintaining natural and cultural heritage, practices, and landscapes.

In our study area, efforts toward the preservation of traditionally managed landscapes and their character as traditional and cultural ecosystem service suppliers have been put through management and policy actions (e.g., agro-environmental schemes of the CAP) (Rescia et al. 2008). In this context, the degree of restoration of lost ecosystem service values (livestock and cultural services) during 1990–2000 has been scarce, but results beyond 2000 in this study showed trends toward a relatively stable state. At this state, despite the existence of landscape homogenization, maintaining a certain degree of spatial heterogeneity of the landscape mosaic in mountain systems would be beneficial, as it might enhance a more diversified bundle of ecosystem services provided by the different kinds of ecosystems (Lavorel et al. 2017). However, we must note that reported links between land cover and ecosystem service dynamics are temporal and spatial scale dependent (Locatelli et al. 2017). Therefore, even if we found similar trends in land cover and ecosystem services at local and regional scales, these trends might vary across other temporal and spatial scales. Additionally, in this study, relationships between land cover changes and ecosystem service supply are assumed to be linear. In this way, we did not consider land use intensity which might shape trajectories of ecosystem service supply and make that the capacity of particular land cover classes to provide ecosystem were not constant over time (Lavorel et al. 2017). Despite these limitations, our study provides valuable contribution to understanding interactions between land cover changes and ecosystem services supplied by mountains landscapes to be used in decision-making processes. Thereunder, novel management and policy strategies, aiming at the preservation of traditional landscapes and their ecosystem services, would require adaptation in order to cover current socioecological needs. This can be achieved through the inclusion of socioecological connections and synergies among the primary, secondary, and tertiary sectors (Lago and Sevilla 2008), which enable traditional ecosystem services to be maintained (e.g., livestock), complemented by current new sustainable ones (e.g., tourism).

Conclusions

Our analysis of land cover dynamics in the Cantabrian Mountains at both regional and local scales revealed a trend toward landscape homogenization and highlighted the importance of considering the temporal scale when analyzing land cover and ecosystem services dynamics. Landscape homogenization affected the multifunctional character of Cantabrian Mountains landscapes. The spread of woodland systems increased the potential supply of regulating and provisioning services in the Cantabrian Mountains. At the same time, the decline in semi-natural open landscapes negatively affected the supply of services linked to traditional uses such as livestock. A poor depiction of the loss of cultural services associated to traditionally managed landscapes suggests the need to revise the Stoll matrix for its correct application in this type of systems. The increasing use of some ecosystem services associated to changes in land cover emphasized the need to integrate both the supply and the future use of all ecosystem services in management plans. The identification of trends in land cover change and ecosystem service supply and use reported in this study could help develop future scenarios to tackle future challenges in ecosystem service supply.

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