Evaluating Ecosystem Services in Transhumance Cultural Landscapes

An Interdisciplinary and Participatory Framework

Ecosystem services assessment can contribute to the conservation of the customary practice of livestock movements. Our comprehensive framework facilitates the dialogue between different knowledge systems and promotes multi-scale participatory decision-making.

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Abstract

Following the concept of ecosystem services, we propose in this article an interdisciplinary and participatory methodological framework for ecosystem services assessment and participatory decision-making in Mediterranean cultural landscapes linked with transhumant pastoralism. It is based on four sequential phases: 1. characterisation of the social-ecological network associated with transhumance, 2. preliminary identification and characterisation of ecosystem services, 3. evaluation of ecosystem services (in biophysical, socio-cultural, and economic terms), and 4. future scenario planning for the analysis of social conflicts related to ecosystem services use and trade-offs as well as the proposal of management strategies. Applying the framework to a case study on one of the major transhumance landscapes in Spain, we could identify and evaluate more than 30 ecosystem services. The framework facilitated the design of robust policy measures that aim to maintain this livestock raising model and its associated flow of ecosystem services. It also contributes to provide the basis for the implementation of adaptive co-management strategies.

Keywords

adaptive co-management, Conquense Royal Drove Road (CRDR), decision-making, future scenario planning, social-ecological network

Since the release of the *Millennium Ecosystem Assessment* (MA 2005), the science of ecosystem services has attracted much attention in the scientific community, as the increasing number of publications in recent years shows (Fisher et al. 2009, de Groot et al. 2010). The concept of ecosystem services, i. e., the direct and indirect contributions of ecosystems to human well-being (TEEB 2010), has become highly relevant in policy-making capturing the attention and interest of a wide range of institutions and decision-makers involved in biodiversity conservation, landscape planning and socioeconomic development.

Ecosystem services evaluation can be particularly useful in cultural landscapes (Schaich et al. 2011), such as the Mediterranean basin, where ecosystems and human societies have coevolved for millennia, producing a unique and characteristic landscape configuration (Makhzoumi and Pungetti 1999). In Mediterranean cultural landscapes, extensive management and traditional land-use practices have left room for highly biologically diverse agro-ecosystems responsible for the provision of important ecosystem services.

Transhumance, the seasonal migration of livestock between summer pastures in highlands at northern latitudes and winter pastures in lowlands at more southern latitudes, is one of the many customary practices developed by ancient Mediterranean societies to adapt to an unpredictable and highly fluctuating environment (Gómez Sal 2000, Herzog et al. 2005). Matching grazing pressure to seasonal peaks in pasture productivity allows an optimal exploitation of existing resources (Ruiz and Ruiz 1986, Manzano-Baena and Casas 2010).

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Transhumance has been acknowledged for its role in habitat conservation, seed dispersal, fire prevention, high quality meat production and cultural identity among other ecosystem services (Bunce et al. 2006). Although the latter are not always directly related to or dependent on livestock movement, the traditional practice is responsible for the conservation of crucial features of the social-ecological system that make the provision of ecosystem services possible.

In this article we present a methodological framework for ecosystem services evaluation, trade-offs analysis, and prioritisation of management strategies, which is particularly designed for transhumance cultural landscapes. We then illustrate its application to the case study of the Conquense Royal Drove Road (CRDR), one of the major Spanish drove roads still in use. In the end, we address the relevance and usefulness of the framework for policy-making and adaptive co-management in Mediterranean cultural landscapes.

Methodological Approach for Ecosystem Services Evaluation in Transhumance Landscapes

In order to develop a conceptual framework for ecosystem services evaluation, we have approached transhumance cultural landscapes as *social-ecological networks* (*sensu* Janssen et al. 2006), i. e., as "networks of biophysical and social flows generated and maintained by the movement of herders and livestock," including summering and wintering areas, the network of drove roads linking them and the associated social capital elements (Oteros-Rozas et al. forthcoming).

Our methodological framework is structured into four sequential phases (figure 1):

1. characterisation of the social-ecological network associated with transhumance,
2. preliminary identification and characterisation of ecosystem services,
3. evaluation of ecosystem services (in biophysical, socio-cultural and economic terms), and
4. future scenario planning for the analysis of social conflicts related to ecosystem services use and trade-offs as well as the proposal of management strategies.

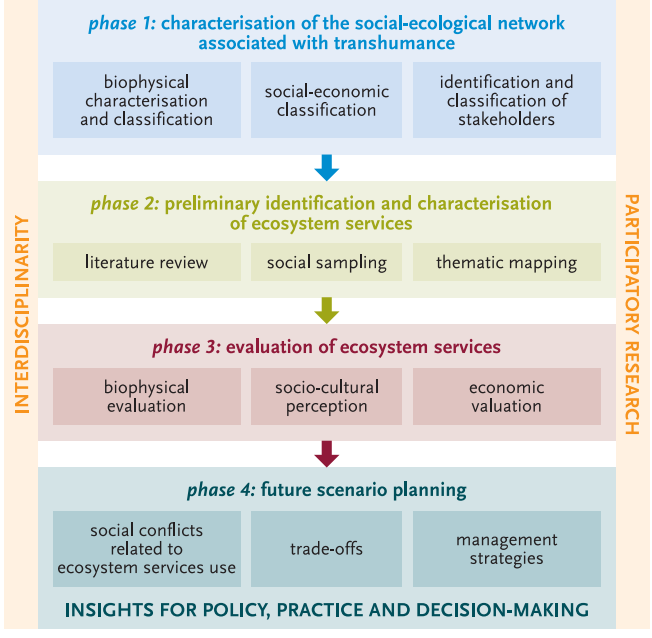
Two crosscutting issues permeate the entire process: interdisciplinarity and stakeholder participation. Despite its socio-cultural and ecological relevance, transhumance has been traditionally approached only from uni-disciplinary perspectives – either ethnological, historical or ecological. However, in order to highlight the importance of livestock movement from ecological, social and economic viewpoints (i. e., different value domains of ecosystem services) (Martín-López et al. 2009, De Groot et al. 2010), an interdisciplinary assessment of ecosystem services is particularly appealing. It is, moreover, fundamental to develop the whole assessment within a participatory process (Reed 2008), i. e., involving the diverse stakeholders, in order to accurately address the ongoing trade-offs and conflicts among ecosystem services beneficiaries and losers (Harrington et al. 2010). As specific stakeholders involved, transhumant herders as well as academics from different disciplines, environmental and cultural non-governmental organisations committed to the preservation of transhumance, and decision-makers involved in drove road management should be included in the implementation of such a participatory framework.

Phase 1: Characterisation of the Social-Ecological Network Associated with Transhumance

Looking at transhumant landscapes from a perspective of social-ecological networks requires first of all its ecological, social and economic characterisation and stakeholder identification (Liu et al. 2007).

Biophysical characterisation and classification: The aim is to spatially delimit and map ecological units; in our case, those linked to transhumant movement, including both summering and wintering areas as well as drove roads. A multiscalar cartography of the different ecosystems is therefore required. Through ecological classification, discrete and homogeneous units are obtained that are distinct from one another and can be described by the biophysical variables selected (Klijn and Udo de Haes 1990). The underlying assumption here is that the factors used for the classification determine the biological response of the ecosystems to human actions, so that in every ecological unit, the biological response would be homogeneous.

FIGURE 1: Methodological framework proposed for the evaluation of ecosystem services provided by the transhumance social-ecological network and its use as a tool for participatory decision-making.



Social-economic classification: An integrated and quantified description of the various social components of the social-ecological network and their reciprocal relations can be obtained not only by a superposition of social-economic data but also by analysing how the different administrative units (e. g., municipalities) relate to each other and to the natural system. Every unit is described following a list of socio-economic and cultural variables (e. g., population size and age, unemployment, educational level, household size, economic activity, land-use and ownership), which are grouped using a multivariate analysis (de Aranzábal et al. 2008).

Identification and classification of stakeholders: It is essential to identify differences and convergences in the stakeholders' relationships with the ecosystem services and management practices, their visions and priorities, and their management capacities. Semi-structured interviews with key informants and a classification analysis of social perceptions are used to characterise the different stakeholders. Environmental behaviour variables, other socio-cultural (such as sense of place) and demographic (such as age, gender or parental origin) variables and local ecological knowledge (of transhumance and drove roads, in our case) are used to describe each of the stakeholder groups.

Phase 2: Preliminary Identification and Characterisation of Ecosystem Services

The information necessary for the evaluation of ecosystem services (in phase 3) is gathered by using three different methods.

Literature review: Previous works on ecosystems and ecosystem services related to transhumance and other related issues (e. g., pastoralism and livestock movements) are reviewed.

Social sampling: We use deep, semi-structured interviews with key informants, specifically local inhabitants from the entire study area, experts from academia (ecology, anthropology and history), decision-makers and institutional representatives. Interviewees are asked to discuss the past, present and future of transhumance, related ecosystems, ecosystem services and the drivers of change that have determined the past and might influence the future.

Thematic mapping: Spatially explicit information on land use changes, protected areas and species, as well as any other social and biophysical variables related to the identified ecosystem services are charted.

Phase 3: Evaluation of Ecosystem Services

Once ecosystem services have been listed and described, the evaluation (phase 3) takes place. A wide range of methodologies can be used (see De Groot et al. 2010 for a review). The systemic perspective of our framework and the overall aim to highlight the importance of ecosystem services require the combination of three types of evaluation: *biophysical, socio-cultural* and *economic*. For an individual evaluation, specific ecosystem services are selected according to the importance stakeholders have given them in the first interviews (see phase 2, *social sampling*).

Biophysical evaluation: Mainly regulating services are evaluated through diverse mapping analyses with geographic information systems (GIS) and remote sensing (e. g., ecological and geological variables modelling), as well as experimental field samplings (e. g., habitat for species, biodiversity, soil erosion control, soil fertility or plant regeneration).

Socio-cultural perception: A social sampling with questionnaires is made based on a representative survey among identified stakeholders. The questionnaire is divided into sections regarding the person's knowledge of the practice (e. g., herders' names, issues about livestock movement or drove road location), social acknowledgement of and dependence on ecosystem services, tendencies and factors affecting ecosystem services flows in the future, responsible institutions and personal questions regarding socio-economic conditions and environmental attitudes (e. g., recycling habits or visits to protected areas). A further socio-cultural ecosystem services evaluation can be performed through visual tests (e. g., identifying and valuing ecosystem services in photographs of transhumance landscapes and livestock herds).

Economic valuation: The relative importance that the stakeholders assign to ecosystem services can be measured in monetary terms through different valuation methods, which are usually divided into three groups: *market-based, revealed preferences* and *stated preferences* (Chee 2004). Market-based methods estimate the contribution of an ecosystem service in different existing markets using *production functions,* i. e., based on the estimation of the contribution an ecosystem service makes for the production of another service with market value (Mäler et al. 1994), and *cost-based methods,* i. e., replacement and damage costs, which estimates the potential expenditure incurred in replacing or substituting the ecosystem service that is lost (Garrod and Willis 1999). Revealed preferences methods infer the value of the service using information about behavioural changes in real markets of a related commodity. The most widely applied techniques are *travel costs* and *hedonic pricing* (Freeman 1993). Stated preferences methods avoid conventional markets and explore hypothetical markets through individual questionnaires or discourse-based techniques (Wilson and Howarth 2002, Spash 2007). Most frequently used are *contingent valuation,* in which interviewees are asked about their individual willingness to pay or accept a payment for a change that affects the quality or quantity of the ecosystem services supply (Mitchell and Carson 1989), and *choice modelling* in which interviewees choose the most preferred option among the presented alternatives based on the notion that each of the alternatives can be described with a set of attributes and the levels that these attributes take (Hanley et al. 1998).

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Phase 4: Future Scenario Planning

The objective of phase 4 is to analyse past and future potential social conflicts related to ecosystem services use, trade-offs and management strategies in hypothetical future scenarios. Because social-ecological systems are characterised by uncertainty and are difficult to control, scenario planning is an extremely useful strategy to develop models for adaptive co-management practices[1] that permit a sustainable ecosystem services flow (Peterson et al. 2003, Palomo et al. 2011). The future scenario planning is carried out in a two-day workshop. The participatory process has various aims:

- the participants' reflection on possible future scenarios,
- the strengthening of social capital and the empowerment of participants through debates and interactions that occur during the workshop,
- the proactive analysis of possible and accurate solutions to problems or management practices that can anticipate future crises.

The workshop begins with analysing the changes that have occurred in the network (drivers of change), followed by a discussion of the strategies and adaptations it has developed. Then, plausible future scenarios (description of storylines, analysis of social conflicts and of trade-offs) are characterised and, finally, strategies for the maintenance of ecosystem services flows (backasting) are proposed.

Social conflicts related to ecosystem services use: The workshop provides the input to describe the relationships among the main characteristics of the current state of the social-ecological network. Changes from past to present are also covered, including stakeholders who have benefited from and/or have been affected by these changes.

Trade-offs: Trade-offs and synergies among ecosystem services result from the management of the social-ecological network (Bennett et al. 2009, Gordon et al. 2010). Having at hand information regarding ecosystem services flows and beneficiaries allows for assessing the complex interactions that emerge from ecosystems management, making it possible to know and deal with the pros and cons of each action and to assign different priorities (Martín-López et al. 2009). In this sense, the ecosystem services analysis conducted during the workshop results in a trade-offs analysis, both among ecosystem services flows in different scenarios and between different stakeholders (beneficiaries and losers).

Management strategies: By the end of the workshop, a complete, realistic and diverse proposal for management practices, policies and strategies to be taken by different stakeholders at different scales is obtained. From the whole set of measures, the most interesting and robust will be those that were common to all scenarios, independent of whether they were proposed for avoiding a negative aspect or enhancing a positive one.

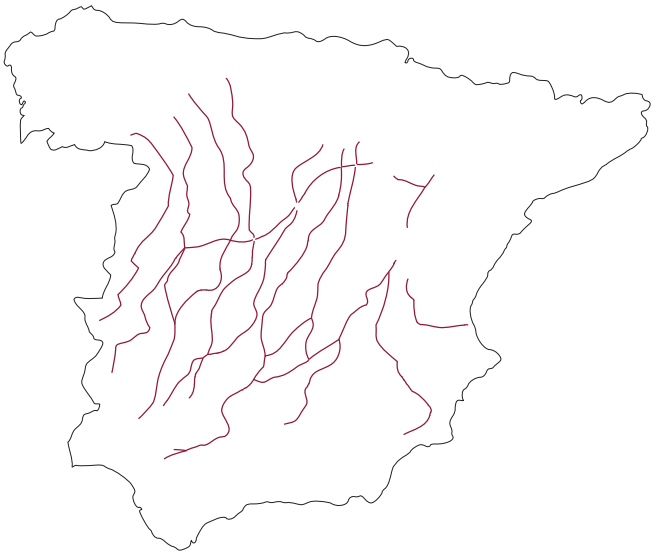

FIGURE 2: The major drove roads of the Spanish network for seasonal migration of sheep and cattle. Granted legal protection in 1995, the network extends over approximately 125 000 kilometres and occupies roughly 422 000 hectares (Cazorla et al. 2008). Not all drove roads are in regular use anymore.

The Conquense Royal Drove Road as a Case Study

Our framework proved its potential use in the study of the CRDR between 2009 and 2011. Within the Spanish network of drove roads (figure 2), the CRDR is the longest drove road in Spain that is still used by herders on foot to move their cattle and sheep. It includes a summering area located in the eastern forests of the Montes Universales (the Teruel, Guadalajara and Cuenca provinces), a wintering area located in southeastern Sierra Morena and the southern fields of La Mancha (the Jaén, Córdoba and Ciudad Real provinces), and the drove road itself, a 75-metres-wide (in most parts) corridor that crosses the central Iberian plateau (mostly in the Cuenca and Ciudad Real provinces) for approximately 410 kilometres (figure 3). A total of 15 transhumant shepherds walked the drove road in 2009 with 8 886 ovine heads and 1 184 bovine heads (Oteros-Rozas et al. forthcoming).[2]

1 We understand adaptive co-management following Folke et al. (2002) as "a process by which institutional arrangements and ecological knowledge are tested and revised in a dynamic, ongoing, self-organized process of trial-and-error."

2 According to official livestock movement permits granted by the Local Agrarian Offices in 2009, in the CRDR transhumance social-ecological network, a total of 87 shepherds with 57 769 ovine livestock heads were transhumant. Most (72) of the current transhumant shepherds use trucks or trailers to move their livestock. The CRDR shows that transhumance in Spain has made its way into the 21st century, although on a much smaller scale and with a different structure than it had in the past. This transhumance social-ecological network is therefore a unique and interesting example of a living, traditional, sustainable land-use practice positively associated with nature conservation.

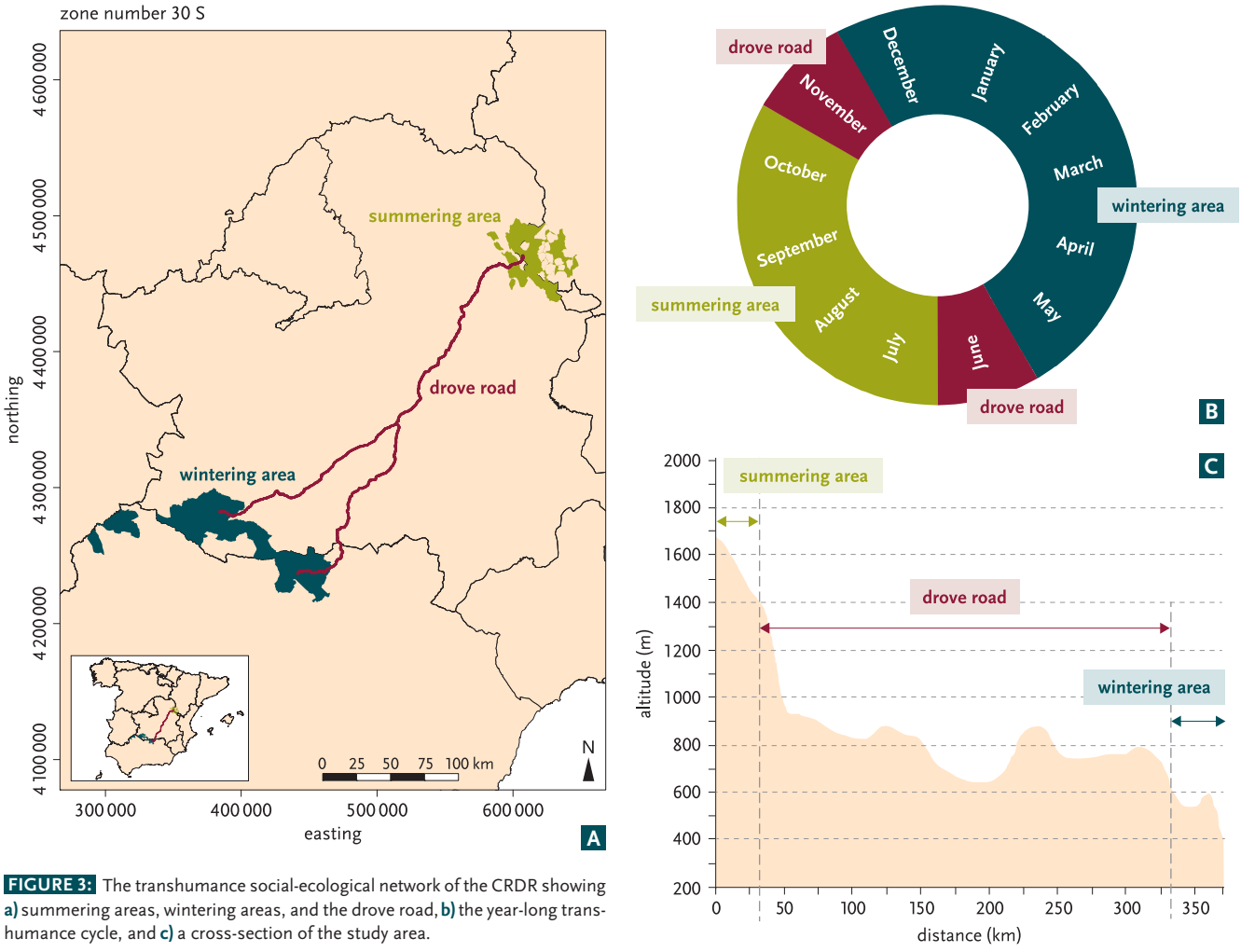

FIGURE 3: The transhumance social-ecological network of the CRDR showing **a)** summering areas, wintering areas, and the drove road, **b)** the year-long transhumance cycle, and **c)** a cross-section of the study area.

From July to November, sheep and cattle herds escape the dry Mediterranean summer by staying in the high plateau and mountainous areas, where they find refuge, food, and water. The summering area is characterised by vegetation of semi-deciduous and coniferous forests mixed with agricultural patches of fodder crops. In early November, when primary productivity drastically declines in the northern forests because of the great decrease in temperature, most shepherds and herds start the 25-to-30-day journey, crossing the central Iberian plateau along the drove road mostly surrounded by cultivated areas (vineyards and fields of sunflowers, cereals, and olives). Winter pasturelands, where shepherds and herds spend the next six months, are more dispersed, being located in lowlands characterised by a typical Mediterranean *dehesa* landscape, i. e., an agrosilvopastoral system mainly aimed at extensive livestock grazing, but from which also crops and non-timber forest products are obtained (figure 4, p. 190).

Interviewees (in phase 2) acknowledged a total of 33 ecosystem services in the three areas that form the network. Of these, ten were classified (following MA 2005) as provisioning, eleven as regulating and twelve as cultural services. Some of these services are mostly delivered by the summering area (e. g., fire prevention), some are mostly supplied by the wintering area (e. g., tree regeneration) and some by the drove road (e. g., seed dispersal), but most of them are associated with the whole network. In addition, even though not all ecosystem services identified are directly linked to the practice of transhumance, the integrity of the whole social-ecological network is.

Evaluation of ecosystem services provided a quantification of some ecosystem services flows; for some we simply proved their existence or their dependence on the presence of transhumant livestock, but have not yet quantified their supply.

The complete set of techniques that we propose for ecosystem services assessment in our framework (figure 1, phase 3) and used in this case study is presented in table 1 (p. 191). The specific evaluation of ecosystem services as directly or indirectly dependent on transhumance was achieved by comparing scenarios with and without transhumance, where all other variables were as similar as possible (with the same bio-geographical locations, ecological conditions, socio-cultural realities, economic conditions). From a biophysical perspective, we evaluated the capacity to provide different regulating services, such as tree regeneration, habitat for species (focused on both invertebrate and vertebrate taxonomic >

groups), soil formation and fertility, and fire prevention. In the socio-cultural evaluation, we asked interviewees about ecosystem services that would decrease or be degraded, either quantitatively or qualitatively, if there was no transhumance, and evaluated their perception of ecosystem services in photographs with and without transhumance elements (the drove road and a herd). Finally, from an economic viewpoint, we carried out market analysis of most provisioning services and cost-based analysis for different regulating services (e. g., fire prevention). We also performed a contingent valuation study in which we explored the willingness to pay for maintaining transhumance and the ecosystem services associated to this activity. Three examples of biophysical, socio-cultural and economic ecosystem services assessments are shown in table 2 (p. 192).

The results of the ecosystem services assessment were then used in a participatory "bottom-up" process to develop and prioritise adaptive co-management strategies for the maintenance of transhumant pastoralism in the CRDR as well as to provide insights for policy-making regarding transhumance at the national level. Participants of the two-day workshop came from the whole range of stakeholders related with transhumance management at different spatial scales (local, regional and national). A trade-offs analysis conducted during this process showed that current trends are triggering a loss of most regulating (e. g., fire prevention) and some cultural services (e. g., cultural identity), while promoting the production of some other cultural (e. g., recreational services) and provisioning services. Taking into account current patterns of global change (e. g., availability of fossil fuels, climate change), the participants characterised four plausible future scenarios for transhumance in the CRDR and discussed the expected trends of the different ecosystems services in each scenario. Finally, more than 90 management strategies and actions were proposed in order to foster the desirable aspects and to avoid the negative factors identified in the four scenarios. During the backasting, participants prioritised the implementation of schemes of payments for ecosystem services, the creation of cooperatives and associations of transhumants, the improvement of product commercialisation and the protection of drove roads against land-use changes as the most urgent needs.

Lessons Learnt and Insights for Policy-Making and Future Research

The application of our interdisciplinary and participatory methodological framework to the transhumance social-ecological network of the CRDR provided useful insights, which may be of interest for other similar studies:

- By highlighting the close links between ecosystems and human well-being (through the concept of ecosystem services), the framework was effective at drawing attention from civil society and facilitated the mobilisation of different stakeholders, particularly decision-makers.
- The methodological framework allowed researchers to address problems from a systemic angle and contributed to break down territorial barriers by considering the whole system as a social-ecological network with multiple connections at different spatial scales.
- All the phases of the methodological framework were embedded in an interdisciplinary research approach. The ecosystem services concept provided a common language that contributed to improve understanding and communication between the social and biophysical sciences and facilitated working under a single comprehensive and holistic perspective.
- The participatory research approach promoted the dialogue of complementary knowledge paradigms, putting scientific (experimental learning) and local (experiential learning) knowledge on the same level.

FIGURE 4: Transhumant herd of sheep in a *dehesa* within the wintering areas of the CRDR, La Carolina (Jaén, Spain).

Our interdisciplinary and participatory framework provided a base line upon which adaptive co-management strategies could be developed and tested. It basically contributed by encouraging stakeholders to share management responsibility while learning from their actions (Ruitenbeek and Cartier 2001). It also fostered deliberative activities, which are considered as a key component of adaptive co-management systems (Daily et al. 2009). Shared visions about current problems, future scenarios and possible alternatives for transhumance revitalisation were built in

TABLE 1: All the ecosystem services identified and the specific methods of evaluation used in the case of the CRDR: biophysical, socio-cultural and economic. The social value of all the ecosystem services was also evaluated using questionnaires of individual and social perception, and the monetary value was estimated through contingent valuation.

ecosystem services type	ecosystem services	type of evaluation				data source
		biophysical	*socio-cultural*	*economic*		
				market analyses	*stated preferences*	
provisioning	gathering (e. g., wild plants)		x	x	x	questionnaires, statistical databases
	manure	x	x	x	x	questionnaires, statistical databases
	feed for animals (e. g., fodder)		x	x	x	questionnaires, statistical databases
	food from livestock (e. g., lamb and beef)	x	x	x	x	questionnaires, statistical databases
	food from agriculture (e. g., oil)		x	x	x	questionnaires, statistical databases
	food from hunting (e. g., rabbit meat)		x		x	questionnaires
	products from apiculture		x		x	questionnaires
	fibre (e. g., wool, fur)	x	x	x	x	questionnaires, statistical databases
	wood and timber		x		x	questionnaires
	genetic pool (e. g., local breeds)		x		x	questionnaires
regulating	tree regeneration (e. g., *dehesa* maintenance)	x	x		x	ecological field samplings (oak regeneration in the wintering area), questionnaires
	biological control		x		x	questionnaires
	fire prevention (natural hazard)	x	x		x	remote sensing and geographic information system (GIS) tools, statistical analyses of fire frequencies and questionnaires
	connectivity and seed dispersal	x	x		x	GIS tools (fragmentation and travel cost indexes), questionnaires
	maintenance of soil fertility	x	x	x	x	GIS, statistical analyses of secondary information, questionnaires
	soil erosion control	x	x		x	soil sampling, questionnaires
	air purification		x		x	questionnaires
	habitat for species	x	x		x	ecological field samplings (distribution of hunting species, invertebrate taxonomic and functional diversity), questionnaires
	pollination		x		x	questionnaires
	microclimate regulation		x		x	questionnaires
	hydrological regulation		x		x	questionnaires
cultural	cultural identity (sense of place)		x		x	questionnaires
	spiritual value		x		x	questionnaires
	nature recreation activities (e. g., sports)		x		x	questionnaires, statistical databases
	recreational hunting		x		x	questionnaires
	bullfighting events		x		x	questionnaires
	rural tourism (e. g., gastronomic)		x		x	questionnaires, statistical databases
	tranquillity/relaxation		x		x	questionnaires
	way of cultural exchange		x		x	questionnaires
	environmental education		x		x	questionnaires
	scientific knowledge		x		x	questionnaires
	aesthetic value		x		x	questionnaires (specific social perception test through photographs)
	local ecological knowledge		x		x	in-depth interviews, focus groups and specific questionnaires

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workshops and focus groups. Moreover, our framework tackled some other key features that characterise adaptive co-management (Armitage et al. 2007). Multi-scale stakeholders were involved and encouraged to develop higher degrees of dialogue, interactions and collaboration. The need to share out responsibilities for action and decision-making emerged from several of the management strategies suggested to support transhumance. The active search for consensus allowed all stakeholders, at different levels, to cooperate in search of win-win solutions that enable economic, social and ecological sustainability of transhumance. Finally, the whole process allowed stakeholders to more easily recognise and embrace uncertainty (e. g., global markets tendencies, Common Agricultural Policy or climate change), hence alleviating tensions and opening their minds for innovation and systematic learning.

The ecosystem services assessment proposed here has contributed to the conservation and support of the drove road system and the transhumance cultural landscapes by:

- scientifically proving the existence of some ecosystem services related to transhumance (e. g., tree regeneration in *dehesas*) that, to date, had just been hypothesised,
- providing primary data about some ecosystem services in transhumance cultural landscapes, therefore making the dependence of human well-being on agro-ecosystems more visible to society,
- providing information about people's motivations for maintaining these ecosystem services,
- drawing attention to the consequences of land-use changes in terms of ecosystem services trade-offs,
- facilitating the implementation of precise locally driven actions and management measures for the conservation of transhumance in the region, and
- developing a broad interdisciplinary vision for landscape management at the national level based on the maintenance of the wide spectrum of ecosystem services supplied by the transhumance social-ecological network.

Case studies such as the one presented here are vital to transfer conceptual constructs into operative actions and face new challenges in ecosystem services assessment while enriching researchers with experiences, skills and tools. In addition, our methodology integrates into a single and comprehensive framework the different facets that, according to Seppelt et al. (2011), should characterise the holistic ideal of ecosystem services research, by using an integrative approach that considers biophysical, socio-cultural and economic indicators and measures, deriving results from primary data, evaluating simultaneously diverse ecosystem services in order to explore trade-offs and synergies, considering uncertainty in ecosystem services assessment, and involving stakeholders throughout the whole research process.

All in all, we believe that the proposed framework can be applied to other cultural landscapes or social-ecological systems, especially in the Mediterranean region. Conceptual and methodo-

TABLE 2: Examples of biophysical, socio-cultural and economic evaluations of three ecosystem services performed in the CRDR social-ecological network.[a]

type of evaluation/ecosystem service evaluated	methodological approach	main results
biophysical evaluation: structural and functional connectivity provided by the presence of the drove road	A GIS polygon file was built with current land cover in the CRDR network. Structural connectivity was evaluated through polygon counts under three different scenarios (absence of drove road, drove road with its actual width, and a hypothetical drove road with the legal 75-m width). Functional connectivity was evaluated using the travel cost index (a GIS tool based on resistance). Three types of matrices (forest, drove road and agrarian) and three theoretical matrix resistance values for different wildlife species (low, medium and high) were explored.	The current drove road physically connects seven forest patches comprising 9 350 ha, while a drove road with its legal width would connect 25 forest patches totalling 77 180 ha. Regarding functional connectivity, the presence of the drove road reduces resistance to wildlife movement by 0.2 to one percent on the whole trip between summering and wintering areas (up to ten percent in the case of the drove road with legal width). However, this effect is particularly important in those stretches that cross a highly transformed agrarian matrix, where the resistance reduction effect can reach 62 percent.
socio-cultural evaluation: aesthetic value of the drove road and livestock presence as perceived by different stakeholders	Questionnaires (n = 286) were applied to local inhabitants and non-residents, asking them to express their aesthetic preferences when comparing 30 photographic pairs. Pictures in every pair were very similar except for the presence/absence of a drove road, or the presence/absence of livestock. Differences were analysed using Kruskal-Wallis tests and multivariate analyses.	Overall, no significant effect was observed regarding the presence of the drove road in the landscape, but differences were found among certain groups of stakeholders. All consulted stakeholders positively selected the presence of livestock in the landscape. Livestock herders (either transhumant or not) and neo-rural people were the stakeholders with a higher preference for the presence of the drove road and livestock in all the landscapes.
economic evaluation: soil fertility provided by sheep manure in stubble fields of the summering area	Total manure production of sheep was estimated by multiplying the number of transhumant sheep heads by the average daily rate of manure deposition and the number of days sheep spent feeding in stubble fields in the summering area. The equivalent monetary value of fertilisation using sheep manure as fertiliser was calculated at current market prices.	Over 1 000 tonnes of manure are produced every year by transhumant sheep in the summering area, and distributed over 19 000 ha of stubble fields (ca. 54 kg/ha). The monetary investment needed to replace this fertilisation service would reach over 35 500 EUR at market price (not including the labour necessary to distribute manure, another service also provided by sheep).

a More detailed information on the methods and a full report with examples of other ecosystem services that have been evaluated can be accessed at *www.uam.es/gruposinv/socioeco/ficha_proyecto_4.htm*.

logical frameworks such as the one presented here can foster new paradigms of interdisciplinary and participatory science-based action that could allow society to successfully face the challenges associated with the current patterns of global change.

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