Cross-site analysis of perceived ecosystem service benefits in multifunctional landscapes

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Nora Fagerholm[a,b,*] ncfage@utu.fi, Mario Torralba[c], Gerardo Moreno[d], Marco Girardello[e], Felix Herzog[f], Stephanie Aviron[g], Paul Burgess[h], Josep Crous-Duran[i], Nuria Ferreiro-Domínguez[j], Anil Graves[h], Tibor Hartel[k], Vlad Măcicăsan[l], Sonja Kay[f], Anastasia Pantera[m], Anna Varga[n], Tobias Plieninger[c,o]

[a]Department of Geosciences and Natural Resource Management, University of Copenhagen, 1958 Frederiksberg C, Denmark
[b]Department of Geography and Geology, University of Turku, 20014 Turku, Finland
[c]Faculty of Organic Agricultural Sciences, University of Kassel, Steinstr. 19, 37213 Witzenhausen, Germany
[d]INDEHESA, Forestry School, University of Extremadura, Plasencia 10600, Spain
[e]cE3c – Centre for Ecology, Evolution and Environmental Changes/Azorean Biodiversity Group and University of the Azores, Açores, Portugal
[f]Agricultural Landscapes and Biodiversity Research Group, Agroscope, 8046 Zurich, Switzerland
[g]UMR BAGAP, INRA Agrocampus ESA, 35042 Rennes cedex, France
[h]School of Water, Energy and Environment, Cranfield University, Cranfield, Bedfordshire, MK43 0AL, UK
[i]Forest Research Centre, School of Agriculture, University of Lisbon, 1349-017 Lisbon, Portugal
[j]Department of Crop Production and Engineering Projects, High Polytechnic School, University of Santiago de Compostela, 27002-Lugo, Spain
[k]Department of Biology and Ecology in Hungarian and Center of Systems Biology, Biodiversity and Bioresources (Center of '3B'), Babes-Bolyai University, Str. Clinicilor 5–7, Cluj-Napoca, Romania
[l]Faculty of Environmental Sciences and Engineering, Babes-Bolyai University, 400294, Cluj-Napoca, Romania
[m]Agricultural University of Athens, 36100 Karpenissi, Greece
[n]MTA Centre for Ecological Research, 2163, Vácrátót, Hungary
[o]Department of Agricultural Economics and Rural Development, University of Göttingen, Platz der Göttinger Sieben 5, 37073 Göttingen, Germany

*Corresponding author at: Department of Geosciences and Natural Resource Management, University of Copenhagen, 1958 Frederiksberg C, Denmark.

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Abstract

Rural development policies in many Organization for Economic Co-operation and Development (OECD) member countries promote sustainable landscape management with the intention of providing multiple ecosystem services (ES). Yet, it remains unclear which ES benefits are perceived in different landscapes and by different people. We present an assessment of ES benefits perceived and mapped by residents (n=2,301) across 13 multifunctional (deep rural to peri-urban) landscapes in Europe. We identify the most intensively perceived ES benefits, their spatial patterns, and the respondent and landscape characteristics that determine ES benefit perception. We find outdoor recreation, aesthetic values and social interactions are the key ES benefits at local scales. Settlement areas are ES benefit hotspots but many benefits are also related to forests, waters and mosaic landscapes. We find some ES benefits (e.g. culture and heritage values) are spatially clustered, while many others (e.g. aesthetic values) are dispersed. ES benefit perception is linked to people's relationship with and accessibility to a landscape. Our study discusses how a local perspective can contribute to the development of contextualized and socially acceptable policies for sustainable ES management. We also address conceptual confusion in ES framework and present argumentation regarding the links from services to benefits, and from benefits to different types of values.

Keywords

Cultural ecosystem services; landscape management; landscape values; landscape characteristics; PPGIS; Europe

1. Introduction

People perceive a variety of benefits in their everyday landscapes in which they live, work, engage in recreational activities, encounter other people and search for relaxing and restorative experiences (Stephenson, 2008). These perceptions are place-specific (Williams, 2014) and can be defined as the benefits that people derive from the structures and processes generated by nature, i.e. ecosystem services (ES) (Millennium Ecosystem Assessement, 2005). Recently, there has been an increased effort to map ES benefits as perceived by people (Scholte et al., 2015). The existing empirical evidence is, however, typically limited to studies that address specific socio-economic and landscape contexts. Such studies are unlikely to illustrate ES benefits across wider societies and regions. An approach that moves beyond single case studies is necessary to understand the role of common global drivers of landscape change, such as urbanization, agricultural intensification, land abandonment, and landscape simplification in shaping the ways in which people appreciate landscapes (Levers et al., 2015). Increasingly, these drivers of change have raised concerns since they may be linked to a diminishing capacity of the landscape to provide ES, thus compromising human well-being (Wu, 2013).

Participatory mapping is a powerful tool for grasping the socio-cultural realities of communities, regions, landscapes, and ecosystems. This method, which often combines surveys with a mapping component, has successfully engaged stakeholders in identifying and mapping a range of ES (e.g. a review of empirical studies by Brown and Fagerholm, 2015; Garcia-Martin et al., 2017; Ridding et al., 2018; Samuelsson et al., 2018). Based on Public Participation Geographical Information Systems (PPGIS) and other participatory methods, such approaches highlight ecosystem benefits to people (Termorshuizen and Opdam, 2009) and the spatial heterogeneity of ES benefits. The relevance of such local knowledge has been particularly emphasized by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) (Turnhout, 2012). Conceptually, participatory mapping of ES benefits communicates assigned values, i.e. the judgement regarding the appreciation of objects such as places, ecosystems and species (Nahuelhual et al., 2016; Seymour et al., 2010; Van Riper and Kyle, 2014). It focuses on the personal perception, which is typically place-based, that emerges from everyday embodied experience and accumulated knowledge (Stephenson, 2008; Williams and Patterson, 1996), having roots in human geography and post-phenomenological discussions (Brown and Raymond, 2007; Hausmann et al., 2016). It is also valuable for understanding broad public benefits of ES and generating insights beyond proxy-based studies that often only address single ES (e.g. Raudsepp-Hearne et al., 2010; Weyland and Laterra, 2014). Globally, PPGIS approaches have been applied for socio-cultural ES assessment and mapping in a variety of contexts such as national forests and parks (Crossman et al., 2013; Sherrouse et al., 2014), agricultural landscapes (Fagerholm et al., 2016, 2012; Plieninger et al., 2013) and conservation lands (Brown and Brabyn, 2012; Hausner et al., 2015).

Multifunctional landscapes in Europe make an interesting case study for the assessment of ES benefits. Landscape multifunctionality as a normative concept recognizes that rural landscapes have multiple functions beyond agricultural and forest-based commodity production. Accordingly, multifunctional landscapes generate a diverse set of ES that are accessible to a broad range of beneficiaries (Fischer et al., 2017). The concept underpins many agricultural support and rural development policies of the OECD member countries and also the Common Agricultural Policy

(CAP) of the EU (OECD, 2001; Renting et al., 2009). Several studies have examined the multiple benefits that people derive from ecosystems in multifunctional landscapes. However, these have either used multiple indicators at local scales (Oteros-Rozas et al., 2018) or a single, coarse indicator at continental scales (van Zanten et al., 2016). An empirical analysis across several landscapes can improve understanding of the linkages between multiple ES benefits as subjectively perceived by different actors, with different socio-demographic characteristics and backgrounds, and multifunctional land use systems, where landscapes and their components have multiple uses and purposes (Sayer et al., 2013; Scholte et al., 2015; Small et al., 2017). Understanding the spatially explicit patterns of ES benefits is crucial for integrated ES assessments and for the development of effective land development policies in the coming decades (Crossman et al., 2013; Maes et al., 2012).

The aim of this paper is to analyze ES benefits as perceived by local communities across European multifunctional landscapes. Across 13 study areas in ten countries 2,301 local residents responded to a web-based mapping survey and located (as mapped point locations) subjectively perceived ES benefits in their everyday landscape. The study areas comprise multifunctional farming landscapes in Europe, representing a broad range of land-use systems and varying degrees of rurality and peri-urbanity as well as different levels of landscape protection (Fig. 1 panel a, Supplementary Table A.1). Based on the conceptual framework presented by Scholte et al. (2015), we explore both the role of the characteristics of the survey respondents as well as the characteristics of the landscape as determinants of ES benefit perception (Fig. 2). Our research questions are:

1) Do identified ES benefits vary across 13 European sites and are they spatially clustered into landscape-level hotspots?

2) Is the type of perceived ES benefits influenced by the respondents' socio-demographic characteristics and their relationship to the landscape?

3) Is the type and intensity of the ES benefits influenced by landscape characteristics such as land cover, accessibility, and the presence of conservation areas?

2. Material and methods

2.1 Study areas

This study was conducted at 13 different study areas in ten European countries: Montaña Oriental Lucense, Spain (SP-MO), Canton de Loudeac, France (FR-CL), the Brecks, United Kingdom (UK-BR), Linköping, Sweden (SE-LI), Franches Montagnes, Switzerland (CH-FM), Schwarzbubenland, Switzerland (CH-SB), Hochkirch-Weißenberg, Germany (DE-HW), Saxon region, Romania (RO-SA), Llanos de Trujillo, Spain (SP-LT), Serena Campiña, Spain (SP-SC), Kassandra, Greece (GR-KA), Montemor-o-Novo, Portugal (PT-MN), and Zala, Hungary (HU-ZA) (Fig. 1). The study areas were identified as landscapes that most residents identify with and/or depend on for their lifestyles and livelihoods based on knowledge of local members of the research team (Brown et al., 2015b). They represent the major types of multifunctional landscapes in Europe and spread across a large gradient of land-use and biogeographic conditions (Kay et al., 2017) and degrees of rurality (Supplementary Table A.1). Following the FARO typology of rurality (van Eupen et al., 2012), our study areas cover situations from “deep rural” (e.g. SP-MO) to “peri-urban” (e.g. CH-SB) and represent a gradient of economic density and accessibility (the key parameters describing the degree of rurality). Conservation areas account for between 0.4% and 84.0% of each study area. Each study area was located within a larger rural area with similar land-uses and socio-economic characteristics. Our approach resembles other cross-site studies (e.g. Billeter et al., 2008; Kleijn et al., 2006; Schneider et al., 2014).

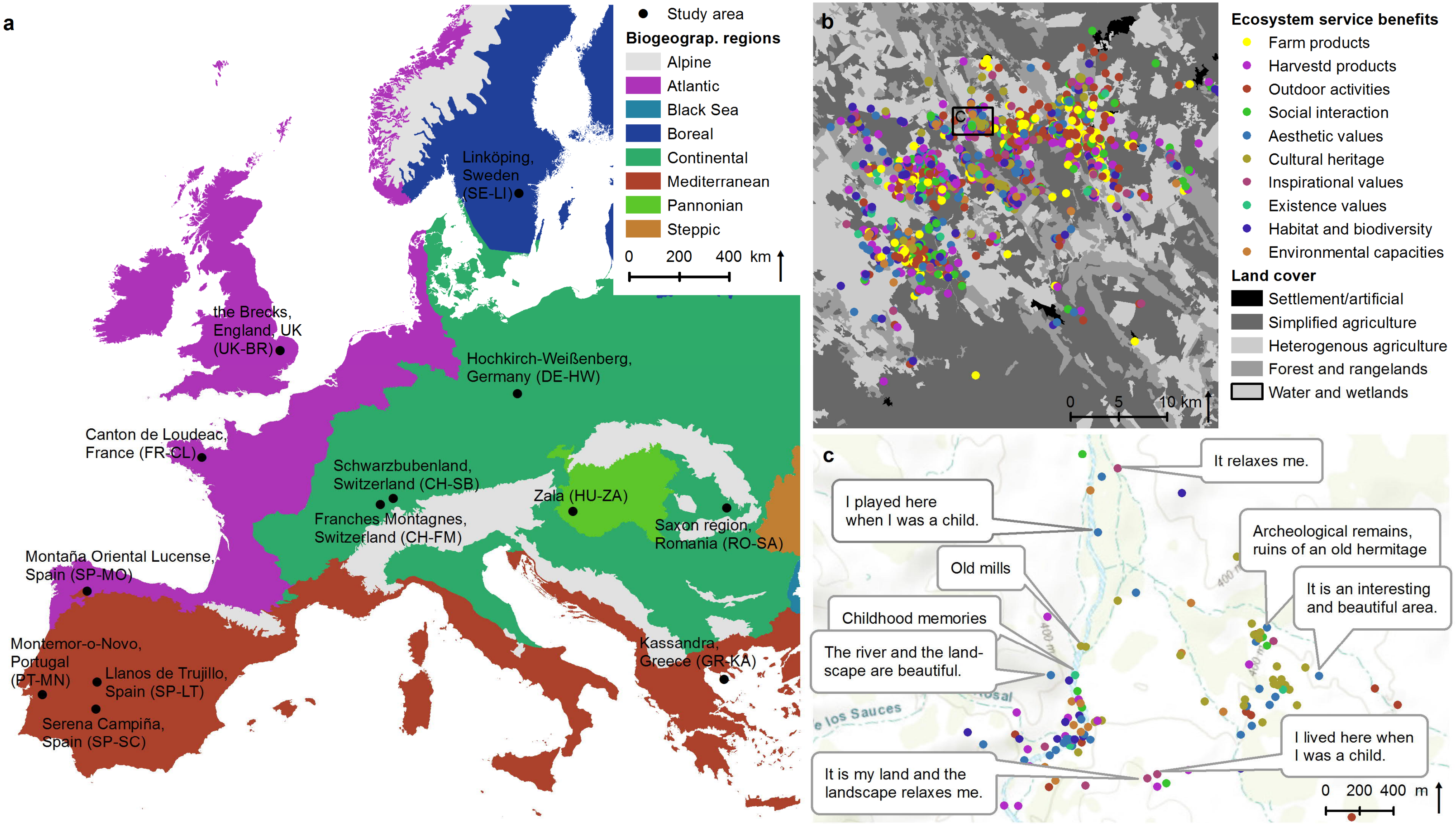

Figure 1. Study areas and example of mapped ES benefits. Panel a shows location of the 13 study areas within five biogeographic regions of Europe. Panel b illustrates the spatial distribution of ES benefits in Serena Campiña, Spain (SP-SC). Panel c visualizes descriptive attributes given to mapped places.

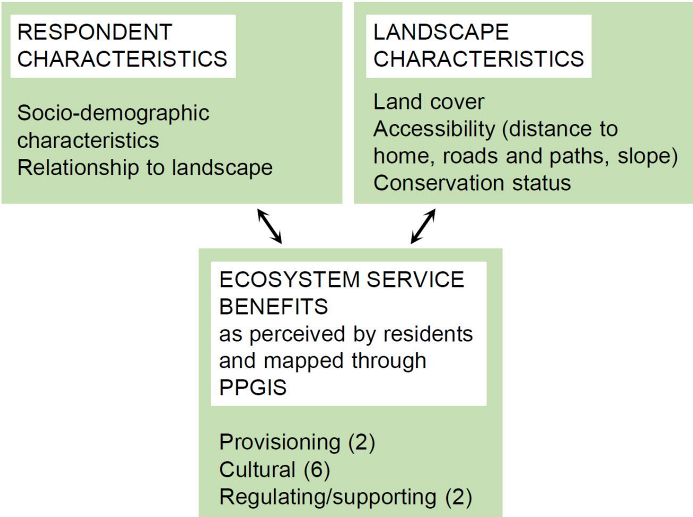

Figure 2. Study design. Framework for analyzing the role of survey respondents' characteristics and landscape characteristics as determinants of ES benefits.

2.2 Typology for mapping ES benefits

In our socio-cultural ES assessment, we recognise the links from services to benefits, and from benefits to values (cf. Chan et al., 2012; Haines-Young and Potschin, 2010). We mapped perceived ES benefits (cf. Van Riper et al., 2017) in multifunctional landscapes with local residents and connected these benefits to different ES (Table 1). Based on existing ES frameworks and empirical studies applying participatory approaches (Brown and Reed, 2000; Millennium Ecosystem Assessement, 2005; Raymond et al., 2009; Roy Haines-Young and Potschin, 2013; Vallés-Planells et al., 2014), we developed a typology of ES benefits that aims to capture both the material and symbolic/intrinsic benefits of ES in relation to local actors' everyday landscape and covers provisioning, cultural, regulating/supporting services and biodiversity. ES benefits were mapped through operationalized statements (Table 1) and include, for example, places where a person practices various outdoor activities, harvests wild products from nature, spends time together with other people or appreciates aesthetic landscapes, culture and heritage or plants, animals and ecosystems. Respondents were always asked about their personal perceptions, not about the general perceptions about a specific ES benefit. This way, when a respondent mapped a place, for example, as a source of inspiration or as a place to practice outdoor activities, he/she referred to his/her personal view. The typology was tested in the ES-LT study area (Fagerholm et al., 2016), where the chosen ES benefits were meaningful for residents and applicable and practical for participatory research.

The typology particularly addresses both the subjective perceptions and uses of the landscape (Scholte et al., 2015). It also connects to the on-going discussion on benefit-relevant indicators of "what is valued" by particular beneficiaries (Olander et al., 2018). As we understand that these benefits are provided by perceptions that emerge from the interaction with the landscape (Setten et al., 2012) and from the relationships among the people and between people and the landscape (Pascual et al., 2017), we followed the common approach in PPGIS studies where mapped ES benefits stress the subjective values and activities of respondents in the landscape which are often linked to the cultural ES category (Brown and Fagerholm, 2015). In fact, socio-cultural approaches to ES mapping commonly target landscape level and landscape perceptions (e.g. Brown and Raymond, 2014; Casado-Arzuaga et al., 2013; García-Nieto et al., 2015).

Similarly as Nahuelhual et al. (2016) and Van Riper and Kyle (2014), our typology of ES benefits targets a subset of individual anthropocentric self-regarding values, particularly values assigned by a person to the landscape (assigned values) leaving out possible other types of values discussed, for example, by Chan et al. (2012) and Kenter et al. (2015). These anthropocentric values are both instrumental (e.g. the ES benefits related to farm and harvested products) and relational (e.g. the ES benefits related to social interaction and inspiration) but cannot always be placed to one category only (e.g. ES benefit related to harvesting practised both for subsistence, recreation and inspiration) (cf. Pascual et al., 2017). An exception to the anthropocentric values is the inclusion of existence values (appreciation of a place just for its existence regardless of benefits for humans), which is an "other-regarding value" (Kenter et al., 2015) and, similarly as in Raymond et al. (2009), we decided to include it as an intangible ES benefit with potentially interesting place-based character.

Table 1. ES typology and respective operational definitions (related survey question: Do you find some particular place or area special in this landscape?) applied in the mapping exercise.

ES category	ES	ES benefit	Operational definition	ES benefit acronym in figures and tables
Provisioning	Food	Farm products	I appreciate, produce or can buy farm products here	Farm products / Farm pro
	Food	Freely harvested wild products	I harvest fruits, berries, mushrooms, fish, game etc.	Harvested products / Harv pro
Cultural	Recreation	Outdoor recreation activities	I practice outdoor sports, walking, hiking, biking, dog walking etc.	Outdoor recreation / Outdoor
	Social relations	Social interaction	I spend time together with other people	Social interaction / Social
	Aesthetic values	Beautiful landscape or landmark	I enjoy seeing this beautiful landscape or landmark	Aesthetic values / Aesthetics
	Cultural diversity, cultural heritage values	Appreciation of local culture, cultural heritage or history	I appreciate the local culture, cultural heritage or history	Cultural heritage / Culture
	Inspiration, spiritual and religious values	Inspirational, spiritual or religious place, feeling or value	I am inspired by feelings, new thoughts, religious or spiritual meanings etc.	Inspirational values / Inspiration
	Existence value	Appreciation of a specific place as such, independent of any benefit to humans	I appreciate this place just for its existence regardless of benefits for me or others	Existence values / Existence
Regulating/ supporting	Provisioning of habitat, biodiversity	Appreciation of plants, animals, wildlife, ecosystems etc.	I appreciate the plants, animals, wildlife, ecosystems etc.	Habitat and biodiversity / Habitat
	Erosion control, soil fertility, water and climate regulation, air quality maintenance	Appreciation of environmental capacity to produce, preserve, clean, and renew air, soil and/or water	I appreciate the environmental capacity to produce, preserve, clean, and renew air, soil, and/or water	Environmental capacities / Env cap

2.3 Data collection

Our survey covered full or part-time local residents who were recruited through purposive stratified sampling based on the following three stratification criteria: 1) municipality; 2) gender, and; 3) age (young: 15-29 years, middle-aged: 30-59 years, seniors: ≥ 60 years). The first criterion was based on the geographical balance of respondents within each study area, while the latter two were in proportion to local census data (except for RO-SA where local census statistics were unavailable). Respondents were approached in key public locations such as market places, cafés, streets, schools, and health care centers (Bieling et al., 2014; Scolozzi et al., 2014). A crowdsourced sample (allowing any interested person to fill in the survey) through distributing an URL link was additionally included in CH-SB. Data collection was tested in SP-LT and CH-SB in May-August 2015 (Fagerholm et al., 2016). At the other study areas, the interviews were carried out in February-September 2016 through a web-based PPGIS survey (Maptionnaire platform) on tablets and laptops. Due to the lack of internet coverage, we performed the surveys using paper questionnaires and maps in RO-SA and then inserted the data to the survey platform. The survey was filled in with the help of facilitators who were trained to use a standardized protocol. In the survey introduction the facilitators stressed the focus on the informant's personal relationship to nature and landscapes in the everyday surroundings. The survey started by identifying the respondents' home locations and then subsequently ES benefits as points (Table 1, Fig.1, example survey from ES-SC, accessible at: https://app.maptionnaire.com/fi/869). Respondents could map an unlimited number of ES benefits or choose also not to map a specific ES benefit. The background map was a Bing satellite image with overlaid Open Street Map objects. A minimum zoom level of 1:25 000 was enforced to ensure spatial scale coherence in mapping. After each mapped item, a pop up window opened asking description of the mapped place (these descriptions helped to contextualize the mapped places but are not systematically treated in this paper). ES benefit mapping was followed by an open question "How does this area and the opportunities it offers contribute to your well-being?" (not discussed in this paper). The final survey pages included questions on socio-demographic characteristics (gender, age, education, household income) and relationship to the study area landscape (landownership, self-estimated knowledge of the area, length of residency and field of work in agriculture) addressing the 'personal characteristics' and 'social context' presented in the Scholte et al. (2015) framework .

2.4 Respondents, ES benefits and relationship to personal characteristics

Identified ES benefits and respondents' characteristics were analyzed in SPSS 24 through descriptive statistics and by cross tabulation, where Chi square tests were applied and standardized adjusted residuals explored to identify significant associations. The family-wise error rate in multiple pair wise tests (type I error, 80 tests) was controlled by the Benjamini-Hochberg method (Benjamini et al., 1995) to 5%. The reported p-values are the original ones. Cramer's V test was applied to measure the strength of association across the cross classification tables. Identified ES benefits were also interpreted in the context of wealth level (GDP/capita), population density, and rurality of the study area (Supplementary table A.1.).

2.5 Sample representativeness and comparison of facilitated and crowdsourced sampling in CH-SB

Representativeness of the sample for the population of the study areas was assessed with census data on the variables of age and gender. Overall, the difference between the sample and census was good with less than 3.7% difference per age/gender group with the exception of elderly women, who were difficult to reach and 6.8% less represented compared to sample (Supplementary Table A.3). Among individual study areas, men aged 30-59 years were challenging to interview in CH-FM, DE-HW, SP-LT and UK-BR (sample-census difference: -6.3-14.8%) and were compensated by men of other ages. Young people were proportionally less represented in CH-SB (sample-census difference: men -14.8%, women -11.2%), but were more represented in DE-HW (sample-census difference men 11.5%, women 9.2%) and SE-LI (sample-census difference: men 8.3%, women 14.5%).

CH-SB survey participant profiles were examined for differences in facilitated and crowdsourced sample. There are no statistically significant differences between the facilitated (130 respondents) and open (91 respondents) approach in CH-SB related to gender, age or level of education. The number of mapped places per ES benefit is different depending on the survey approach (X^2(10, N=2877)=116.54, p=0.00). In the facilitated approach, respondents mapped more points (16.0 vs. 8.7) compared to the crowdsourced approach. Crowdsourced respondents mapped more recreational benefits and facilitated respondents more farm and harvested products, culture and heritage, inspirational, spiritual or religious values, and environmental capacities. This could indicate that facilitation encourages respondents to map a broader range of benefits and not only recreation (Brown, 2012). However, when comparing the distribution of mapped ES benefits in CH-SB to the other Swiss study area (CH-FM) there is a similar trend, and the share of outdoor recreation in CH-SB is the same as the average across all study areas (Fig. 3). Hence, the crowdsourced respondents do not seem to bias the results significantly. The point mapping method also possibly contributes positively to the quality of the crowdsourced data as PPGIS participants tend to find point mapping straightforward (Brown and Pullar, 2012).

2.6 Spatial patterns of ES benefits

Spatial patterns of mapped ES benefits were analyzed in ArcGIS 10.4. We studied the spatial arrangement of the ES benefit point layers with nearest neighbor statistics (NN) to explore random distribution and clustering (Ebdon, 1985). NN statistics measures the average Euclidian distance between each point and its nearest neighbors and divides this by the average distance in a hypothetical randomly distributed point layer within the analysis area, i.e. the area of smallest polygon enclosing all mapped points for each study area excluding outliers. NN ratio below 1 exhibits spatial clustering. Secondly, we calculated the Euclidian distance between respondent home and mapped locations as it was expected that variation in distance might explain spatial patterns (Fagerholm et al., 2012).

2.7 Land cover overlay

In order to analyse the relationship with land cover, mapped points were buffered with 250 m radius and overlaid with land cover data (CORINE Land Cover 2012 (CLC) version 18.5, available by the European Environment Agency (EEA) at: http://land.copernicus.eu/pan-european/corine-land-cover/clc-2012). CLC data had been reclassified into five major land cover classes: settlement and artificial surfaces (all artificial surfaces, CLC classes 111-142), simplified agricultural land (arable lands, permanent crops and pastures, CLC classes 211-231, 321), heterogeneous agricultural land (heterogeneous agricultural areas, CLC classes 241-244), forest (forests, scrub and herbaceous vegetation associations, open spaces with little or no vegetation, CLC classes 311-313, 322-335), and water bodies and wetlands (water bodies and wetlands, CLC classes 411-523). Buffering the mapped point locations acknowledges the landscape context in which the specific benefits are found and also appreciates uncertainty in spatial precision of mapping. Based on the mapping scale, the aims of the survey to address local everyday landscapes and our experience from the surveys, a 250 meter buffer was chosen for our data. The proportional shares (%) of different land cover classes were compared between the different ES benefits and the analysis area. Z scores were calculated for each ES benefits and land cover pair (Supplementary Eq. A.1) to determine whether specific mapped ES benefits were represented statistically significantly more (z score >+1.96) or less (z score <-1.96) frequently than expected (two-tailed test, α=0.05) (Brown et al., 2015a).

2.8 Analysis area

In order to calculate the nearest neighbor statistics and different land cover classes in each study area, an analysis area was defined for each study area by creating the smallest convex polygon enclosing the mapped points. Single points located on the outskirts of the mapped point pattern were identified visually in each study area and a specific threshold distance from the study area boundary was specified to discard the outliers. Depending on the character of the study area, these threshold distances vary between 15 and 45 km (excluding GR-KA peninsula where the threshold was not applied as it is surrounded by the sea). Mapped points falling within the analysis area represent 95.5% of the original points.

2.9 Generalized Linear Mixed Models

A linear modelling approach (Bolker et al., 2009) was applied to quantify the relationship between biophysical landscape characteristics and mapped ES benefits. We decided to use a GLMM approach to deal with the potentially confounding effects derived from spatial autocorrelation. Although a variety of spatial regression-methods exist for dealing with spatial autocorrelation (Anselin and Bera, 1997), a GLMM approach was preferred because of the grouped structure of our data. Our dataset consisted of spatially separate sites within which spatially autocorrelated observations exist. GLMMs represent a natural framework for analyzing such data structured in groups or clusters (Gelman and Hill, 2007).

The model included the different categories of land cover, with interest in the comparison of simplified vs. heterogeneous agricultural landscapes, and these vs. natural (not agricultural) landscapes. As reported in literature (Hausner et al., 2015; Laatikainen et al., 2017), the use of the landscape is also determined by accessibility. Thus, additional predictors such as distance to home, density of roads, and slope were included. The protection status of the land was also included given that conservation areas can attract people for recreational and habitat-related ES benefits, but also can prohibit the use of the land for provisioning ES. We produced two databases for the modelling. The first one was based on the individual mapped points and a 250 m buffer around each point (n=27952, after removing 19 points as outliers with distance to home > 100 km) as a response variable. The second database was created as a grid with 400 m cell size (n=20497, after removing the outliers) where we calculated as response variables the sum of all mapped ES benefits (i.e. intensity) and ES benefit diversity (based on Shannon diversity index). Study area was included as a random effect to deal with confounding effects of spatial autocorrelation within each study area (n=13).

Nine different predictors of landscape characteristics were calculated for each point buffer and grid cell including:

- share of each land cover class,
- land cover richness (number of different land cover types),
- share of conservation area (Natura 2000 data by EEA, available at: https://www.eea.europa.eu/data-and-maps/data/natura-7#tab-metadata and Nationally designated areas by EEA, available at: https://www.eea.europa.eu/data-and-maps/data/nationally-designated-areas-national-cdda-11#tab-metadata), and
- accessibility (distance to home (calculated as metres from respondent home point to each mapped point), length of roads and paths (in metres based on OpenStreetMap data downloaded from https://www.geofabrik.de/data/download.html in February 2017), and average slope)).

Settlement and artificial surfaces and length of roads and paths were highly correlated (r>0.5) and, therefore, only the latter was retained for modelling. All other variables were weakly or not correlated with each other. There were few significant correlations between the landscape predictors and socio-demographic variables (Supplementary Table A.4).

Models were fitted through a Bayesian framework using integrated nested Laplace approximations (INLA, Rue et al., 2009) in R v3.4.0. INLA was chosen as it represents an analytical short-cut for estimating Bayesian regression parameters without the need to employ computationally expensive Markov Chain Monte Carlo algorithms. Details of the fitted models including equations are reported in Eq. A.2 in Supplementary Material. Models were tested for sensitivity to priors for hyperparameters. Varying priors did not alter the results and we, therefore, kept INLA defaults. Models were checked for adequacy using data residuals plots. Moran's correlogram was computed to assess the degree of spatial autocorrelation. An inspection of residual spatial autocorrelation (SAC) through correlograms indicated that the models effectively removed SAC (Supplementary Fig. A.5).

3. Results

3.1 Respondent profile

Women (49.3% of respondents) and men (50.7%) were equally represented in the sample (Supplementary Table A.2). 21.2% of respondents were younger than 30 years, 48.5% were aged between 30 and 59 years old, and 30.3% were 60 years or older. Of the respondents, 27.2% had a university or polytechnic degree, 68.5% had a lower level of education and 4.3% had no formal schooling. The lowest levels of education were found in DE-HW, SP-LT, SP-MO, SP-SC and PT-MN. Income level varied with 47.8% having income above the median in the region and 52.2% below. 61.6% of respondents were employed, 20.8% were retired, and 18.1% were parenting at home, students, or unemployed. 13.7% were working in agriculture, forestry or fishery (especially in RO-SA, PT-MN and SP-MO >25.0%), while 86.3% were not. 60.2% of respondents were landowners. 78.2% reported having extremely or quite good knowledge of the local area, 17.0% moderate knowledge, and 4.8% poor knowledge. Most people (77.0%) had lived for more than 15 years in the area, 9.0% less than 5 years, and 14.0% between 6 and 15 years. Long residency was prominent in SP-MO, SP-SC and RO-SA (>60.0% more than 30 years).

3.2 Identified ES benefits and their spatial patterns

The 2,301 survey respondents mapped 28,878 places indicating ES benefits (Fig. 3). On average (mean±SD), each respondent mapped 12.5±5.2 places (ranging from a minimum in DE-HW of 9.4±4.3 to a maximum in CH-FM of 14.8±5.2). Outdoor recreation activities were clearly the most mapped ES benefits with the highest share in eleven out of the thirteen study areas (Fig. 3). Across all study areas, outdoor recreation activities were attributed to 17.1% of places, but most prominently (>20% of mapped places) they were perceived in Central and Northern European study areas (CH-FM, CH-SB, UK-BR, SE-LI). These areas have high GDP/capita, population density and economic density, and high/average accessibility (Supplementary Table A.1). Other commonly mapped ES benefits were aesthetic values and sites for social interaction, representing 13.1% and 12.9% of all mapped places respectively. Across all study areas, cultural heritage was related to 9.8% of places. Benefits of farm and harvested products linked to provisioning ES were also frequently mapped (10.6% and 9.5% of mapped places respectively). These benefits, particularly the harvesting of wild products, played an important role in Mediterranean and Eastern European study areas. These areas typically have the highest share of respondents working in agriculture (mostly >20%), and low GDP/capita, population density and economic density, and low/average accessibility (Supplementary Table A.1). Existence values, environmental capacities and, inspirational, spiritual and religious values attracted the least attention, with shares of 5.5%, 6.6% and 6.8% out of all mapped places respectively. Across all the study areas, habitat and biodiversity was associated with 10.0% of all places.

We found a statistically significant spatial clustering of the mapped places (point patterns) for individual ES benefits in each of the study areas. The most clustered patterns were detected for appreciation of culture and heritage at seven study areas (DE-HW, SP-LT, SP-MO, SP-SC, UK-BR, GR-KA, and RO-SA), for farm products at four study areas (CH-FM, CH-SB, FR-CL, and PT-MN), and for habitat and biodiversity (SE-LI) and social interaction (HU-ZA) at one study area each (Table A.5, Fig. A.1). Patterns were most dispersed for harvesting (SP-SC, UK-BR, GR-KA, SE-LI), habitat and biodiversity (CH-FM, FR-CL, RO-SA), social interaction (DE-HW, PT-MN), outdoor recreation activities (CH-SB), aesthetic values (SP-LT), inspirational, spiritual or religious values (SP-MO), and existence values (HU-ZA). Places for the appreciation of farm products were closest to respondents' homes at seven study areas and ranked among the three closest at other study areas (range from CH-SB, mean 823±1162 m, to SE-LI, mean 9402±11 232 m) (Supplementary Fig. A.2). At ten study areas, harvested products ranked among the three ES benefits that were perceived closest to respondents' homes. Outdoor recreation activities and social interaction were also frequently situated close to homes. Aesthetic values were located furthest away from respondents' homes at four study areas and were among the three most distant ES benefits in six study areas (range from CH-SB, mean 1784±1571 m, to FR-CL, mean 14 193±30 085 m). Benefits linked to regulating/supporting ES were among the three most distant in six study areas.

ES/Site		ATLANTIC			BOREAL	CONTINENTAL				MEDITERRANEAN				PANONIAN
	ALL	SP-MO	FR-CL	UK-BR	SE-LI	CH-FM	CH-SB	DE-HW	RO-SA	SP-LT	SP-SC	GR-KA	PT-MN	HU-ZA
	(2169/29687)	(171/2640)	(146/2104)	(174/1731)	(172/2299)	(167/2574)	(221/2877)	(159/1551)	(182/2036)	(219/2594)	(181/2438)	(173/2254)	(174/2547)	(167/2042)
Farm pro	10.6	12.0	12.4	7.3	5.2	10.5	10.6	15.3	10.3	11.3	8.9	15.9	8.2	11.1
Harv pro	9.4	12.4	7.3	3.6	9.5	9.0	5.9	8.5	10.9	12.8	9.5	8.9	13.9	7.3
Outdoor	17.1	12.2	17.2	20.4	23.1	21.0	25.8	19.2	10.4	16.5	16.9	10.3	14.4	13.4
Social	12.2	9.7	11.5	14.6	19.4	10.4	8.9	10.6	9.9	10.4	16.4	12.7	11.5	13.8
Aesthetics	12.0	9.1	14.3	13.9	12.0	10.4	12.9	14.2	9.9	11.8	12.7	14.8	11.1	11.2
Culture	9.1	11.3	8.0	6.3	6.1	9.0	8.8	7.0	9.6	9.8	13.4	9.8	8.3	8.8
Inspiration	6.3	5.9	6.5	6.4	4.3	7.4	5.5	5.0	8.2	5.2	6.6	7.4	5.4	8.7
Existence	5.1	6.3	7.1	6.2	4.0	4.1	4.3	3.0	5.9	3.9	4.2	5.7	4.9	7.3
Habitat	9.4	7.3	8.0	11.8	11.5	9.4	12.1	7.5	11.3	9.9	7.7	7.0	8.4	9.5
Env cap	6.1	7.6	6.7	7.9	3.9	5.0	3.2	6.1	9.7	5.4	3.6	7.5	6.2	9.0

Figure 3. Proportion of mapped ES benefits in ten categories across study areas. Relative proportion (%) of ES benefits mapped by survey respondents at each study area and in total. Numbers in brackets refer to number of informants/number of mapped places (points). Study sites in biogeographic regions: SP-MO=Montaña Oriental Lucense, Spain; FR-CL=Canton de Loudeac, France; UK-BR=the Brecks, England, UK; SE-LI=Linköping, Sweden; CH-FM=Franches Montagnes, Switzerland; CH-SB=Schwarzbubenland, Switzerland; DE-HW=Hochkirch-Weißenberg, Germany; RO-SA=Saxon region, Romania; SP-LT=Llanos de Trujillo, Spain; SP-SC=Serena Campiña, Spain; GR-KA=Kassandra, Greece; PT-MN=Montemor-o-Novo, Portugal; HU-ZA=Zala, Hungary.

3.3 Respondent characteristics as determinants of ES benefits

Respondents' relationship to the study area was significantly related to the type of mapped ES benefits (Table 2). The differences between the respondent groups in terms of independent variables are, however, mostly between 10 and 20%, expressing a low degree of association. Owning land in the area increased the likeliness of mapping most types of ES benefits (except sites for outdoor recreation and social interaction) and was the most significant respondent characteristic. Land ownership showed the strongest (but still moderate) association with farm products (90.8% of landowners vs. 69.5% of non-landowners mapped these, $X^2(1, N=2048)=152.01^{***}$, $V=0.272$). The higher the self-estimated knowledge of the landscape, the higher the likelihood that respondents would map a specific ES benefit (except sites for outdoor recreation and social interaction). A similar pattern was also observed for length of residency, where longer residency was related to an increased likelihood of mapping farm products ($X^2(3, N=2144)=34.00^{***}$, $V=0.126$), harvested products ($X^2=42.00^{***}$, $V=0.140$), aesthetic values ($X^2=9.90^{*}$, $V=0.068$), and culture and heritage values ($X^2=45.30^{***}$, $V=0.145$). Long residency (particularly more than 31 years) is also related to work in agriculture ($X^2(3, N=2112)=52.6^{***}$). Respondents working in agriculture mapped significantly more benefits linked to provisioning ES (farm products $X^2(1, N=2261)=22.53^{***}$, $V=0.100$, harvested products $X^2=29.32^{***}$, $V=0.114$), regulating/supporting benefits (provision of habitat $X^2=6.21^{*}$, $V=0.052$, environmental capacities $X^2=5.82^{*}$, $V=0.057$), and culture and heritage values ($X^2=6.32^{**}$, $V=0.053$), but less outdoor recreation ($X^2=11.56^{**}$, $V=0.072$), compared to respondents in other fields of work. There were few statistically significant relationships between either gender, age, level of education, or household income and the type of mapped ES benefit (Supplementary Table A.6).

Table 2. Relationship between mapped ES benefits and respondent characteristics related to relationship to landscape. Information is presented as percentage of respondents who mapped specific ES in each category with Chi square test of significance of association (***=p<0.001, **= p<0.01 an *=p<0.05) and Cramer's V test measuring the strength of association (0.0 to <0.1 negligible, ≥0.1 to <0.2 weak, ≥0.2 to <0.4 moderate association (Rea and Parker, 1997)).

	Farm products	**Harvested products**	**Outdoor recreation activities**	**Social interaction**	**Aesthetic values**	**Cultural heritage**	**Inspirational values**	**Existence values**	**Habitat and biodiversity**	**Environmental capacities**
Land ownership[1]	V=0.272	V=0.098	ns	ns	V=0.050	V=0.128	V=0.123	V=0.102	V=0.051	V=0.100
X^2(df 1, N=2048)	152.01***	19.68***			5.16**	33.75***	31.04***	21.41***	5.31**	20.52***
Yes / No [%]	90.8/69.5	71.2/61.6			94.3/91.7	79.8/68.3	73.9/62.2	62.1/51.6	83.2/79.1	68.2/58.3
Self-estimated knowledge	V=0.093	V=0.162	ns	ns	V=0.104	V=0.090	V=0.080	V=0.100	V=0.092	V=0.101
X^2(df4, N=2263)	19.62**	59.55**			24.36***	18.26**	14.56**	22.71***	19.16**	22.91***
Extremely good / Good	84.6/84.2	72.1/70.9			94.3/93.7	79.5/74.3	69.7/68.8	56.7/57.8	85.9/81.1	67.5/62.7
Moderate	78.1	60.2			90.9	78.9	65.4	59.5	78.6	60.2
Poor /Extremely poor [%]	70.4/83.3	42.9/25.0			86.7/66.7	63.3/66.7	52.0/58.3	38.8/16.7	73.5/66.7	48.0/33.3
Length of residency (yrs)	V=0.126	V=0.140	ns	ns	V=0.068	V=0.145	ns	ns	ns	ns
X^2(df3, N=2144)	34.00***	42.00***			9.90*	45.30***				
0-5 / 6-15	73.3/75.6	52.4/61.4			89.5/93.7	59.2/71.9				
16-30 / >31 [%]	83.6/86.6	69.1/73.4			91.5/94.6	76.0/80.7				
Field of work in agriculture	V=0.100	V=0.114	V=0.072	ns	ns	V=0.053	ns	ns	V=0.052	V=0.051
X^2(df 1, N=2261)	22.53***	29.32***	11.56**			6.32*			6.21*	5.82*
Yes / No [%]	92.3/84.6	81.5/66.1	95.6/91.1			82.4/76.0			87.2/81.4	69.9/62.6

[1]Does not include SP-LT.

3.4 Landscape characteristics as determinants of ES benefits

Settlement and other artificial surfaces comprised only 3.1% of the analysis area, but mapped ES points were heavily over-represented in this land cover (20.0% of area in mapped locations, z=173.44, $p\leq0.05$). Settlement and artificial surfaces were particularly related to high amounts of ES benefits related to farm products (40.3% of area in mapped locations, z=119.25, $p\leq0.05$), appreciation of culture and heritage (39.7%, z=108.58, $p\leq0.05$) and sites for social interaction (29.5%, z=90.62, $p\leq0.05$) (Supplementary Fig. A.3 and Fig. A.4).

Looking at all predictors of landscape characteristics, the multivariate regression revealed accessibility (distance to home, length of roads and paths, and slope) as the most important predictor of individual mapped ES benefits, ES benefits sum and ES benefits diversity (Fig. 4, Fig. 5, Supplementary Table A.7). Benefits linked to provisioning ES and outdoor recreation activities decreased with increasing distance from the respondents' home. In contrast, aesthetic values, culture and heritage, regulating/supporting benefits (habitat and biodiversity, environmental capacities) and ES benefit sum and diversity showed an increase with greater distance from respondents' homes. Benefits linked to regulating/supporting and provisioning ES (especially harvesting) decreased with increasing length of roads and paths, while benefits linked to cultural ES increased, as did ES benefit sum and diversity. Slope played a less important role, showing a negative relationship (i.e. connection to flat terrain) with farm products and social interaction, but a positive one (i.e. connection to hilly and mountainous terrain) with aesthetic values, existence values and habitat and biodiversity perception.

Each ES benefit showed the same general response to the three types of land cover (simplified agricultural land, heterogeneous agricultural land, forests/water) (Fig. 4 and Fig. 5, Supplementary Table A.7). The abundance of forest/water was more positively related to harvesting of wild products than other land covers, while forest/water was the most negative predictor of farm products. Forest/water was also a positive significant predictor of regulating/supporting service-related ES benefits (i.e. habitat and biodiversity and environmental capacities), outdoor activities and aesthetic values. Although land cover richness showed a low explicative power for individual ES benefits, it was positively associated with the sum and diversity of ES. Conservation areas were also relevant determinants of ES benefit perception. While regulating/supporting benefits and aesthetic values as well as the sum of ES benefits increased with a growing proportions of the land designated as conservation areas, a reverse trend was identified for provisioning service-related ES benefits (appreciation of farm products and harvested products), outdoor recreation activities, and social interaction.

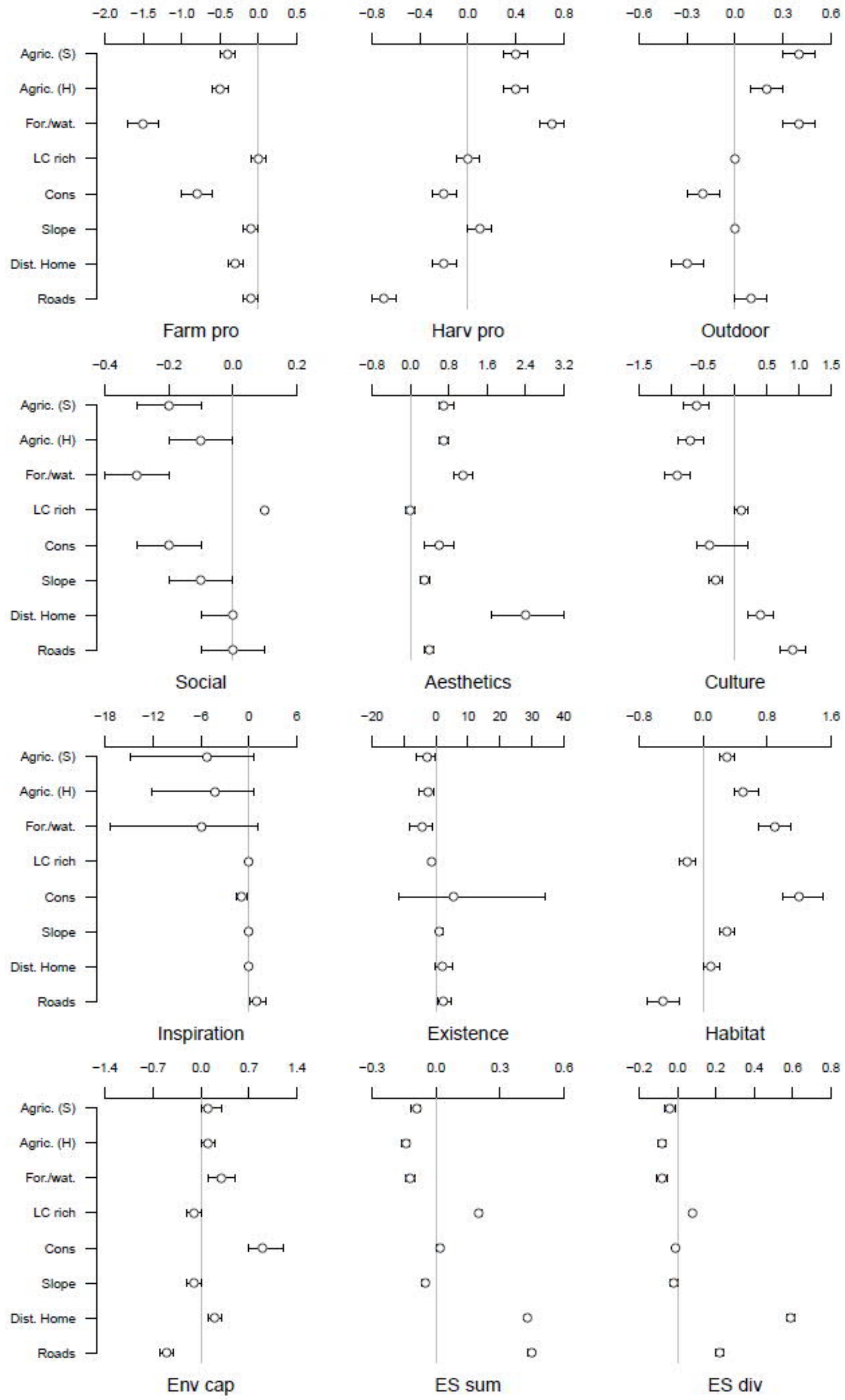

Figure 4. Relationship between predictors of landscape characteristics and ES benefits. Parameter estimates for the GLMM are based on summaries of the marginal posterior distributions of the predictors. Predictors describing landscape characteristics are shown on the vertical axis and include share of land cover class (Agric. (S)=simplified agricultural land, Agric. (H)=heterogeneous agricultural land), land cover richness (LC rich), share of conservation area (Cons), average slope (Slope), distance to home (Dist. Home), and length of roads and paths (Roads). Predictors with horizontal bars (95% credibility intervals) not crossing the zero line are interpreted as significant

(with negative values indicating a negative correlation and positive values a positive correlation, for values, see Supplementary Table A.7). For ES benefit acronyms, see Table 1, ES sum=sum of all mapped ES benefits, ES div=diversity of mapped ES benefits.

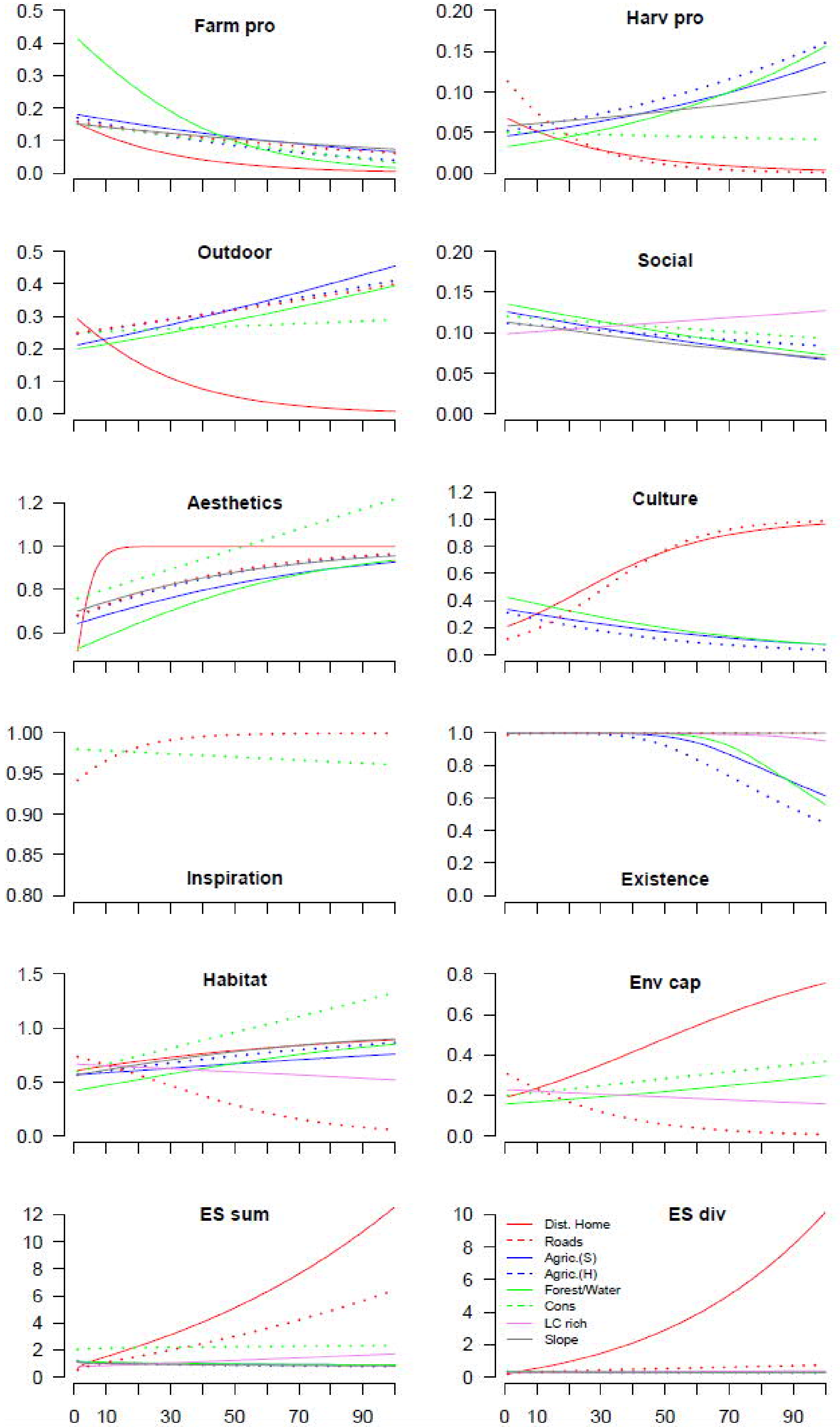

Figure 5: Partial dependence plots between ES benefit datasets and landscape characteristics predictors, as obtained from the GLMM analysis. Curves indicate how the probability that the response variables (individual ES (for ES benefit acronyms, see Table 1), ES sum and ES diversity displayed on vertical axis) varies in relation to landscape characteristics (share of land cover class (Agric. (S)=simplified agricultural land, Agric. (H)=heterogeneous agricultural land), land cover

richness (LC rich), share of conservation area (Cons), average slope (Slope), distance to home (Dist. home), and length of roads and paths (Roads), displayed on horizontal axis, normalized to 0-100 range). The curves are only presented for the influential predictors (i.e. the bolded ones in Supplementary Table A.7). Partial dependence plots were created following the method suggested by Elith et al. (2005).

4. Discussion

4.1 ES benefits in multifunctional landscapes

This study addresses ES benefits perceived by people in their everyday landscapes across the major types of multifunctional landscapes in Europe. Many studies have addressed PPGIS in the context of national forests and parks (e.g. Brown, 2012; Palomo et al., 2013; Sherrouse et al., 2014). In contrast, our study focuses on rural landscapes that are of particular importance in people's everyday life. Our findings show substantial consistency across the 13 study areas, with outdoor recreation, aesthetic values, and social interactions being the key ES benefits perceived. The importance of these three ES benefits has also been observed in participatory mapping studies performed with residents (Garcia-Martin et al., 2017; Hausner et al., 2015) and tourists (Scolozzi et al., 2014; Zoderer et al., 2016) elsewhere. The importance of recreation (often combined with tourism) and aesthetics is further stressed by the fact that these have received most attention among cultural ES assessments that applied a variety of methods (Hernández-Morcillo et al., 2013; Martínez-Harms and Balvanera, 2012; Milcu et al., 2013). Social interaction has been targeted less often, but our analysis suggests that it is a fundamental ES benefit of multifunctional landscapes.

Some variation in ES benefits across the 13 study sites is observed highlighting the economic growth- and wealth-related drivers of these social-ecological systems (Nelson et al., 2006). The economically marginal study areas (common in Mediterranean and Eastern Europe) typically have a high proportion of people working as farmers (partly carrying out subsistence farming), who are more dependent on and invest more in local benefits linked to provisioning ES. In contrast, the study areas with a more peri-urban landscape character and higher GDP usually have fewer subsistence farmers and the proportion of people directly employed on the land (and therefore directly involved in generating provisioning ES) is low. In these study areas the appreciation of landscapes is more related to recreational and other benefits linked to cultural ES, which suggests that this is a sector where rural entrepreneurs should invest as a country becomes wealthier and more urbanized.

Our analysis reveals particular spatial patterns in the perception of ES benefits and highlights that settlements in multifunctional landscapes are hotspots for ES benefits perceived by respondents (c.f. Garcia-Martin et al., 2017; Ridding et al., 2018). Sites for social interaction are clustered near respondents' homes, highlighting the importance of everyday landscape in providing sites for planned and unplanned social encounters. Outdoor recreation activities, in a similar way as the harvesting of wild products, generally take place close to people's homes. Thus, easy access to nature in multifunctional landscapes seems a key for providing these ES benefits and crucial for people's well-being, similarly observed by Ridding et al., (2018). An immediately accessible natural environment is not, however, commonly associated with aesthetic values, which are the ES benefits located furthest away from respondents' homes. Possibly, people find 'unusual' landscapes with less built structures more aesthetically attractive. ES benefits representing cultural and heritage values are highly clustered (typically displaying spot-like features, e.g. an ancient bridge or a wayside shrine), which suggests that there are well-known places which are valued by many people. These places can be easily identified and maintained through landscape planning and conservation efforts. At the same time, however, rural landscapes are intensively appreciated for ES benefits related to individual preferences and experiences such as aesthetic values, harvesting wild products, habitat and biodiversity, outdoor recreation activities, and inspirational, spiritual, religious and existence values. Since these ES benefits are not clustered, but dispersed across the landscape, they cannot be rigorously delineated and, thus, require careful land use planning for multiple types of uses to sustain them and for not to be compromised by development projects.

The respondents' deep-rooted relationship with the study area (rather than more general socio-demographic characteristics, similarly observed by Ode et al., 2009) is significantly linked to the type of ES benefits that they mapped. The appreciation of ES benefits is higher among landowners, agricultural workers, people who know the landscape well and long-term residents, generalizing earlier findings on the role of land ownership (Garcia-Martin et al., 2017) and local ecological knowledge (Barthel et al., 2010; Martín-López et al., 2012) as determinants of ES appreciation. Such understanding is important for those researching and managing rural landscapes, as it allows to identify key beneficiaries of ES. Howley et al., (2012) also suggest that people with overall appreciation of cultural and biological diversity in rural landscapes support actions aimed at landscape protection. To understand these relationships more deeply, future research should address the role of place attachment in the perception of ES benefits, e.g. by including community participation to contextualize the ES framework (Pascua et al., 2017).

Our study addresses the important role of accessibility in the perception of ES benefits (Schröter et al., 2014), applying a set of variables available across Europe, and shows that landscape characteristics related to accessibility are particularly important for the presence of perceived ES benefits. This same pattern has also been identified through analysis of geo-tagged social media photos and the pivotal importance of accessibility in terms of outdoor recreation and aesthetic values (van Zanten et al., 2016). The role of accessibility further highlights the settlements as ES benefit hotspots as distances to home are the shortest, and road and path network the densest. Although settlements host many ES benefits, particular benefits in settlement areas include the appreciation of agricultural products from home gardening and local farmers, the presence of culture and heritage sites, and sites for social interaction linked to easy accessibility. It is intuitive that more ES benefits are found in villages and towns where the landscape-people interaction is the most intensive and where heritage is prominently present. This points to the discussion on the co-production of ES, in this case especially of the cultural ES (Palomo et al., 2016). Our results highlight the interactions between biophysical and socio-cultural processes, people and place, as essential for generating these ES benefits (Fischer and Eastwood, 2016). Noteworthy is, though, that people often map places they have access to and are most familiar with and that these sites are not necessarily the most valuable areas in terms of biodiversity or provision of other ES.

In terms of farm products sold in villages, settlement land cover is an intermediate for ES benefits provided by the surrounding agricultural land. With our survey, we mapped how people perceive their everyday landscapes. However, our results revealed how these perceptions are driven by personal characteristics and related to cultural and socio-economic conditions as well as to the ES capacity of the landscape to provide these; pointing out to potential mismatches between supply and demand of ES (Bagstad et al., 2014; Wei et al., 2017). This highlights the relevance of ES flows (Palomo et al., 2013, Bagstad et al., 2014, Villamanga et al., 2014) for future research on perceived ES benefits. It also highlights the challenges related to extrapolation and upscaling (Crossman et al., 2013). Nevertheless, PPGIS approaches may successfully complement integrated ES modelling and decision support tools (Grêt-Regamey et al., 2017) by particularly emphasising a wider variety of cultural ES compared to proxy indicators that are often restricted to recreation (Bagstad et al., 2017).

Our land cover analysis and regression modeling demonstrate particular appreciation of forest and water bodies which confirms the results from various landscape perception studies (e.g. Brown et al., 2015a; Howley et al., 2012; Petrova et al., 2015; Ridding et al., 2018). Both the ES benefit sum and diversity increase with land cover richness and suggest that mosaic landscapes (e.g. at the interface of settlement and artificial surfaces and other land uses) are favored by people, which highlights the importance of multifunctionality and spatial patterns for generating socio-cultural values (Van Zanten et al., 2014). Conservation areas are predominantly appreciated for benefits linked to regulating/supporting ES and aesthetic values, but less so for benefits linked to provisioning and some cultural ES (i.e. outdoor recreation activities, social interaction and inspirational values). These deficits may be addressed through protected area management and planning strategies that encourage more intensely tangible human-nature interactions (Chan et al., 2016).

4.2 Considering the method

Our limited number of case studies makes it impossible to be representative of multifunctional landscapes in Europe as a whole and hence our study is not a continent-wide study. Rather it is illustrative of the diversity of European multifunctional landscapes. We acknowledge that residents represent a very relevant, but not the only group of stakeholders benefitting from ES in these landscapes. Published studies show that different stakeholders with variable power, interests and worldviews perceive ES benefits differently and at different scales (Martín-López et al., 2012; Van Riper and Kyle, 2014). Participatory mapping provides a means of assessing the less tangible benefits that landscapes and ecosystems provide to humans, the lack of which has been a recurring criticism of the ES framework (Daniel et al., 2012; Setten et al., 2012; Small et al., 2017). In our PPGIS approach the mapped individual benefits are aggregated without group deliberation. However, as these mapped ES benefits are tied to a place, connect to the sense of place, landscape, community and way of life, they are likely to be strongly shared as communal values (Kenter et al., 2015).

Our facilitated approach to survey data collection allowed, firstly, better control of respondent population compared to pure random household sampling which is the most common sampling approach applied in PPGIS mapping of ES benefits and frequently leads to samples that include older and male respondents disproportionately (Beverly et al., 2008; Brown and Reed, 2009; Raymond and Brown, 2007). However, as our sampling considered only gender and age, we acknowledge that the sample does not necessarily represent the population in terms of other socio-demographic factors. Secondly, the facilitated approach allowed in-depth discussion with the informants on the meanings and placement of the mapped ES benefits. We observed this increased spatial data precision and also the amount of mapped places compared to self-administered surveys, as was shown in the CH-SB study area.

4.3 Implementation in sustainable landscape management

Covering 28-37% of the Earth's surface (Millennium Ecosystem Assessement, 2005), agricultural land has a key role in safeguarding ES, within which multifunctional production systems play a significant role. The multifunctionality of rural areas is globally promoted under the umbrella of "integrated landscape management" (ILM) (Denier et al., 2015). ILM is in line with international policies safeguarding biodiversity, ES, and human well-being, such as the UN-Aichi Biodiversity Targets (Secreteriat of the Convention on Biological Diversity, 2014) and the European Union (EU) Biodiversity Strategy to 2020 (European Commission, 2011). It is highlighted as a central approach to reach the 17 Sustainable Development Goals (SDG) driving transformation towards sustainable development and a transition to sustainable lifestyles (Mann et al., 2018). ILM is also the main message of the European Landscape Convention (Council of Europe, 2000), which identifies the key role of human perception and attitudes as drivers of landscape change. ILM strategies particularly acknowledge the role of local stakeholders in designing unique and contextual sustainable landscape solutions (e.g. field, farm, and forest practices) and investment and innovation towards green economies (Creutzig, 2017; Denier et al., 2015). Participatory mapping of ES benefits as developed in this study could help to operationalize implementing ILM (Cowling et al., 2008; Sayer et al., 2013). We suggest that existing planning practices in multifunctional landscapes and efforts to map and assess ES and green infrastructure in general (such as those related to Actions 5 and 6 in the EU Biodiversity Strategy (European Commission, 2016, 2011)) would substantially benefit from participatory approaches mapping perceived ES benefits on landscapes. Such a place-based approach integrating participation of local stakeholders through e.g. surveys, meetings, workshops or social media would have potential to identify ES benefits, concrete actions to sustain multiple ES and to counteracting the development of simplified, productive, mono-functional landscapes with decreasing landscape quality and increasing land use conflict potential (Gobster et al., 2007; Mann et al., 2018).

5. Conclusions

While most previous socio-cultural assessments of ES have been local-level case studies, we have assessed ES benefits perceived by residents across major types of multifunctional landscapes in Europe with a standardized methodology. Our study finds that settlement areas, the lived environments, are hotspots of ES benefits. Benefits linked to provisioning ES are emphasized in study areas with low GDP and population density, while benefits linked to cultural ES are more appreciated in peri-urban study areas with high GDP and population density. Some mapped ES benefits (e.g. culture and heritage values) are spatially clustered to same places but many others (e.g. aesthetic values) dispersed, highlighting individual preferences and experiences. Our results show that significant determinants of ES benefits are people's relationship with a landscape (particularly land ownership) and landscape characteristics related to accessibility. Many ES benefits are also related to forests, waters and mosaic landscapes. We expect the patterns we found are similar to those in other multifunctional landscapes in developed countries. Our study indicates that participatory mapping of ES benefits is valuable to highlight their multiple benefits for people.

Our data and results give weight to the growing body of knowledge on how people benefit from ES for those researching and applying the ES framework in research and management. As Nahuelhual et al. (2016) highlight, there should be more theoretical discussion on mapping social values for ES. In addition, the conceptual confusions among researchers' about distinguishing between services, benefits and values, the "conflation problem", may hinder the mainstreaming of ES framework in decision making (Chan et al., 2012). Hence, in this paper, we aim to offer an in-depth argumentation of the theoretical underpinnings of mapped ES benefits to promote further clarification regarding the links from services to benefits, and from benefits to different types of values. Our study emphasizes the importance of local-level perspectives to the development of contextualized and socially acceptable public policies for ES management. Deliberative and participatory methods can especially help to reinforce the currently weak link between ES assessment and decision-making with the on-ground implementation of contextual actions (Kenter et al., 2015; Raymond et al., 2014). Thus, participatory mapping supporting ILM has potential to be a mechanism for the operationalization of the SDGs in European multifunctional landscapes.

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Supplementary material

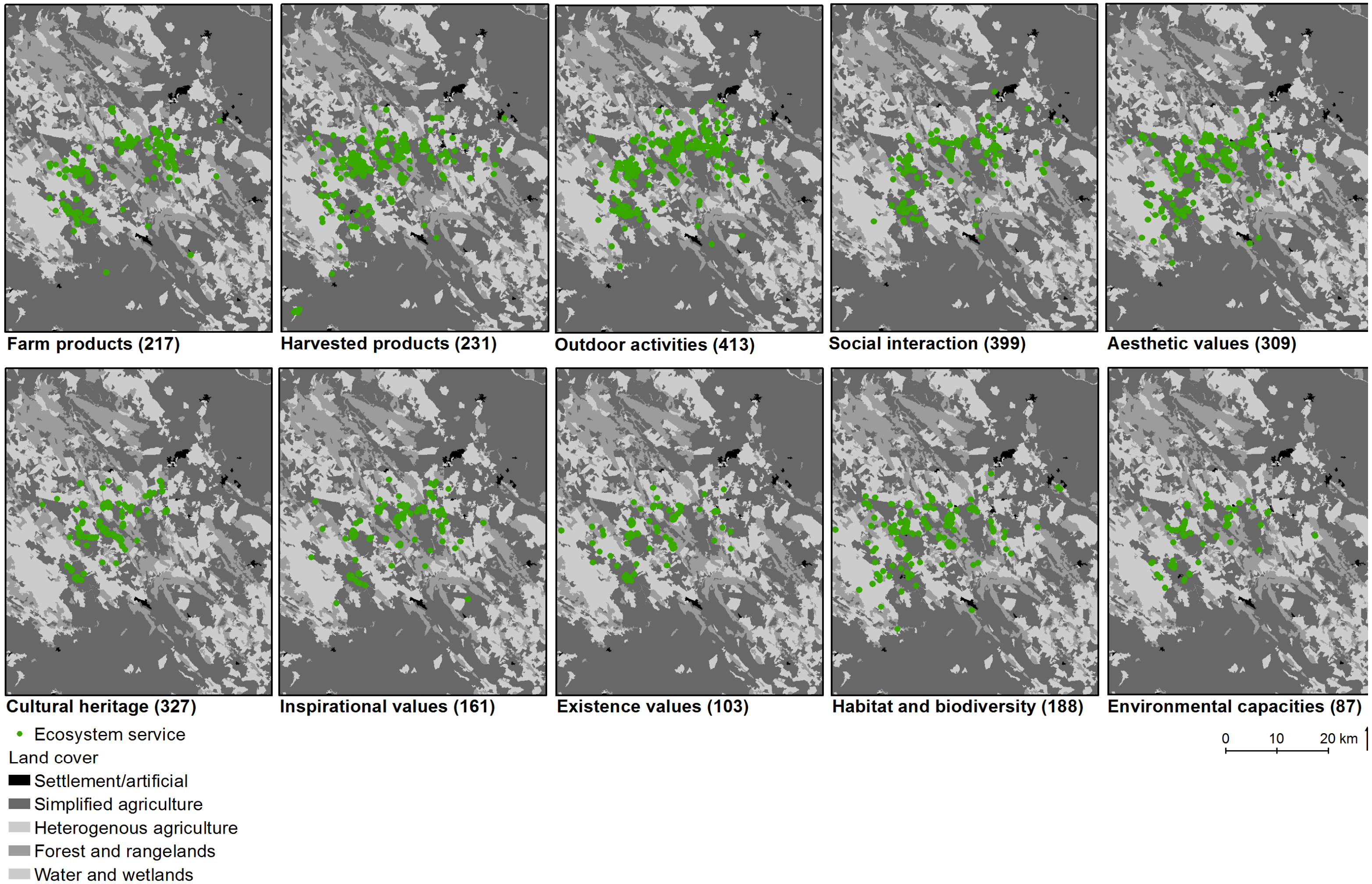

Figure A.1. Spatial patterns of mapped ES benefits in Serena Campiña, Spain (SP-SC). 181 residents mapped in total 2,438 places (as point locations, in brackets the number of places for each service).

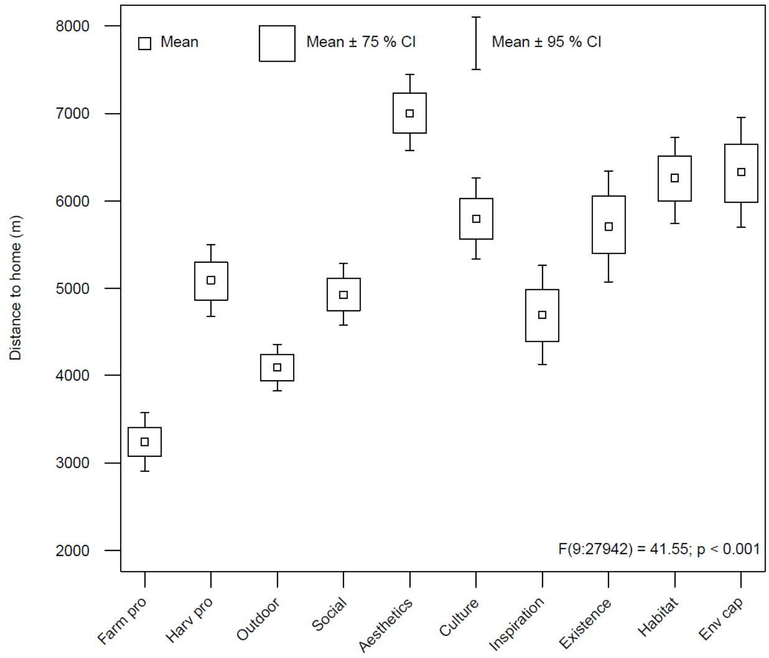

Figure A.2. Mean distance (m) between respondent home location and mapped places for ES benefits. CI=Confidence interval. For ES benefit acronyms, see Table 1.

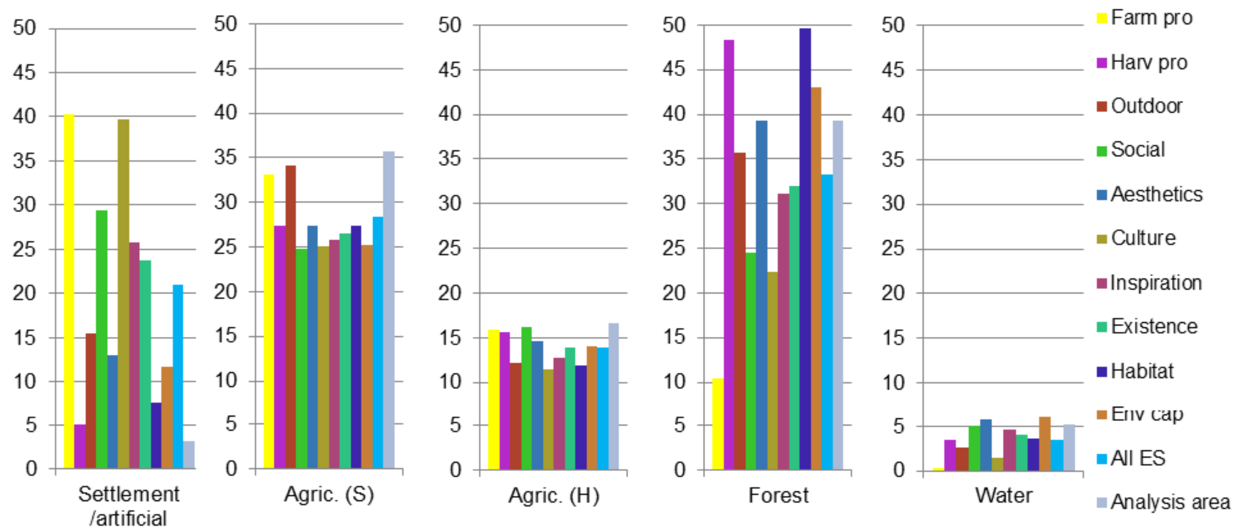

Figure A.3. Relative share (%) of each land cover class in 250 m buffer around each mapped point categorized per ES benefit type. For comparison, all ES benefits (i.e. the total share of all ES benefits across all case study areas) and each land cover class in the analysis area (polygon enclosing the mapped points per study site) are also shown. Land covers: Agric. (S)=simplified agricultural land; Agric. (H)=heterogeneous agricultural land; Water=water and wetlands. For ES benefit acronyms, see Table 1.

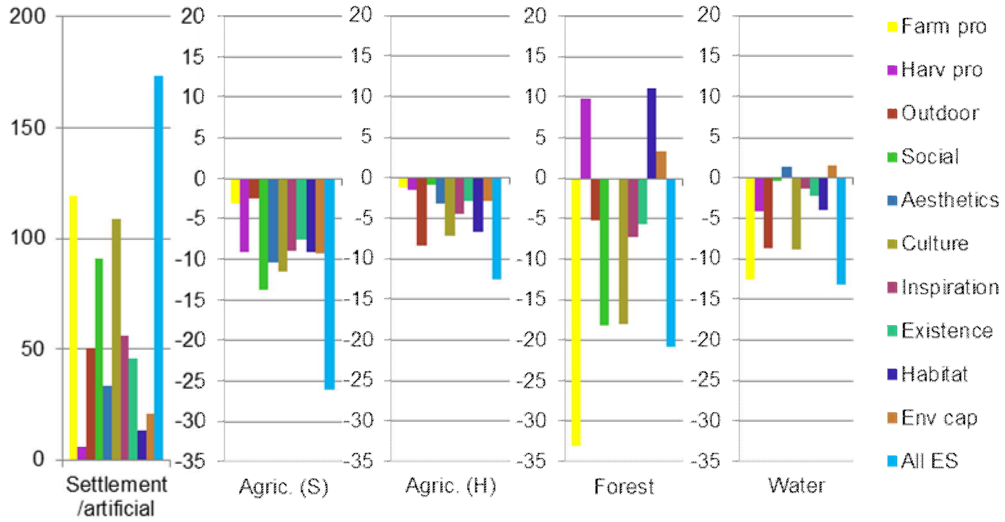

Figure A.4. z-Scores (y-axis) of mapped ES benefits by land cover class (x-axis) for each ES benefit and all services together. Z-Score bars higher than +1.96 and lower than -1.96 indicate that the specific ES benefit is statistically significantly ($p \leq 0.05$) over- or under-represented in a specific land cover class based on the proportion of that land cover class in the analysis area. Land covers: Agric. (S)=simplified agricultural land; Agric. (H)=heterogeneous agricultural land; Water=water and wetlands. For ES benefit acronyms, see Table 1.

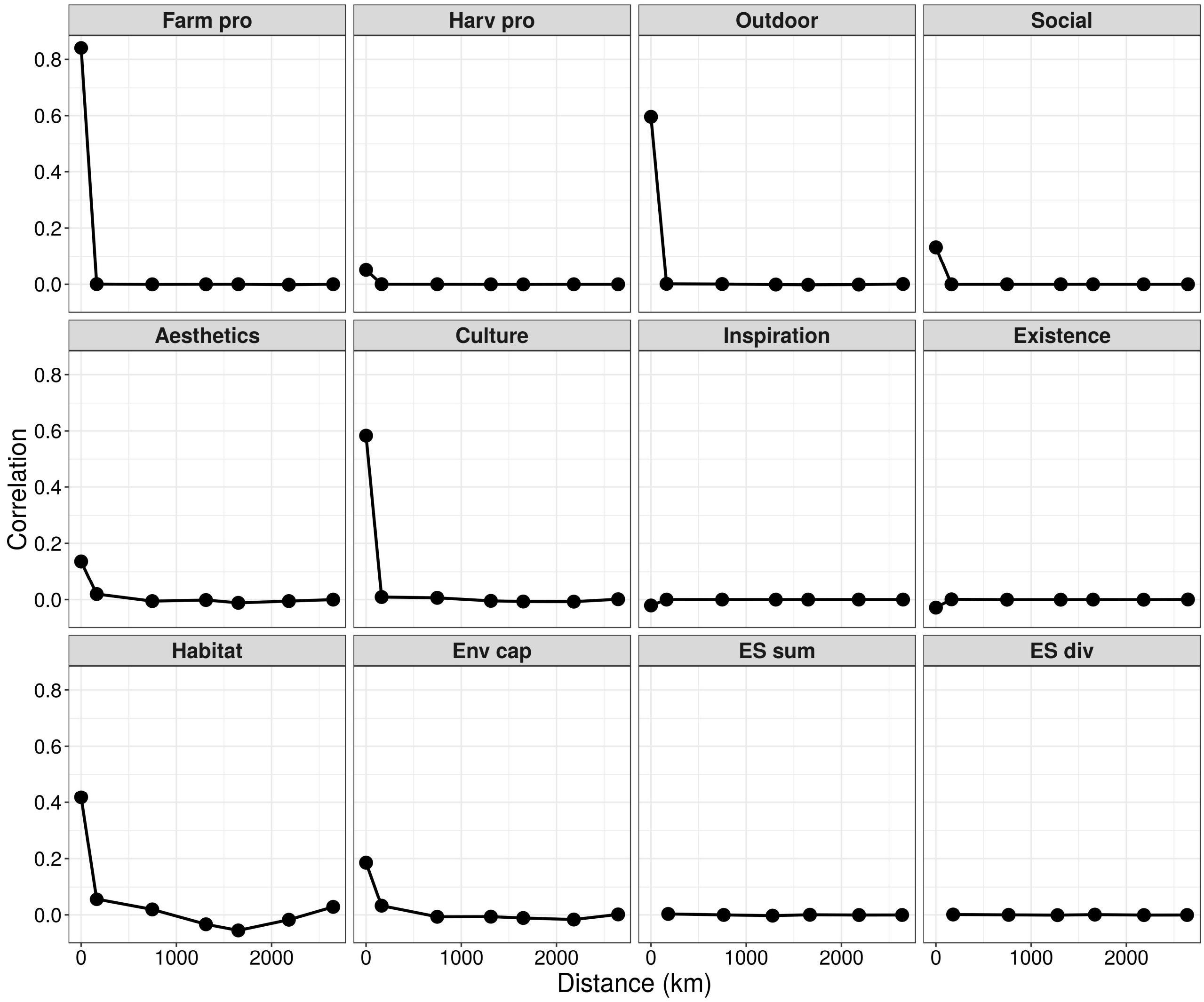

Figure A.5. Correlograms for residuals of GLMM models fitted to the individual ES benefits, sum of ES benefits and ES benefit diversity. For ES benefit acronyms, see Table 1, Sum ES=sum of all mapped ES benefits, ES div=diversity of mapped ES benefits.

Table A.1. Characteristics of study areas.

Study site name	Biogeo gr. region	Analysis area km²	Landscape description	Land cover[1] (% within analysis area)	Conservation area cover (% within analysis area)	Pop. den. inh./ km²	Wealth level (gross domestic product/ capita, €)[2]	Economic density[3]	Accessibility[3]	Most frequent ES benefits[4] (% of all mapped places)	Least frequent ES benefits (% of all mapped places)
Montaña Oriental Lucense, Spain (SP-MO)	Atlantic	3730	Mountainous area with river basin, small villages, suffering from migration to cities, forests, pastures, arable land, semi-natural traditional chestnut (*Castanaea sativa*) groves	S: 0.8% AS: 4.9% AH: 28.6% F: 65.1% W: 0.6%	19.1%	15	19,500	Low	Low	Harv pro (12.4%), outdoor (12.2%), farm pro (12.0%)	Inspiration (5.9%), existence (6.3%), habitat (7.3%)
Canton de Loudéac, France (FR-CL)	Atlantic	3258	Flat terrain with villages, arable land with mixed diary, fodder and grain production dominating, some grasslands, traditional hedgerow networks on arable land (*bocage*)	S: 3.5% AS: 61.2% AH: 23.6% F: 11.4% W: 0.2%	0.8%	20	22,300	Average	Low	Outdoor (17.2%), aesthetic (14.3%), farm pro (12.4%)	Inspiration (6.5%), env cap (6.7%), existence (7.1%)
The Brecks, England, UK (UK-BR)	Atlantic	1138	Lowland open rural landscape, with small towns and villages, free draining sandy soils which (with irrigation) can be used for intensive agriculture, but elsewhere used for outdoor pig production, crop and vegetable production, and plantation conifer forestry	S: 6.5% AS: 68.0% AH: 4.8% F: 20.2% W: 0.5%	39.0%	46	32,000	Average	Low/Average	Outdoor (20.4%), social (14.6%), aesthetic (13.9%)	Harv pro (3.6%), existence (6.2%), culture (6.3%)
Linköping, Sweden (SE-LI)	Boreal	9330	Flat peri-urban area with 10 municipalities, in north arable and urban land, southern part mostly coniferous forest, largest remnant area of cultural landscapes in Sweden with open and patchy oak	S: 2.8% AS: 26.0% AH: 3.7% F: 55.2% W: 12.3%	5.1%	96	34,440	High	Average/High	Outdoor (23.1%), social (19.4%), aesthetic (12.0%)	Env cap (3.9%), existence (4.0%), inspiration (4.3%)

			pastures of (*Quercus robur and Quercus petraea)*								
Franches Montagnes, Switzerland (CH-FM)	Continental	1854	Mountain plateau with small villages, forest and grasslands with trees, outdoor recreation tourism, wood pastures with free ranging horses and cattle	S: 4.4% AS: 44.6% AH: 7.5% F: 43.3% W: 0.1%	15.0%	75	56,400	High	Average	Outdoor (20.0%), aesthetic (10.4%), social (10.4%)	Existence (4.1%), env cap (5.0%), inspiration (7.4%)
Schwarzubenland, Switzerland (CH-SB)	Continental	320	Gently rolling hills with small villages, farmland, grasslands and traditional orchards (esp. cherry) with mosaic of forest patches, recreation area for nearby city	S: 20.7% AS: 33.3% AH: 2.4% F: 43.0% W: 0.7%	0.4%	168	61,200	High	High	Outdoor (25.8%), aesthetic (12.9%), habitat (12.1%)	Env cap (3.2%), inspiration (5.9%), existence (6.3%)
Hochkirch-Weißenberg, Germany (DE-HW)	Continental	3136	Gently undulating fertile loess land with small villages and intensive agriculture, forests, heterogeneous agricultural land with arable crops mixed with semi-natural features (hedgerows, farm trees, woodlots, riparian woodlands)	S: 10.4% AS: 54.5% AH: 2.0% F: 30.5% W: 2.6%	47.2%	62	20,700	High	Average	Outdoor (19.2%), farm pro (15.3%), aesthetic (14.2%),	Existence (3.0%), inspiration (5.0%), env cap (6.1%)
Saxon region, Romania (RO-SA)	Continental	957	Traditional land use practices and low levels of infrastructure development, small villages, pastures with scattered trees, typically oak (*Quercus robur, Quercus petraea*), forests and arable fields	S: 2.3% AS: 59.7% AH: 4.5% F: 32.9% W: 0.6%	84.0%	26	4,600	Low	Average	Habitat (11.3%), harv pro (10.9%), outdoor (10.4%)	Existence (5.9%), inspiration (8.2%), culture (9.6%)
Llanos de Trujillo, Spain (SP-LT)	Mediterranean	5931	Flat land with small villages around larger town, dry grasslands, dehesa, shrublands, extensive cereal crops, extensive grazed holm oak (*Quercus ilex*), pastures (Iberian *dehesa*), livestock breeding (sheep, cattle, Iberian black pigs), increasing	S: 0.9% AS: 33.6% AH: 32.8% F: 31.6% W: 1.2%	53.1%	12	15,700	Low	Average /High	Outdoor (16.5%), harv pro (12.8%), aesthetic (11.8%)	Existence (3.9%), inspiration (5.2%), env cap (5.4%)

			nature tourism								
Serena Campiña, Spain (SP-SC)	Mediterranean	2479	Flat and hilly lands with small villages, arable lands, arable lands with scattered oaks (*dehesa*), forest and shurblands, increasing nature tourism	S: 0.8% AS: 60.6% AH: 24.6% F: 13.7% W: 0.3%	38.0%	10	15,600	Low/Average	Low	Outdoor (16.9%), social (16.4%), culture (13.4%)	Env cap (3.6%), existence (4.2%), inspiration (6.6%)
Kassandra, Greece (GR-KA)	Mediterranean	595	Gently undulating peninsula with 14 villages, small arable land (cereals) of small farms half of it covered by scattered olive trees, pine forests, olive groves with understory cultivation or grazing or both, tourism main economic activity	S: 3.0% AS: 23.9% AH: 13.7% F: 17.8% W: 41.6%	10.9%	49	15,000	Average	Low	Farm pro (15.9%), aesthetic (14.8%), social (12.7%)	Existence (5.7%), habitat (7.0%), inspiration (7.4%)
Montemor-O-Novo, Portugal (PT-MN)	Mediterranean	4470	Flat area with slight undulation, oak (*Quercus suber, Quercus rotundifolia*) pastures (*montado*) combined with dry lands agriculture (cereals)	S: 1.3% SA: 22.4% SH: 26.5% F: 45.0% W: 4.8%	37.2%	3	13,500	Low/Average	Low/Average	Outdoor (14.4%), harv pro (13.9%), social (11.5%)	Existence (4.9%), inspiration (5.4%), env cap (6.2%)
Zala, Hungary (HU-ZA)	Pannonian	1288	Hilly area, belongs partly to national park, mainly small scale farming: traditional agroforestry, vineyards, forest, woodland (dominated by oak and planted *Pinus nigra*) and small patches of ancient oak wood pastures, and arable lands, water (Balaton lake) a crucial part of the landscape and the economy (holiday region)	S: 6.4% AS: 40.7% AH: 7.2% F: 29.5% W: 16.2%	43.5%	185	6,300	Low/Average	Low	Outdoor (13.4%), social (13.8%), aesthetic (11.2%)	Existence (7.3%), inspiration (8.7%), culture (8.8%)

[1]S=settlement area, AS=simplified agricultural land, AH=heterogeneous agricultural land, F=forest, W=water and wetlands
[2]Year of reference: 2011. NUTS 3 level. Sources: Eurostat, Swiss Federal Statistics Office
[3]Following the FARO typology of rurality (van Eupen, M. et al. A rural typology for strategic European policies. Land use policy 29, 473–482 (2012))

[4]ES: Farm pro=farm products; Harv pro= harvested products; Outdoor=outdoor activities; Social=social interaction; Aesthetics=aesthetic values; Culture=culture and heritage; Inspiration=inspirational values; Existence=existence values; Habitat=habitat and biodiversity; Env cap=environmental capacities

Table A.2. Respondent characteristics (%) at 13 study sites and average for all sites.

		Atlantic			Boreal	Continental			Mediterranean					Pannonian
Study site	**ALL**	**SP-MO**	**FR-CL**	**UK-BR**	**SE-LI**	**CH-FM**	**CH-SB**	**DE-HW**	**RO-SA**	**SP-LT**	**SP-SC**	**GR-KA**	**PT-MN**	**HU-ZA**
Gender														
Men	49.3	48.8	49.0	52.3	51.5	45.3	52.8	45.6	49.4	51.1	49.2	48.5	54.2	41.3
Women	50.7	51.2	51.0	47.7	48.5	54.7	47.2	54.4	50.6	48.9	50.8	51.5	45.8	58.7
	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Age														
15-29 yrs	21.2	9.8	16.8	25.4	28.6	29.4	6.4	24.5	19.1	24.2	17.3	26.6	21.8	28.7
30-59 yrs	48.5	42.1	51.7	46.2	54.2	38.0	56.8	48.4	54.5	45.7	49.7	50.9	45.9	44.9
≥ 60 yrs	30.3	48.2	31.5	28.3	17.3	32.5	36.8	27.1	26.4	30.1	33.0	22.5	32.4	26.3
	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Highest level of education														
University degree or polytechnic	27.2	24.6	33.6	28.0	45.5	19.4	48.4	15.9	10.5	18.1	19.6	30.4	11.2	44.8
Vocational training. secondary school / college	41.8	25.1	52.7	53.6	47.9	63.0	47.9	44.9	50.0	25.4	22.3	52.0	23.7	40.5
Primary or secondary school	26.7	26.3	13.0	16.7	6.7	17.6	3.2	37.0	36.6	49.8	45.3	17.5	63.3	14.1
No formal schooling	4.3	24.0	0.7	1.8	0.0	0.0	0.5	2.2	2.9	6.8	12.8	0.0	1.8	0.6
	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Household monthly net income														
Above median for region	47.8	70.3	79.3	59.9	71.6	40.6	81.7	38.2	29.5	30.3	19.9	26.2	8.5	79.6
Below median for region	52.2	29.7	20.7	40.1	28.4	59.4	18.3	61.8	70.5	69.7	80.1	73.8	91.5	20.4
	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Field of work in agriculture														
No	86.3	75.4	80.7	96.5	91.2	90.4	94.0	95.8	71.3	81.7	92.7	87.8	74.1	89.6
Yes	13.7	24.6	19.3	3.5	8.8	9.6	6.0	4.2	28.7	18.3	7.3	12.2	25.9	10.4
	99.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Landownership[1]														

Yes	60.2	88.9	26.9	30.1	37.6	46.4	80.0	58.4	80.2	no	61.8	82.0	30.1	87.7
No	39.8	11.1	73.1	69.9	62.4	53.6	20.0	41.6	19.8	data	38.2	18.0	69.9	12.3
	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0		100.0	100.0	100.0	100.0
Self-estimated knowledge														
Extremely good	38.0	17.6	26.7	47.4	29.8	38.8	52.1	33.3	67.8	40.2	25.7	25.7	37.3	43.3
Quite good	40.2	52.9	43.8	42.7	35.1	46.1	37.4	52.0	24.3	39.3	33.5	44.4	34.3	40.2
Moderate	17.0	28.2	21.9	5.8	26.3	8.5	8.2	12.7	7.3	13.7	29.6	21.6	26.0	13.4
Quite poor	4.3	0.6	6.8	3.5	8.2	4.8	1.8	2.0	0.6	5.0	11.2	7.0	1.8	3.0
Extremely poor	0.5	0.6	0.7	0.6	0.6	1.8	0.5	0.0	0.0	0.0	0.0	1.2	0.6	0.0
	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Length of residency														
less than 5 yrs	9.0	3.6	14.7	21.7	15.9	8.8	13.9	4.9	6.1	4.8	3.0	4.5	6.0	8.5
6-15 yrs	14.0	7.7	11.6	21.1	22.0	20.0	25.0	4.9	7.5	16.8	1.2	14.1	10.8	12.4
16-30 yrs	29.0	22.6	25.6	30.1	25.0	30.6	25.5	34.3	25.2	26.4	35.8	34.6	25.7	38.6
31 yrs or more	48.0	66.1	48.1	27.1	37.2	40.6	35.6	55.9	61.2	51.9	60.0	46.8	57.5	40.5
	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

[1]Not included in test phase data collection in SP-LT.

Table A.3. Respondent characteristics at each study site by sampling scheme gender and age categories with comparison to census data (%).

	Atlantic						Boreal		Continental							
	SP-MO		FR-CL	UK-BR			SE-LI[1]		CH-FM		CH-SB		DE-HW[2]		RO-SA[3]	
	Sample	Census	Sample	Sample	Census	Census	Sample	Census	Sample	Census	Sample	Census	Sample	Census	Sample	Census
Male																
15-29	8.9	10.3	17.4	23.6	26.3	20.9	44.2	35.9	27.8	24.3	5.3	19.3	26.1	14.6	18.6	23.4
30-59	44.3	41.2	49.3	41.6	47.9	47.9	31.4	31.9	33.3	48.2	50.9	49.7	50.7	61.4	50.0	53.1
60-	46.8	48.4	33.3	34.8	25.8	31.2	24.4	32.2	38.9	27.6	43.9	31.0	23.2	24.0	31.4	23.4
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Female																
15-29	11.0	11.2	16.2	26.8	24.8	17.0	46.9	32.4	30.7	23.6	7.8	18.9	23.5	14.3	20.2	20.4
30-59	39.0	35.0	54.1	52.4	45.6	44.3	25.9	30.6	42.0	47.2	64.1	48.8	45.9	50.2	58.4	50.6
60-	50.0	53.8	29.7	20.7	29.6	38.7	27.2	37.0	27.3	29.2	28.2	32.3	30.6	35.5	21.3	29.1
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

	Mediterranean								Pannonian	
	SP-LT		SP-SC		GR-KA		PT-MN		HU-ZA	
	Sample	Census	Sample	Census	Sample	Census	Sample	Census	Sample	Census
Male										
15-29	21.4	16.5	19.3	22.9	28.0	27.0	20.2	14.7	26.1	18.7
30-59	47.3	54.4	52.3	48.1	51.2	49.7	43.8	41.7	46.4	52.0
60-	31.3	29.1	28.4	29.1	20.7	23.2	36.0	43.5	27.5	29.4
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Female										
15-29	27.1	14.8	15.4	21.2	25.3	26.9	24.7	12.4	30.6	13.2

30-59	43.0	48.6	47.3	42.9	50.6	45.7	46.8	36.0	43.9	50.4
60-	29.9	36.5	37.4	35.9	24.1	27.4	28.6	51.6	25.5	36.4
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

[1]Age categories 18-34 years, 35-54 years, ≥ 55 years

[2]First age category 0-29 years

[3]Based on Eurostat 2014 NUTS 3 statistics

Table A.4. Correlation between landscape predictors and respondents' socio-demographic variables. Bold letters indicate the significant correlations. (Agric. (S)=simplified agricultural land, Agric. (H)=heterogeneous agricultural land), land cover richness (LC richness), share of conservation area (Conservation), average slope (Slope), distance to home (Dist. Home), and length of roads and paths (Roads).

	Agric. (S)	**Agric. (H)**	**Forest/Water**	**LC richness**	**Conservation**	**Slope**	**Dist. Home**	**Roads**
Gender	0.002 p=0.995	0.267 p=0.402	-0.043 p=0.895	0.188 p=0.558	-0.234 p=0.463	-0.074 p=0.821	-0.008 p=0.981	-0.080 p=0.805
Age	-0.320 p=0.311	0.409 p=0.187	0.322 p=0.307	0.085 p=0.793	-0.189 p=0.555	**0.745** **p=0.005**	-0.409 p=0.187	-0.313 p=0.322
Education	0.380 p=0.224	**-0.723** **p=0.008**	-0.114 p=0.725	0.005 p=0.989	-0.444 p=0.148	-0.167 p=0.605	0.274 p=0.389	**0.724** **p=0.008**
Household income	0.284 p=0.372	-0.445 p=0.148	0.249 p=0.436	-0.152 p=0.637	-0.456 p=0.137	0.246 p=0.441	-0.071 p=0.828	**0.633** **p=0.027**
Field of work in agriculture	-0.377 p=0.227	0.438 p=0.154	0.106 p=0.744	0.560 p=0.058	0.295 p=0.351	0.327 p=0.299	-0.167 p=0.604	**-0.757** **p=0.004**
Land ownership	-0.312 p=0.324	-0.099 p=0.760	0.324 p=0.304	0.358 p=0.254	0.170 p=0.598	**0.655** **p=0.021**	-0.505 p=0.094	-0.170 p=0.597
Self-estimated knowledge	0.291 p=0.359	-0.539 p=0.071	-0.241 p=0.452	0.476 p=.117	0.365 p=0.244	0.051 p=0.876	**-0.657** **p=0.020**	0.219 p=0.494
Length of residency	-0.260 p=0.415	0.559 p=0.059	0.098 p=0.763	0.151 p=0.639	0.355 p=0.257	0.298 p=0.347	-0.140 p=0.665	**-0.800** **p=0.002**

Table A.5. Nearest neighbour (NN) ratio and z-score for mapped ES benefits for each study site. Results are significant at the level of p<0.001.

	Atlantic						Boreal		Continental							
	SP-MO		FR-CL		UK-BR		SE-LI		CH-FM		CH-SB		DE-HW		RO-SA	
	NN ratio	z-score	NN ratio	z-score	NN ratio	z-score	NN ratio	z-score	NN ratio	z-score	NN ratio	z-score	NN ratio	z-score	NN ratio	z-score
Provisioning services																
Farm products	0.24	-25.79	0.32	-20.85	0.37	-13.52	0.34	-13.87	0.19	-25.46	0.23	-25.66	0.37	-18.51	0.21	-21.73
Harvested products	0.32	-23.59	0.38	-14.82	0.58	-6.35	0.58	-11.96	0.31	-20.00	0.32	-16.81	0.38	-13.67	0.31	-19.75
Cultural services																
Outdoor activities	0.33	-22.99	0.49	-18.62	0.53	-16.90	0.28	-31.84	0.36	-28.43	0.50	-25.92	0.41	-19.51	0.33	-18.46
Social interaction	0.21	-24.20	0.41	-17.44	0.37	-19.03	0.29	-28.72	0.25	-23.38	0.34	-20.09	0.50	-12.31	0.28	-19.52
Aesthetic value	0.34	-19.57	0.39	-20.07	0.52	-14.34	0.38	-19.50	0.39	-19.14	0.50	-18.35	0.43	-16.19	0.34	-18.04
Culture and heritage	0.14	-28.25	0.45	-13.50	0.28	-14.22	0.25	-17.07	0.27	-21.31	0.28	-21.80	0.19	-15.90	0.16	-22.40
Inspirational. spiritual or religious values	0.40	-14.45	0.36	-14.19	0.44	-11.19	0.51	-9.33	0.39	-16.07	0.36	-15.22	0.38	-10.44	0.31	-16.97
Existence values	0.27	-18.02	0.52	-11.28	0.49	-10.20	0.22	-14.41	0.27	-14.27	0.39	-13.14	0.43	-7.47	0.40	-12.72
Regulating/supporting services																
Habitat and biodiversity	0.27	-19.34	0.50	-12.48	0.46	-14.82	0.19	-25.17	0.40	-17.77	0.40	-21.60	0.29	-14.43	0.44	-16.33
Environmental capacities	0.25	-20.37	0.39	-13.84	0.46	-12.20	0.19	-14.67	0.34	-14.21	0.34	-12.19	0.26	-13.58	0.40	-16.19

	Mediterranean								Pannonian	
	SP-LT		SP-SC		GR-KA		PT-MN		HU-ZA	
	NN ratio	z-score	NN ratio	z-score	NN ratio	z-score	NN ratio	z-score	NN ratio	z-score
Provisioning services										
Farm products	0.30	-22.78	0.42	-16.38	0.40	-21.73	0.16	-23.19	0.20	-22.61
Harvested products	0.47	-18.15	0.59	-11.95	0.64	-9.69	0.30	-25.16	0.31	-16.19
Cultural services										
Outdoor activities	0.27	-28.88	0.38	-24.15	0.45	-16.08	0.21	-28.81	0.33	-21.09

Social interaction	0.35	-20.25	0.27	-27.68	0.35	-21.11	0.31	-22.67	0.19	-25.86
Aesthetic value	0.48	-17.03	0.35	-21.84	0.42	-20.32	0.23	-24.70	0.31	-19.86
Culture and heritage	0.23	-23.32	0.16	-29.06	0.34	-18.79	0.19	-22.48	0.29	-18.01
Inspirational. spiritual or religious values	0.38	-13.80	0.42	-14.18	0.44	-13.73	0.24	-17.03	0.45	-13.87
Existence values	0.43	-10.54	0.35	-12.53	0.46	-11.76	0.25	-15.99	0.49	-11.96
Regulating/supporting services										
Habitat and biodiversity	0.41	-17.68	0.44	-14.71	0.49	-12.23	0.22	-21.69	0.34	-17.42
Environmental capacities	0.46	-11.76	0.27	-12.95	0.60	-9.96	0.19	-19.33	0.36	-16.43

Table A.6. Relationship between mapped ES benefits and respondent socio-demographic characteristics across all case study sites. Information is presented as percentage of respondents who mapped specific ES benefit in each category with Chi square test of significance of association (***=p<0.001, **= p<0.01 and *=p=<0.05) and Cramer's V test measuring the strength of association (0.0 to <0.1 negligible, ≥0.1 to <0.2 weak, ≥0.2 to <0.4 moderate association). For ES benefit acronyms, see Table 1.

	Farm pro	**Harv pro**	**Outdoor**	**Social**	**Aesthetic**	**Culture**	**Inspiration**	**Existence**	**Habitat**	**Env cap**
Gender X^2(df 1, N=2261) Men / Women [%]	ns	ns	ns	ns	ns	ns	V=0.076 12.94*** 63.9 / 70.9	ns	ns	ns
Age X^2 (df 2, N=2264) 15-29 / 30-59 / > 60 yrs [%]	V=0.088 17.65*** 76.4/84.8/84.2	ns	ns	V=0.090 18.24*** 93.5/89.2/85.6	ns	ns	ns	ns	ns	ns
Education X^2 (df 1, N=2038) High / Low level [%]	V=0.050 5.18* 84.3/80.1	V=0.059 7.19** 69.0/62.7	ns	ns	ns	ns	ns	ns	V=0.058 6.92** 80.6/85.6	ns
Household income X^2 (df1, N=2116) Below / Above median [%]	ns	V=0.083 14.63*** 72.0/64.3	V=0.054 6.21** 93.8/96.1	ns	ns	ns	ns	V=0.076 12.20*** 53.3/60.8	V=0.052 5.82* 80.4/84.4	V=0.055 6.29* 60.8/66.1

Table A.7. Parameter estimates for the GLMM models based on summaries of the marginal posterior distributions of the predictors. Values within brackets indicate 95% credibility intervals. Bold letters indicate the influential predictors (black for positive effects and grey for negative ones) based on credibility intervals that not include the zero.

Predictor	**Intercept**	**Agric. (S)**	**Agric. (H)**	**For./wat.**	**LC rich**	**Cons**	**Slope**	**Dist. Home**	**Roads**
Farm pro	-1.68 [-2.17, -1.16]	**-0.39 [-0.49, -0.3]**	**-0.45 [-0.56, -0.36]**	**-1.52 [-1.72;-1.35]**	0.03 [-0.02;0.09]	**-0.8 [-0.98;-0.62]**	**-0.1 [-0.19;-0.02]**	**-0.25 [-0.33;-0.18]**	**-0.14 [-0.22;-0.06]**
Harv pro	-2.49 [-2.67, -2.17]	**0.41 [0.31, 0.51]**	**0.35 [0.26, 0.44]**	**0.68 [0.56;0.81]**	0.01 [-0.03;0.06]	**-0.18 [-0.28;-0.08]**	**0.07 [0.02;0.12]**	**-0.21 [-0.28;-0.14]**	**-0.66 [-0.76;-0.57]**
Outdoor	-1.51 [-1.73, -1.18]	**0.39 [0.33, 0.45]**	**0.22 [0.16, 0.27]**	**0.39 [0.32;0.46]**	-0.01 [-0.04;0.03]	**-0.16 [-0.25;-0.07]**	-0.04 [-0.08;0.00]	**-0.27 [-0.33;-0.22]**	**0.09 [0.04;0.14]**
Social	-1.83 [-2.09, -1.12]	**-0.24 [-0.3, -0.17]**	**-0.09 [-0.14, -0.03]**	**-0.27 [-0.35;-0.2]**	**0.07 [0.03;0.11]**	**-0.23 [-0.33;-0.12]**	**-0.07 [-0.12;-0.01]**	-0.02 [-0.07;0.02]	0.01 [-0.04;0.07]
Aesthetics	0.82 [0.42, 1.22]	**0.68 [0.54, 0.83]**	**0.7 [0.57, 0.84]**	**1.05 [0.86;1.24]**	0.04 [-0.05;0.13]	**0.61 [0.34;0.89]**	**0.28 [0.15;0.42]**	**2.39 [1.71;3.15]**	**0.36 [0.22;0.5]**
Culture	-0.41 [-1.00, 0.19]	-0.63 [-0.81, -0.47]	-0.72 [-0.88, -0.57]	-0.90 [-1.11, -0.7]	0.07 [-0.01, 0.16]	-0.42 [-0.62, 0.22]	-0.28 [-0.38, -0.18]	0.35 [0.20, 0.53]	0.87 [0.71, 1.05]
Inspiration	5.28 [1.76, 11.31]	-5.17 [-14.89, 0.76]	-4.23 [-12.18, 0.63]	-5.86 [-17.24;1.1]	0.03 [-0.29;0.37]	**-0.88 [-1.52;-0.31]**	0.04 [-0.21;0.34]	-0.04 [-0.21;0.17]	**0.96 [0.18;2.01]**
Existence	7.39 [5.39, 10.11]	**-2.69 [-6.28, -0.17]**	**-2.54 [-5.37, -0.54]**	**-4.23 [-8.37;-1.31]**	**-1.31 [-2.11;-0.67]**	5.53 [-11.77;34.07]	**0.98 [0.02;2.29]**	1.96 [-0.12;4.97]	**2.32 [0.64;4.57]**
Habitat	-0.89 [-1.39, -0.30]	**0.31 [0.18, 0.45]**	**0.46 [0.33, 0.61]**	**0.85 [0.65;1.09]**	**-0.15 [-0.25;-0.06]**	**1.22 [0.98;1.51]**	**0.26 [0.14;0.4]**	**0.13 [0.03;0.25]**	**-0.53 [-0.68;-0.37]**
Env cap	-0.93 [-1.30, -0.55]	0.07 [-0.07, 0.22]	0.12 [-0.01, 0.25]	**0.32 [0.16, 0.49]**	**-0.11 [-0.2, -0.02]**	**0.85 [0.61, 1.1]**	-0.06 [-0.16, 0.04]	**0.18 [0.07, 0.3]**	**-0.53 [-0.67, -0.39]**
ES sum	0.88 [0.75, 1.00]	**-0.09 [-0.11, -0.07]**	**-0.14 [-0.16, -0.12]**	**-0.12 [-0.14, -0.10]**	**0.20 [0.19, 0.22]**	**0.02 [0.00, 0.04]**	**-0.05 [-0.07, -0.04]**	**0.43 [0.42, 0.44]**	**0.45 [0.43, 0.46]**
ES div	**-1.40 [-1.54, -1.25]**	**-0.04 [-0.07, -0.02]**	**-0.08 [-0.11, -0.06]**	**-0.08 [-0.11, -0.05]**	**0.08 [0.06, 0.09]**	-0.01 [-0.02, 0.00]	**-0.02 [-0.04, -0.01]**	**0.59 [0.58, 0.61]**	**0.22 [0.21, 0.24]**

Equation A.1. Calculation of Z scores to indicate over or under-representation of ES benefits in specific land cover classes.

Z scores were calculated as follows:

$$Z = (P_S - P_\mu)/S_p$$

where P_S is the sample proportion (proportion of mapped ES benefits in a land cover class), P_μ the population proportion (proportion of the land cover class in the analysis area) and S_p the standard error of the population. The Z scores give an indication of over or under-representation of ES benefits in specific land cover classes. They need to be interpreted with caution as the assumption (null hypothesis) is proportional distribution to land cover area, which is not the a priori assumption in the mapped data as respondents do not randomly locate the ES benefits.

Equation A.2. Forms for the applied Generalized Linear Mixed Models.

ES benefit occurrence was modelled as a function of landscape-scale predictors using a Generalized Linear Mixed Model (GLMM) of the form:

$$ES_{ij} \sim ZIB(\mu_{ij}, N_{ij}, \pi)$$
$$E(ES_{ij}) = (1-\pi) \times \mu_{ij}$$
$$var(ES_{ij}) = (1-\pi) \times (V_{bin} + \mu_{ij}^2) - (1-\pi)^2 \times \mu_{ij}^2$$
$$logit(\mu_{ij}) = \eta_{ij}$$
$$\eta_{ij} = \alpha + \beta_1 \times AgricS_{ij} + \beta_2 \times AgricF_{ij} + \beta_3 \times Forest_{ij} + \beta_4 \times Lcdiv_{ij} + \beta_5 \times Cons_{ij}$$
$$+\beta_6 \times Slope_{ij} + \beta_7 \times DistHome_{ij} + \beta_8 \times Roads_{ij} + a_i$$
$$a_i \sim N(0, \sigma_{Site}^2)$$
$$logit(\pi) = \gamma_1$$

where the occurrence of a given ES benefit ES_{ij} at study area i at point j, is assumed to follow a zero-inflated binomial distribution. μ_{ij} and N_{ij} are the probability of success and number of trials for the binomial part of the model. The term π is the probability of false zero. The V_{bin} is the variance of the ordinary binomial distribution.

The sum of ES benefits (sum ES) was modeled as a function of landscape-level predictors using a GLMM of the form:

$$All\_ES_{ij} \sim ZIP(\mu_{ij}, \pi)$$
$$log(\mu_{ij}) = \eta_{ij}$$
$$\eta_{ij} = \alpha + \beta_1 \times AgricS_{ij} + \beta_2 \times AgricF_{ij} + \beta_3 \times Forest_{ij} + \beta_4 \times Lcdiv_{ij} + \beta_5 \times Cons_{ij}$$
$$+\beta_6 \times Slope_{ij} + \beta_7 \times DistHome_{ij} + \beta_8 \times Roads_{ij} + a_i$$
$$a_i \sim N(0, \sigma_{Site}^2)$$
$$logit(\pi) = \gamma_1$$

where All_ES_{ij}, is assumed to follow a zero-inflated poisson distribution with a mean μ at study area i in grid square j. The term π indicates the probability of false zero and a_i is a random intercept for study area *i.*

The ES benefit diversity (ES div) was modeled as a function of landscape-level predictors using a GLMM of the form:

$$ES\_DIV_{ij} \sim Gamma(\mu_{ij}, \tau)$$
$$E(ES\_DIV_{ij}) = \mu_i$$
$$var(ES\_DIV_{ij}) = \mu_{ij}^2 / \tau$$
$$log(\mu_{ij}) = \eta_{ij}$$
$$\eta_{ij} = \alpha + \beta_1 \times AgricS_{ij} + \beta_2 \times AgricF_{ij} + \beta_3 \times Forest_{ij} + \beta_4 \times Lcdiv_{ij} + \beta_5 \times Cons_{ij}$$
$$+\beta_6 \times Slope_{ij} + \beta_7 \times DistHome_{ij} + \beta_8 \times Roads_{ij} + a_i$$
$$a_i \sim N(0, \sigma_{Site}^2)$$

where $ES\_DIV_{i,j}$ is assumed to follow a Gamma distribution with a mean μ at study area i in grid square j. a_i is a random intercept for study area *i.*