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RESEARCH ARTICLE

Perceived ecosystem services synergies, trade-offs, and bundles in European high nature value farming landscapes

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Abstract
Context Around 30% of European agricultural landscapes are classified as high nature value (HNV) farmlands. Current policies emphasize the multifunctionality of these landscapes, but little is known about the positive and negative associations of multiple ecosystem services within HNV farmland.
Objectives This study aims to identify perceived ecosystem services synergies, trade-offs, and bundles in agricultural landscapes of HNV from a socio-cultural perspective.
Methods We performed a participatory mapping survey of 10 ecosystem services categories among 2301 rural residents in 13 European sites. We analyzed bivariate synergies and trade-offs between perceived ecosystem services through nonparametric correlation analyses. Spatial bundles of perceived ecosystem services were identified through hierarchical cluster analysis. Multinomial logit models were used to assess the influence of land cover on generating associations of ecosystem services.
Results We find two strong and 16 moderate synergies of perceived ecosystem services (out of 46 possible ecosystem services pairs), mainly among different cultural ecosystem services. We do not reveal moderate or strong trade-offs. We identify five spatial bundles of ecosystem services, termed "Ecosystem services coldspots", "Wild harvesting ranges", "Nature areas", "Recreational spaces", and "Ecosystem services hotspots". Of all land-cover co-variates,

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natural areas, urban areas, and roads have the strongest explanatory power.

Conclusions Our study complements prevailing biophysical and economic analyses of ecosystem services synergies, trade-offs and bundles by a spatially explicit, socio-cultural perspective. We conclude that socio-cultural mapping of ecosystem services is useful for understanding the perceived multifunctionality of a landscape.

Keywords Agricultural landscapes · Cross-site analysis · Ecosystem services bundles · Landscape management · PPGIS · Socio-cultural valuation

Introduction

Evaluating synergies, trade-offs, and bundles has developed into an important field of ecosystem services research (Howe et al. 2014; Cord et al. 2017; Saidi and Spray 2018). Identification of the nature of these interconnections can bring numerous benefits for managers and policy makers when working with complex landscapes. At the same time, it remains one of the most critical challenges of social–ecological systems research (Queiroz et al. 2015). Ecosystem services trade-offs occur when the supply of one service is enhanced through land management at the cost of reducing the supply of another service (Bennett et al. 2009). In turn, ecosystem service synergies arise when multiple services are enhanced simultaneously (Raudsepp-Hearne et al. 2010). With competition for land growing worldwide (Smith et al. 2010), trade-offs around agriculture are likely to increase substantially, in particular conflicts between provisioning services and other ecosystem services (Power 2010). Awareness of trade-offs is a prerequisite for going beyond simplistic win–win assumptions (Daw et al. 2015), especially when managing farmland for multiple ecosystem services (Andersson et al. 2015a). More recently, common sets of ecosystem services that appear repeatedly together across space or time have been termed “ecosystem services bundles”, and a rich literature has investigated such bundles in different settings (e.g., Martín-López et al. 2012; Renard et al. 2015; Ament et al. 2017; Baró et al. 2017).

Trade-offs refer to various situations, and they act across multiple spatial and temporal scales (Rodriguez et al. 2006). On the one hand, trade-offs occur in the form of conflicts between simultaneously provided ecosystem services (ecological or supply–supply trade-offs, sensu Mouchet et al. 2014). For example, ecological trade-offs exist between crop yields and soil quality in Mexican agroecosystems (González-Esquivel et al. 2015). On the other hand, trade-offs find expression in conflicts between different stakeholders’ interests (socio-economic or demand–demand trade-offs) (Martín-López et al. 2014). Such conflicts in ecosystem services valuation have for example been found between fishers, managers, and scientists in coral reef ecosystems (Hicks et al. 2013). Mismatches between supply and demand of ecosystem services are also considered trade-offs (García-Nieto et al. 2013; Castro et al. 2014). Existing studies have identified almost three times more ecosystem services trade-offs than synergies (Howe et al. 2014). Trade-offs are driven by institutional, socio-economic, and biophysical drivers (Turkelboom et al. 2018); they are likely to occur when provisioning services, private interests, and the local scale are involved—such as in the case of agriculture (Howe et al. 2014).

Farming systems that deliver broad sets of ecosystem services have been proposed as a strategy to minimize ecosystem services trade-offs (Rabbinge and Bindraban 2012; Fischer et al. 2014). High nature value (HNV) farming is a European expression of such a strategy (besides others, such as organic farming, agroforestry, or ecological intensification, Plieninger et al. 2016). HNV farmlands are “areas in Europe where agriculture is a major (usually the dominant) land use and where that agriculture supports, or is associated with, either a high species and habitat diversity or the presence of species of European conservation concern, or both” (Andersen et al. 2003, p. 4). HNV farmlands are found in a multitude of environments, climatic conditions, economic contexts, and production systems, covering about 30% of the utilized agricultural area within the European Union (Lomba et al. 2014). HNV farmland comprises grasslands (e.g., wood-pastures, steppes, heathlands), arable lands (in particular those covered by low-intensity cropping systems in dryland areas), permanent croplands (e.g., orchard meadows, terraced olive groves), and mosaic landscapes (composed of diverse agroecosystems that are managed in low intensity)

(Keenleyside et al. 2014). Many HNV farmlands are found in the Mediterranean Basin, Eastern Europe, upland areas, and on the margins of Northwestern Europe (Cooper et al. 2007). Key determinants of high biodiversity and diverse ecosystem service delivery of HNV farming systems are practices of low intensity in terms of fertilizer and pesticide inputs, machinery, and livestock stocking levels used; the substantial coverage of semi-natural vegetation; and diversity of land cover (Dorresteijn et al. 2015).

HNV farming systems have been primarily studied for the biodiversity values that they support (e.g., Doxa et al. 2012; Aue et al. 2014). However, HNV farming landscapes have the potential to supply a wide diversity of ecosystem services such as provisioning (e.g., high-quality food and maintenance of genetic resources), regulating (e.g., soil quality regulation, pollination, and water purification), and cultural services (e.g., heritage, recreation, and ecotourism). The role of HNV farmlands for biodiversity conservation, ecosystem services supply, and rural development has been acknowledged within several agricultural and environmental policies of the European Union (Strohbach et al. 2015). For example, the extent of HNV farmland is used as an indicator for the effectiveness of the EU Rural Development Programs (Lomba et al. 2015). But despite this recognition, many of Europe's HNV farming systems are vulnerable due to social and economic changes (i.e. depopulation, loss of economic profitability) (O'Rourke and Kramm 2012). In particular, shifts from local to globalized markets, availability of and higher wages for off-farm jobs, mechanization, and changes in land use practices have put HNV farming under pressure (Plieninger and Bieling 2013; Ribeiro et al. 2014).

Even though HNV farming systems are likely to be more multifunctional than other land-use systems, they have the potential to create trade-offs that require sophisticated analysis (Plieninger and Bieling 2013; Strohbach et al. 2015). Cultural ecosystem services, biodiversity, and diverse stakeholders are important aspects of HNV farming (as highlighted, for example, for European wood-pastures; Plieninger et al. 2015) and thus need to be integrated into analyses of trade-offs around HNV farming. However, these are underrepresented in most of the literature (Howe et al. 2014) where typically only a narrow set of ecosystem services trade-offs and synergies is studied (Nelson et al. 2009). As ecosystem services trade-offs in agriculture are social and ecological phenomena, broad and integrative approaches to identify and manage them are needed (Andersson et al. 2007; Reyers et al. 2013). Such integrative approaches can be especially useful to inform payment schemes for ecosystem services from HNV farming, which are currently being developed in several European countries (Birge et al. 2017). However, ignorance of the complex dynamics of ecosystem services across spatial and temporal scales as well as lacking integration of stakeholder perspectives have so far limited the usefulness of studies on synergies and trade-offs between ecosystem services (Cord et al. 2017). Cross-site studies are a promising way to cope with the first issue of scale effects (Magliocca et al. 2015; Queiroz et al. 2015; Spake et al. 2017). Participatory mapping is increasingly used to elicit stakeholder values of ecosystem services (Brown and Fagerholm 2015) and can thus address the second issue of lacking stakeholder integration. Therefore, this study combines cross-site and socio-cultural mapping approaches. We aim to identify ecosystem services synergies, trade-offs, and bundles in 13 European agricultural landscapes as perceived by rural residents and to analyze how these are mediated by land-cover factors. Focusing on HNV farming landscapes, we ask the following research questions:

- To what extent do local residents' perceptions and uses of ecosystem services overlap spatially, and what are the resulting synergies and trade-offs of ecosystem services?
- Which bundles of ecosystem services do local residents perceive in HNV farming landscapes?
- Which land-cover properties determine particular bundles of ecosystem services as perceived by local residents?

Methods

Study areas

This study was performed in 13 study sites in 10 European countries: Canton de Loudeac (France), Franches Montagnes (Switzerland), Hochkirch-Weißenberg (Germany), Kassandra (Greece), Linköping (Sweden), Llanos de Trujillo (Spain), Montaña Oriental Lucense (Spain), Montemor-o-Novo

(Portugal), Saxon Region (Romania), Schwarzbubenland (Switzerland), Serena Campiña (Spain), The Brecks (UK), and Zala (Hungary). These sites are predominantly agricultural landscapes and form ecologically and socio-culturally consistent units (Martín-López et al. 2017). The four major types of HNV farmlands are represented (livestock dominated systems, arable dominated systems, permanent crop dominated systems, mosaic HNV landscapes) (Keenleyside et al. 2014), and between 0.1 and 92.7% are covered by HNV farmland. For example, the Montaña Oriental Lucense area in Spain is a mountainous mosaic landscape comprised of a river basin, small villages, forests, pastures, arable land, and traditional chestnut (*Castanea sativa*) groves. The Linköping area in Sweden covers livestock dominated systems in peri-urban areas and includes the largest extent of Fennoscandinavian wood-pastures (composed by *Quercus robur* and *Quercus petraea*). The study sites differ in size between 320 and 9330 km^2, host a population density between 3 and 185 inhabitants per km^2, and show enormous differences in wealth levels. Between 0 and 84% of each site are parts of protected area networks. Most areas are predominantly rural regions (e.g., the Romanian and Spanish sites), while some are classified as intermediate regions (e.g., the Swedish site). They are located in the Mediterranean, Atlantic, Continental, Boreal, and Pannonian biogeographic zones of Europe. Table 1 gives an overview of the most characteristic features of each site.

Ecosystem services assessment

We developed a locally relevant ecosystem services typology that places specific focus on the socio-cultural dimension of landscapes, starting from existing typologies (Millennium Ecosystem Assessment 2003; Haines-Young and Potschin 2013). We used 10 ecosystem services categories, covering provisioning services, regulating services, cultural services, and biodiversity: (1) farm products, (2) wild products, (3) outdoor activities, (4) social interactions, (5) aesthetic values, (6) cultural heritage, (7) inspirational values, (8) existence value, (9) provisioning of habitats and biodiversity, (10) regulating services (erosion control, soil fertility, water and climate regulation, air quality maintenance). We formulated indicator statements, for example as "I appreciate, produce, or can buy farm products here" (for farm products as ecosystem services, Table 2). Conceptually, our assessment captures the potential demand for ecosystem services (sensu Cord et al. 2017).

In each study site, we performed a survey that covered full or part time local residents whom we recruited through purposive stratified sampling based on the criteria of gender and age (15–29 years, 30–59 years, $\geq$ 60 years) in proportion to local census data. Informants were chosen by convenience sampling on site and approached in key public locations, such as market places, cafés, schools, and health care centers. We carried out data collection between May 2015 and August 2016 through a web-based public participation GIS (PPGIS) survey operated on tablets and laptops (see for example https://app.maptionnaire.com/fi/869 for the survey in the Serena Campiña site). We tested the method in a pilot study in site 6 (Fagerholm et al. 2016). Respondents filled in the survey with the help of facilitators. We provided facilitators with a manual and trained them in 2–3 day on-site visits by two of us (N.F., M.T.) to ensure that ecosystem services categories, the wording, and the web-based survey platform were used consistently across the 13 study sites. We performed the survey in the local languages of all study sites. The survey asked about the spatial location of ecosystem services perception and use within the respective study site, addressing the 10 different ecosystem service categories (including open follow-up questions for contextualization), and also covered socio-demographic characteristics. Respondents could map places (point features) where they use or perceive ecosystem services values. The number of points to be mapped was not limited. The facilitators interviewed a total of 2301 respondents in the 13 sites. Women (50% of responses) and men (49%) were equally considered; 20% of informants were younger than 30 years, 49% between 30 and 59 old, and 30% 60 years and older. 54% of informants were employed, 23% were retired, and 19% were caring for their families, students, or jobless (the remaining 4% did not specify). Of the respondents currently employed, around 15% were working in agriculture or forestry, while the bulk of informants (85%) were not. Within the sample, 78% reported to have extremely good knowledge, 17% quite good knowledge, and 5% poor knowledge of the area.

Table 1 Key social–ecological characteristics of the study sites

Sites	Locations	Countries	Extent (km^2)	HNV farmland cover (%)	HNV types	Protected area cover (%)	Biogeographic zones	Population density (n/km^2)	Wealth (GDP/capita) (€)
1	Canton de Loudeac	France	3258	0.1	Arable dominated	0.8	Atlantic	20	22,300
2	Franches Montagnes	Switzerland	1854	16.6	Livestock dominated	15.0	Continental	75	56,400
3	Hochkirch-Weißenberg	Germany	3136	1.5	Arable dominated	47.2	Continental	62	20,700
4	Kassandra	Greece	595	n/a	Permanent crop dominated	10.9	Mediterranean	49	15,000
5	Linköping	Sweden	9330	9.0	Livestock dominated	5.1	Boreal	96	34,440
6	Llanos de Trujillo	Spain (LT)	5931	92.7	Livestock dominated	53.1	Mediterranean	12	15,700
7	Montaña Oriental Lucense	Spain (ML)	3730	55.8	Mosaic HNV landscapes	19.1	Atlantic	15	19,500
8	Montemor-o-Novo	Portugal	4470	41.5	Livestock dominated	37.2	Mediterranean	3	13,500
9	Saxon Region	Romania	957	53.0	Mosaic HNV landscapes	84.0	Continental	26	4600
10	Schwarzbubenland	Switzerland	320	11.6	Permanent crop dominated	0.4	Continental	168	61,200
11	Serena Campiña	Spain (SC)	2479	70.5	Arable dominated	38.0	Mediterranean	10	15,600
12	The Brecks	UK	1138	7.3	Arable dominated	39.0	Atlantic	46	45,700
13	Zala	Hungary	1288	14.9	Livestock dominated	43.5	Pannonian	185	6300

GDP gross domestic product; year of reference 2011. NUTS 3 level

Sources Eurostat, Swiss Federal Statistics Office

Table 2 Descriptions of the ecosystem services categories used in the participatory mapping exercise

Ecosystem service	Description
Farm products	I appreciate, produce or can buy farm products here
Wild products	I harvest fruits, berries, flowers, mushrooms, asparagus, fish, game etc.
Outdoor activities	I practice outdoor sports, walking, hiking, biking, dog walking etc.
Social interactions	I spend time together with other people
Aesthetic values	I enjoy seeing this beautiful landscape or landmark
Cultural heritage	I appreciate the local culture, cultural heritage or history
Inspirational values	I am inspired by feelings, new thoughts, religious or spiritual meanings etc.
Existence values	I appreciate this place just for its existence regardless of benefits for me or others
Habitats and biodiversity	I appreciate the plants, animals, ecosystems etc.
Regulating services	I appreciate the environmental capacity to produce, preserve, clean, and renew air, soil, and/or water

The column "Descriptions" specified spatially explicit answers to the question: "Do you find some particular place or area special in this landscape?"

Statistical analyses

Based on mapping scale and evaluated accuracy in point placement, we built a grid with 400 m output cell size. We discarded cells with no presence of perceived ecosystem services, resulting in n = 8547. We normalized density values with linear transformation function to scale 0–1 to allow for cross-site analyses.

Prior to further analysis, we ran a principal component analysis (PCA) on the database in order to reduce the dimensionality of the dataset. The variables included in the PCA comprised the full set of perceived ecosystem services, and the units were the number of times that each service was mapped in a cell. To determine the number of axes to retain from the PCA, we followed the Kaiser criterion (eigenvalue > 1) and included enough axes to explain more than 65% of the variability. To analyze pair-wise associations between perceived ecosystem services we used bivariate non-parametric Spearman's rank order correlation (r_s). The analyses were based on the factor loadings produced in the PCA. We categorized correlation coefficients as strong when $r_s \geq 0.5$, as moderate when r_s values ranged from > 0.3 to < 0.5, and as weak when $r_s \leq 0.3$ (Fagerholm et al. 2012).

In order to identify bundles of perceived ecosystem services, we used the factor loadings of the retained components of the PCA (first five components) and carried out two separate hierarchical cluster analyses (HCA). The first HCA identified how perceived ecosystem services bundled by using the factor loadings of the variables analyzed in the PCA (the set of 10 ecosystem services categories). This would identify which perceived ecosystem services tend to consistently co-occur (similar to Martín-López et al. 2012; Torralba et al. 2018). The second cluster analysis identified the spatial bundles of perceived ecosystem services by using the factor loadings of every observation (each grid cell, n = 8547 cells). This would group the landscape sub-units based on the services that were perceived there (cf. Hanspach et al. 2014; Mouchet et al. 2017). As all input variables were continuous, we used in both HCA the Euclidean distance with Ward's technique as an agglomerative method (Ward Jr 1963).

To assess the influence of the landscape in generating associations of perceived ecosystem services, we performed a multinomial logit model that predicted the probability of a cluster membership given changes in the biophysical landscape. We tested for differences in the priorities assigned to individual spatial bundles (dependent variable) in relation to six explanatory independent variables. These were the proportion (in percent) of land within protected areas (using the database of the European Network of Protected Sites, http://www.eea.europa.eu/data-and-maps/data/natura-7 and Nationally Designated Areas, http://www.eea.europa.eu/data-and-maps/data/nationally-designated-areas-national-cdda-11#tab-gis-data) and the share of land within each grid cell (in %) covered by the following land-cover classes respectively: (a) simplified agricultural areas, (b) heterogeneous agricultural

Table 3 Significant bivariate correlations between pairs of variables

Wild products	Outdoor activities	Social interactions	Aesthetic values	Cultural heritage	Inspirational values	Existence values	Habitats and biodiversity	Regulating services	
0.112	0.193	0.295	0.180	**0.450**	0.279	0.211	*− 0.006*	0.128	Farm products
	0.209	0.156	0.258	0.277	0.195	0.089	0.137	0.167	Wild products
		0.317	**0.400**	**0.393**	**0.328**	0.246	0.223	0.242	Outdoor activities
			0.434	***0.598***	**0.370**	0.256	0.081	0.223	Social interactions
				0.305	**0.402**	**0.421**	**0.444**	**0.337**	Aesthetic values
					0.492	***0.625***	**0.499**	0.296	Cultural heritage
						0.341	0.186	0.266	Inspirational values
							0.109	0.257	Existence values
								0.320	Habitats and biodiversity

Italics indicates weak negative correlations (Spearman coefficient $r_s \leq 0.3$), bold moderate positive correlations ($0.5 > r_s > 0.3$) and bold italics strong positive correlation ($r_s \geq 0.5$)

areas, (c) natural areas (forests and water bodies), (d) urban areas (based on 2006 CORINE land cover data, http://www.eea.europa.eu/data-and-maps/data/clc-2006-raster-4). We also tested for relations to the length of roads and paths (in km) within each grid cell as an indicator of access to landscapes (source: OpenStreetMap, https://www.geofabrik.de/data/download.html). All statistical analysis were performed using XLSTAT, version 9.0.

Results

Spatial associations between perceived ecosystem services

We found multiple bivariate associations between perceived ecosystem services (Table 3). All of the 45 possible pairs of perceived ecosystem services were significantly correlated ($p < 0.05$). Two pairs were strongly correlated (Spearman coefficient $r_s \geq 0.5$), 16 were moderately correlated (Spearman coefficient $0.5 > r_s > 0.3$), and 27 were weakly correlated ($r_s \leq 0.3$). Almost all associations were positive, and we did not find any moderate or strong negative interactions. The strongest positive interactions were among cultural heritage and social interactions ($r_s = 0.598$) and among cultural heritage and existence values ($r_s = 0.625$). The highest numbers of moderate and strong positive correlations showed cultural heritage (7), aesthetic values (5), and inspirational values (5). The lowest numbers had wild products (0 moderate or strong correlations) and farm products (1 moderate correlation).

Clusters of ecosystem service categories

In the PCA, the first five components accounted for 67.1% of the variation. This first component explained 28.8% of the variation and showed positive factor loadings for all perceived ecosystem services. The second component accounted for an additional 12.0% and described a spatial trade-off mainly between (a) farm products and cultural heritage values and (b) biodiversity and habitats, regulating ecosystem services, and wild products. It could be interpreted as gradient from more agricultural to more natural ecosystems. The third, fourth, and fifth components

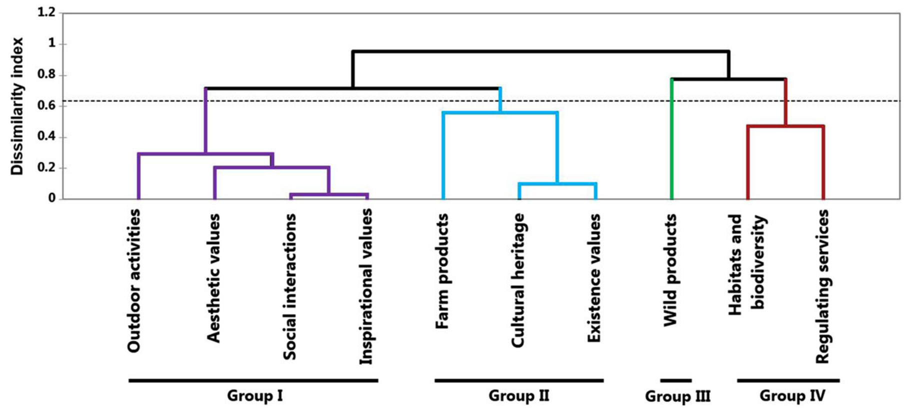

Fig. 1 Dendrogram of the hierarchical cluster analyses of perceived ecosystem services variables

additionally accounted for 9.6, 8.5, and 8.1% of the variation and emphasized the role of wild products, regulating ecosystem services, and outdoor recreation (Table S1; Fig. S1).

The cluster analysis with the factor loadings from the five first components of the PCA classified the ecosystem services indicators into four groups (Fig. 1). Group I comprised key cultural ecosystem services, including those related to activities: outdoor activities, aesthetic values, social interactions, and inspirational values. Group II was diverse, including provisioning services (farm products), cultural services (cultural heritage), and existence values. Group III was composed of wild products only. Group IV united habitats and biodiversity as well as regulating services.

Spatial bundles of perceived ecosystem services

The HCA classified the sites into six well-defined bundles according to their ecological characteristics (Fig. 2; Table S2). The first bundle, termed “Ecosystem services coldspots”, covered places (n = 2425 cells) where people generally allocated very few ecosystem services. Aesthetic values, social interactions, and cultural heritage appeared in low intensities. The second bundle, “Wild harvesting ranges”, were places (n = 1560) that were also generally low in perceived ecosystem services, but harvesting of wild products was of importance here. A particular feature of the places (n = 921) in the third bundle, “Nature areas”, was that biodiversity and habitats and regulating services were perceived as important, while all other ecosystem services categories ranked low. The fourth bundle, “Recreational spaces”, comprised places (n = 2154) important for outdoor activities and biodiversity and habitats. The fifth bundle, “Farmlands”, included places (n = 989) of some importance in terms of farm products. The last bundle (and the smallest one in terms of sites included, n = 498), “Ecosystem services hotspots”, comprised those places where all services (in particular, many cultural ecosystem services) ranked by far highest.

Influence of land-cover predictors

The multinomial logit model revealed that, from all co-variates, natural areas (forests and water bodies; Cox and Snell $R^2 = 0.07$, $p < 0.01$), urban areas (Cox and Snell $R^2 = 0.06$, $p < 0.001$), and roads (Cox and Snell $R^2 = 0.06$, $p < 0.01$) explained most of the variation, with the R^2 of all models being significant, but low (Table 4). Some co-variates (e.g., urban areas, road density) were significant predictors of all bundle types, while others affected only particular bundles. For example, protected area coverage was only a significant predictor for the “Nature areas”, “Recreational spaces”, and “Farmlands” bundles.

Land-cover predictors affected the spatial bundles quite differently (Fig. 3). A high cover of natural area was clearly related to the “Nature areas” bundle. The “Wild harvesting ranges” and the “Recreational spaces” bundles had peak values at intermediate levels of natural area cover, whereas the “Farmlands” bundle showed negative responses to increasing natural area cover. For urban areas, the “Farmlands”

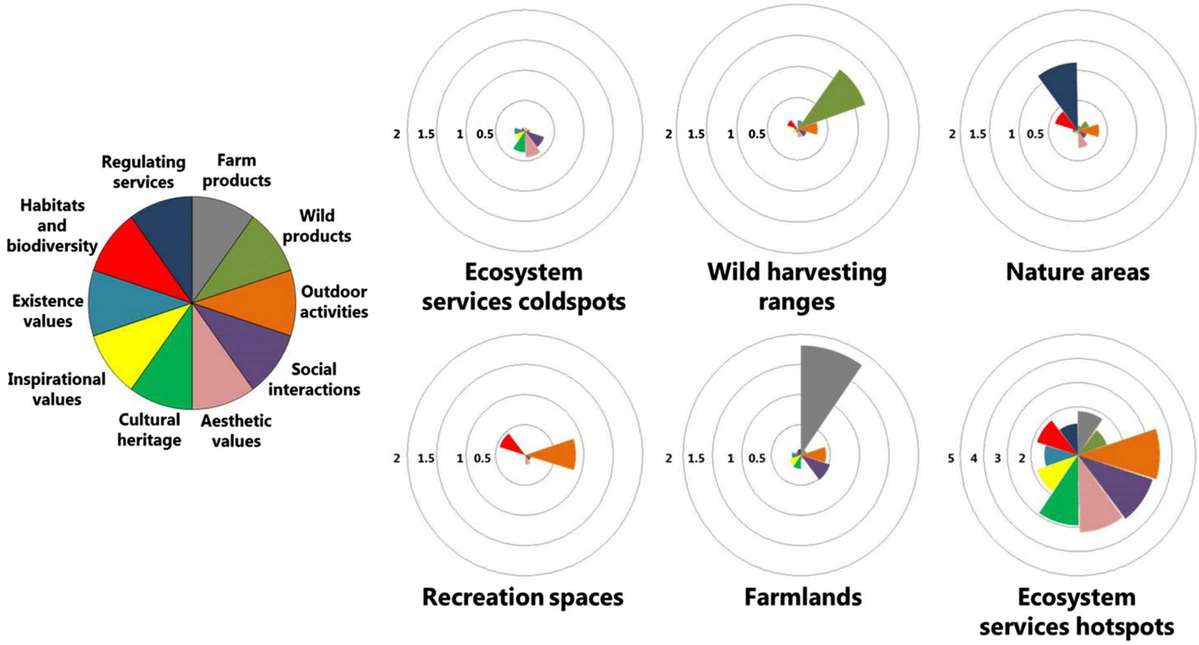

Fig. 2 Flower diagrams specifying the average values of each perceived ecosystem service in each bundle

Table 4 Model parameters and goodness-of-fit tests for the univariate multinomial logit models

Independent variables	Likelihood ratio test	Cox and Snell R^2
Natural areas (forest and water bodies)	$X^2 = 645.93$ $p < 0.01$	0.073
Urban areas	$X^2 = 543.76$ $p < 0.001$	0.062
Roads	$X^2 = 506.86$ $p < 0.01$	0.058
Protected areas	$X^2 = 222.52$ $p < 0.01$	0.026
Simplified agricultural land	$X^2 = 125.16$ $p < 0.001$	0.004
Heterogeneous agricultural land	$X^2 = 30.61$ $p < 0.01$	0.015

The “Ecosystem services hotspots” bundle is used as a reference

bundle tended to respond positively, the “Ecosystem services hotspots” bundle showed a bell-shaped response, whereas all other bundles tended to respond negatively. We identified similar trends for road density, though the “Ecosystem services hotspots” bundle tended to respond positively to increasing road density.

Discussion

A socio-cultural perspective on ecosystem services synergies, trade-offs, and bundles

Our study identifies associations between perceived ecosystem services, groups of ecosystem services categories, spatial bundles, and their land-cover predictors across thirteen study sites in Europe. We

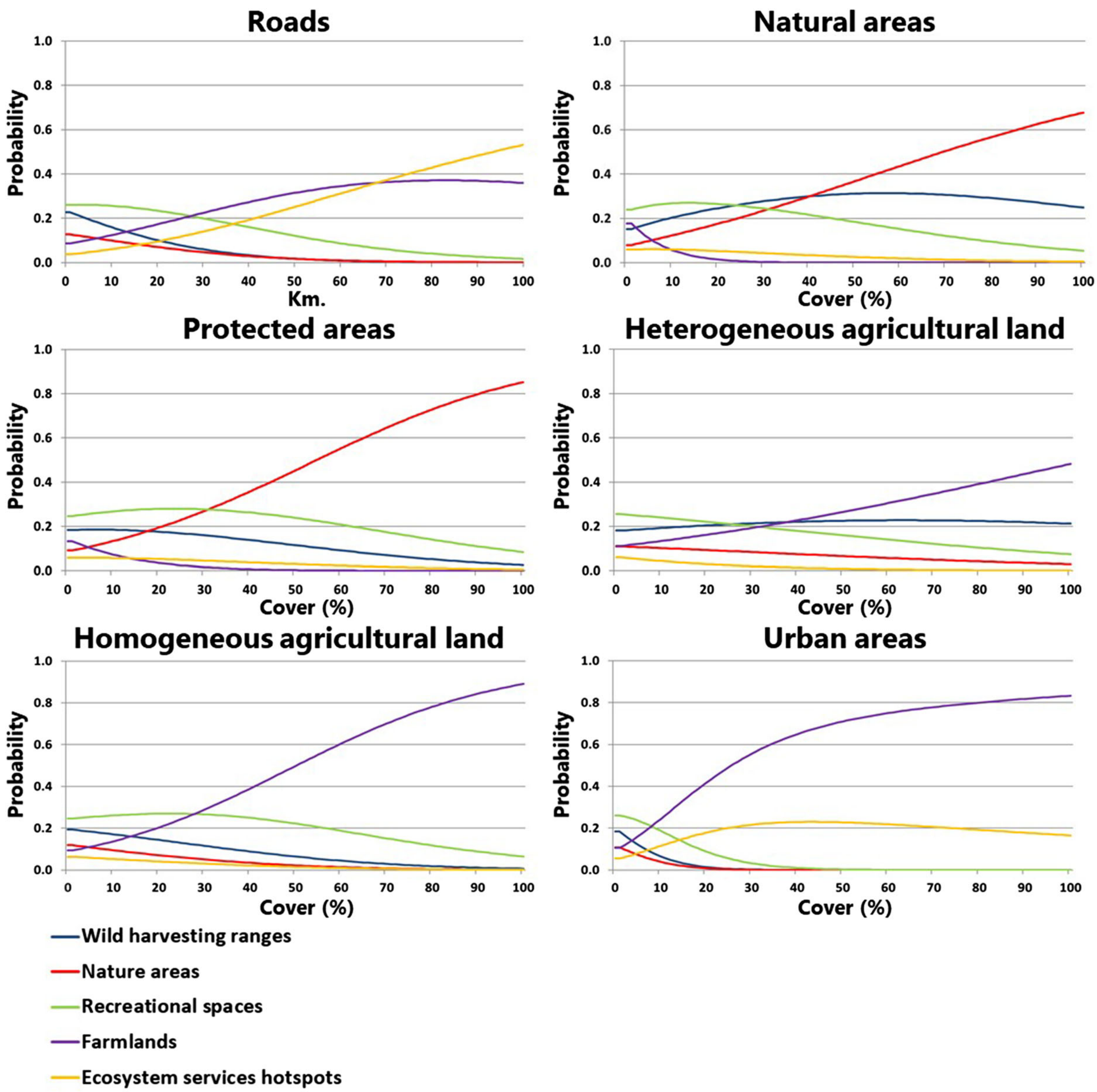

Fig. 3 Univariate multinomial logit models for the spatial bundles. The curves indicate the probability of a specific spatial unit to belong to each of the bundles given an increment in the values of the landscape predictor

particularly focus on ecosystem services synergies and trade-offs in farming landscapes of HNV and on the assessment of ecosystem services trade-offs from a socio-cultural perspective—both aspects that have not been studied intensively before.

One important insight that our study allows is that, when assessed through socio-cultural valuation, the number of ecosystem services synergies is much higher than that of trade-offs perceived (similar to Qiu and Turner 2013; Felipe-Lucia et al. 2014). In fact, we find 18 moderate to strong synergies and not a single moderate or strong trade-off. We conclude that rural residents perceive the specific ecosystem services of a place as largely synergistic. In our survey, respondents do not even identify trade-offs between food production and cultural services, regulating services, and biodiversity, which is the strongest trade-off between ecosystem services globally (Millennium Ecosystem

Assessment 2005). Our results contrast also other (mainly biophysical) studies where trade-offs occur three times more frequently than synergies (Howe et al. 2014). In particular, the absence of strong negative trade-offs between farm products and cultural and regulating services differs strikingly from studies performed in Montreal (Raudsepp-Hearne et al. 2010), Denmark (Turner et al. 2014), and at EU level (Maes et al. 2012; Turkelboom et al. 2018). One explanation for our findings is that, in some of the rural communities included in our study (e.g., the Saxon Region of Romania), people allocate substantial time and effort to farming. Several types of human–nature connections are likely to co-exist in such tightly coupled social–ecological systems (Fischer et al. 2012), and people therefore may not perceive strong trade-offs between farm production and other ecosystem services (Queiroz et al. 2015). Thus, HNV farming seems a successful strategy to maximize ecosystem services synergies (i.e. maintain several types of connections between people and their farming landscapes) and to minimize trade-offs according to the perception of rural residents. Two recent reviews suggest that human–nature connections can be disentangled in cognitive, experiential, and place attachment (Ives et al. 2017) and that relational values are important determinants of landscape stewardship (Chan et al. 2016). Our study suggests that humans can relate themselves to landscapes through several types of values simultaneously and motivate in-depth exploration of value-typologies, linking social–ecological systems in HNV landscapes.

Our analysis further shows that different ecosystem services categories display very disparate patterns in their associations to other ecosystem services. Cultural ecosystem services categories have a much higher number of moderate or strong positive associations than provisioning services (similar to Turner et al. 2014), but also higher than those of regulating services and habitats and biodiversity. These findings support the view of cultural ecosystem services being the most "multifunctional" group among all ecosystem services (Plieninger et al. 2013). However, the multifunctionality of a landscape is also determined by scale and local context (Stürck and Verburg 2017).

When refining the analysis of synergies and trade-offs through a HCA, we identify four clusters of ecosystem services that typically occur together: One group (Group I) assembles four cultural services categories, including activity-related ones (outdoor recreation, social relations), again stressing the multifunctional nature of cultural ecosystem services. Another cluster (Group IV) includes habitats and biodiversity as well as regulating services. These values co-occur most likely in more "natural" settings such as forests or wetlands. A third (closely related to habitats, biodiversity, and regulating services, but yet distinct) cluster (Group III) comprises wild products only. Perhaps the most interesting cluster is Group II that includes a provisioning service (farm products), a cultural service (cultural heritage), and existence values. Group II indicates that people do not separate clearly between ecosystem services categories. Rather, local agricultural production may come with intangible heritage values and also with comprehensive non-use values, which may be assembled as "biocultural diversity" (Plieninger et al. 2018). Such finding also supports the view that many ecosystem services are co-produced by people and nature, especially those generated from agroecosystems (Huntsinger and Oviedo 2013; Palomo et al. 2016).

Results are surprising in regard to the identification of six spatial ecosystem services bundles. Similar studies (e.g., Raudsepp-Hearne et al. 2010; Turner et al. 2014; Renard et al. 2015; Dittrich et al. 2017) established nuanced sets of ecosystem services that repeatedly occurred across sites. In contrast, our socio-cultural mapping reveals six rather simple ecosystem services bundles: One bundle ("Ecosystem services hotspots") shows very high values for most ecosystem services, in particular for cultural services. Another one ("Ecosystem services coldspots") has very low values for most services. Similar to Renard et al. (2015), the remaining four are dominated by single services such as wild products ("Wild harvesting ranges"), farm products ("Farmlands"), outdoor activities ("Recreational spaces"), or regulating services ("Nature areas").

In our analysis, it was not easy to link our ecosystem services bundles to specific land-cover drivers. On the one hand, standardized information on land cover across Europe (the CORINE database) has a coarse grain size (minimum mapping unit: 25 ha) that may be too large to identify relevant land-cover features at local scales (García-Martín et al. 2017). On the other hand, bundles may be driven by other variables (not related to land cover), such as local climate or biodiversity, as well (Mouchet et al. 2017).

Despite these challenges, our data show some significant linkages, in particular to cover of forests/water bodies and of urban areas, and to length of the road network. It corresponds to well-established knowledge on forest ecosystem services (EEA 2016) that forests and water bodies support the "Nature areas" bundle, that they do not support the "Farmlands" bundle, and that the "Recreational spaces" bundle is located at intermediate levels. More surprising is that "Ecosystem services hotspots" and "Farmlands" are linked to higher road lengths and also to medium to high levels of urban area cover. This highlights that access to a landscape is a crucial precondition to the enjoyment of ecosystem services (cf. Fagerholm et al. 2016). It further emphasizes the importance of "everyday" (peri-) urban landscapes for people's use of cultural ecosystem services (Martín-López et al. 2012; Queiroz et al. 2015), even if these may not provide high (biophysical) levels of ecosystem services (Andersson et al. 2015b; Vierikko et al. 2016).

When interpreting the results of this study, some potential caveats should be considered. Most essentially, our samples in the 13 study sites comprise local residents only. While these are an important stakeholder group, they are not the only actors with stakes in HNV farming landscapes. Future studies should therefore assess how multiple types of stakeholders around HNV farming (including, for instance, tourists and farmers) perceive ecosystem services differently (Van Riper and Kyle 2014), in particular because those affected by the impacts of ecosystem services trade-offs are often other stakeholders than those involved in trade-off decision-making (Turkelboom et al. 2018). Related to that is the question of how representative our sample is for the local resident population in the study sites. We controlled our sample for gender and age, but cannot guarantee that it is fully representative in terms of other socio-demographic factors, such as income or educational status. Also, our study sites were not selected randomly, and by that they do not necessarily represent European rural landscapes as a whole. Rather, they were selected to include major types of landscapes characterized by HNV farming and to spread across a gradient of biogeographic conditions and degrees of rurality. By that, we consider them well-suited for illustrating how local people perceive ecosystem services in a variety of HNV farming landscapes of Europe.

Implications for HNV farming and for land-use policy

Traditionally, the HNV farmlands literature has emphasized the links between agricultural production and biodiversity (Strohbach et al. 2015). Other ecosystem services have been less studied. For example, we are not aware of a single study that assessed cultural ecosystem services explicitly for HNV farmlands. In our survey, people do not establish a positive spatial association between farm production and biodiversity. Rather, they map a range of additional services that they consider important in HNV farming landscapes. This calls for expanding the view on the values of HNV farmlands beyond farm production and biodiversity, thereby also strengthening the societal appreciation of these landscapes and their inherent land-use practices. Such perspective is currently being taken up in EU policies. For instance, the Natura 2000 Network of Protected Areas is now becoming aware of other sectorial issues such as cultural heritage (http://ec.europa.eu/environment/nature/natura2000/management/links_natural_cultural_heritage_en.htm). Stronger consideration of cultural heritage values—the most "synergistic" of the ecosystem services that we assessed—in HNV farmlands may allow for an integrated implementation of conventions and instruments from the environmental and cultural heritage fields (Tengberg et al. 2012). Fostering broad bundles of ecosystem services, as perceived by local people, also has potential to contribute to the priority areas that the European Union has recently defined in its "Action Plan for People, Nature, and the Economy" for the future of natural areas management (http://ec.europa.eu/environment/nature/legislation/fitness_check/action_plan/index_en.htm), namely to "Improving guidance and knowledge and ensuring better coherence with broader socioeconomic objectives", "Building political ownership and strengthening compliance", "Strengthening investment in Natura 2000 and improving synergies with EU funding instruments", and "Better communication and outreach, engaging citizens, stakeholders and communities". The emerging principles and experiences of integrated landscape management may be used to guide such consideration of broader societal values when managing HNV farming landscapes (Sayer et al. 2013; Freeman et al. 2015).

The societal values of HNV farmland have until now been mainly supported through Rural Development Programs, in particular through voluntary agri-environmental measures (Uthes and Matzdorf 2013). These schemes represent the highest conservation expenditure in the EU (Batáry et al. 2015). However, agri-environmental measures have been criticized for not being cost-effective, acting at sub-optimal spatial scales, having unclear objectives, and failing to achieve lasting change in farmers' attitudes toward nature conservation (Birge et al. 2017). Current lines of thinking toward sustainable agri-environmental measures center around payments-by-results, incentives for collaborative action by farmers, and the creation of cultural capital among farmers (Burton and Paragahawewa 2011), and ultimately around individual farmers' motivation and behavior. The results of our study can create "actionable knowledge" (Brunet et al. 2018, p. 27) toward putting conservation of HNV farming landscapes "in the hands and minds of farmers" (de Snoo et al. 2013, p. 66) in the following ways:

- Sustainable agri-environmental schemes need to understand not only the underlying social–ecological system of farmers (Strohbach et al. 2015), but also of the rural communities that these are embedded in. Agri-environmental schemes and the larger HNV farming approach should strive to create broader co-benefits for rural citizens, for example by emphasizing links to other priority areas in Rural Development Programs.
- Biodiversity plays a minor role in most ecosystem services bundles that rural people perceive (compared to recreation, social interaction, or aesthetic values). Agri-environmental measures should therefore foster closer interactions between people and nature in farming landscape, for example through creating outdoor recreation possibilities (Paracchini et al. 2014), introducing or strengthening landscape labeling (Mann and Plieninger 2017), dedicating spaces to incidental nature experiences (Beery et al. 2017), or linking agri-environmental practices with the preservation of agricultural heritage features (Koohafkan and Altieri 2010).
- Many ecosystem services perceived by people are located in peri-urban areas, especially those related to farming. These perceptions by people should be included more comprehensively in spatial planning (Wilkinson et al. 2013). At the same time, payment schemes (e.g., agri-environmental measures) could be spatially targeted to such areas to increase the agrobiodiversity and synergistic ecosystem services of farmlands close to residential areas (Zasada 2011)—where they are visible and can be enjoyed by people.

Conclusions

Numerous authors have emphasized the need to complement prevailing biophysical and economic valuation approaches with socio-cultural valuation approaches for ecosystem services (e.g., Chan et al. 2012; Raymond et al. 2013; Martín-López et al. 2014). Indeed, the number of socio-cultural ecosystem services assessments has increased sharply (Scholte et al. 2015). Our study highlights that—in addition to complementing ecosystem services assessments—such socio-cultural perspective can also add to assessments of spatial synergies, trade-offs, and bundles of ecosystem services, which have so far been largely carried out from the biophysical value domain. What can we learn from a socio-cultural identification of synergies, tradeoffs, and bundles? First, people are able to identify particular coldspots and hotspots of ecosystem services in the landscape that are sometimes incongruent with expert-based maps. Second, people do not identify spatial trade-offs around ecosystem services in rural landscapes—possibly because those land-use conflicts that they perceive are often difficult to relate to common ecosystem services typologies (e.g., residential development, energy development) (Brown and Raymond 2014; Karimi and Brown 2017). Third, people identify multiple synergies between ecosystem services. On the one hand, these synergies occur within the cultural ecosystem services class. On the other hand, synergies can also span across multiple ecosystem services categories—for example, in the case of local food production, which people understand as a provisioning, but also as a cultural ecosystem service. Fourth, people allocate different bundles of ecosystem services to different parts of the landscape, which indicates a need for managing ecosystem services at a landscape scale (Nelson et al. 2009; Qiu and Turner

2013). Taken together, we conclude that socio-cultural mapping of ecosystem services is particularly useful for understanding the perceived multifunctionality of a landscape (Mouchet et al. 2017).

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