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Stakeholder perspectives on ecosystem service supply and ecosystem service demand bundles

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ABSTRACT

Recent developments in Ecosystem Service (ES) research show a growing interest in the concept of ES bundles for informing the effective management of landscapes. While the supply of ES bundles was biophysically assessed, there has been little research about the perception of ES bundles, neither in terms of their supply, nor of their demand. This research investigates how various stakeholders perceive the delivery of ES supply bundles across different landscapes and how this differs from the ES demand bundles they request. A questionnaire survey (n = 858) was carried out on the basis of landscape photographs with local farmers, local inhabitants, and visitors in the region of South Tyrol in the Central Alps. The results show that the different stakeholder groups identify identical ES supply bundles (i.e. experiential service, life maintenance service, agroservice bundle) and associate each with a similar set of landscape types. Stakeholders, however, differ in terms of their expressed demand for ES bundles. These findings suggest that stakeholders experience different (spatial) mismatches between the supply and demand of ES, potentially leading to stakeholder conflicts in landscape management. This study concludes by discussing these potential conflicts across different landscapes and in the context of future land use and management decisions.

1. Introduction

The multifunctionality of the landscape is at the core of a sustainable landscape management that aims to secure the short- and long-term delivery of multiple benefits to society (Millennium Ecosystem Assessment (Program), 2005; de Groot et al., 2010; Mastrangelo et al., 2014). Understanding how landscapes can be managed in ways that foster the delivery of multiple ecosystem services (ES) simultaneously, while reducing unwanted side-effects, is considered as one of the most challenging and pressing areas for ES research (Bennett et al., 2009; Carpenter et al., 2009). In response to this challenge, the concept of 'ES bundles' has recently become the focus of a growing number of studies. Defined as 'sets of consistently associated ES' (Saidi and Spray, 2018), ES bundles can draw attention to the complex associations occurring among multiple services and highlight potentials for synergies and trade-offs in ES use (Berry et al., 2015). In particular, applications of the ES bundle approach have proven useful to improve our understanding of the potential outcomes of environmental policy and management decisions by analysing their impacts on the provision of not just single but multiple ES (Mouchet et al., 2014; Cord et al., 2017).

Previous studies adopting the ES bundles approach have identified and quantified ES associations on either the supply or demand side of ES. Most commonly, ES bundles have been assessed on the supply side of ES (*i.e. the ecosystems' potential to deliver services based on biophysical and social properties and functions*, sensu Villamagna et al. (2013)). Using statistical clustering methods, these studies aimed to detect and spatially delineate reoccurring associations among ES across space (e.g. Raudsepp-Hearne et al., 2010; Turner et al., 2014; Queiroz et al., 2015a; Dittrich et al., 2017; Mouchet et al., 2017) and time (e.g. Renard et al., 2015; Egarter Vigl et al., 2017), and relate them to the underlying environmental and socio-economic conditions (Dittrich et al., 2017; Mouchet et al., 2017; Spake et al., 2017). In contrast to this body of literature, studies focusing on the identification and characterisation of ES bundles from the perspective of society's demand for ES remain rare (but see Martín-López et al., 2012; García-Nieto et al., 2013; Iniesta-Arandia et al., 2014; Hamann et al., 2015). Martín-López et al. (2012), for instance, assessed ES demand bundles based on the quantification of people's expressed socio-cultural values of ES, a commonly accepted

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non-monetary measure for people's demand for ES (Villamagna et al., 2013; Wolff et al., 2015).

Even fewer studies analysed ES bundles from both the supply and demand side (e.g. García-Nieto et al., 2013; Baró et al., 2017; Schirpke et al., 2019). García-Nieto et al. (2013), for instance, explored the spatial mismatch between the delivery of ES bundles by forest ecosystems and the ES bundles demanded by local and non-local beneficiaries in a semi-arid Mediterranean mountain area in south-eastern Spain. By contrast, Baró et al. (2017) identified ES supply-demand bundle types by grouping municipalities of the Barcelona metropolitan region into clusters with similar combinations of both ES supply and demand. An integrated focus on both the supply and demand side of ES bundles, however, would provide important information for ES decision-making and policy-making, and in turn for the sustainable management of landscapes (Burkhard et al., 2014; Geijzendorffer et al., 2015). In particular, the joint consideration of both the supply and demand for multiple ES could support the identification and prioritisation of key areas where 'spatial mismatches' exist between the capacity to deliver ES and the demand for those services (Castro et al., 2014; Wei et al., 2017).

Furthermore, it is important to understand how such mismatches between the supply and demand of multiple ES differ among stakeholder groups (Geijzendorffer et al., 2015; Wei et al., 2017). Different stakeholders have different interests, needs and priorities, and therefore perceive and value ES in different ways (Diaz et al., 2011; Martín-López et al., 2012). Depending on their knowledge, place attachment, and the way they engage with their natural surroundings, they can have different and sometimes conflicting perceptions of the ES available in a landscape (Scholte et al., 2015; García-Nieto et al., 2015; Affek and Kowalska, 2017). Hence, different stakeholders can attribute different use potentials to the same biophysical traits of a landscape, and thereby have varying expectations towards which of the services should be mobilised and eventually be delivered (Spangenberg et al., 2014). At the same time, power relationships among stakeholders can influence and mediate which groups of people ultimately have access to, use, and manage ES (Felipe-Lucia et al., 2015; Berbés-Blázquez et al., 2016). As a result, winners and losers are typically created as ES change due to land use and management choices (Howe et al., 2014; Daw et al., 2015). Previous analyses of ES relationships and bundles, however, often overlooked these potentials for conflicts either because they drew attention to the biophysical aspects only or because they considered the demand side on an aggregated level (Cord et al., 2017).

Against this background, the main goal of this research is to identify, characterise, and compare different types of ES bundles as perceived by different stakeholders on both the supply (i.e. ES supply bundles) and demand side (i.e. ES demand bundles). Using the definitions proposed by Saidi and Spray (2018, p.3), we understand ES supply bundles as *'patterns of ecosystem services consistently appearing either across space and/or time'*, and distinguish them from ES demand bundles defined as *'patterns of ecosystem services consistently appearing across individuals as declared preferences or uses'*. Based on data from a questionnaire survey with landscape photographs, we examine how stakeholders perceive the delivery of ES supply bundles across different landscapes and how this differs from the ES demand bundles they request, allowing us to identify spatial mismatches between ES supply and demand. Focusing on three stakeholder groups (i.e. local farmers, residents, and visitors), we further explore variations across stakeholders regarding their identification and characterisation of the ES supply and ES demand bundles, making experiences of spatial mismatches across different stakeholder groups visible. To this end, this study empirically investigates the following themes in the presented order:

(1) the ES supply bundles as identified by stakeholders across landscapes;
(2) the links between ES supply bundles and various landscape types;
(3) stakeholder differences in terms of their identified ES supply bundles;
(4) the ES demand bundles as requested by stakeholders;
(5) variations across stakeholders in terms of their expressed demand for ES bundles.

2. Theoretical background

Before describing the three stakeholder groups and the methods applied in this study in greater detail, we would like to clarify our conceptualisation of both the 'perceived supply of ES' (to capture people's identification of ES supply bundles) and the 'socio-cultural value' of ES (to capture people's demand for ES bundles). Most ES frameworks such as the widely adopted ES cascade model (Haines-Young and Potschin, 2010) conceptualise ES as a linear, unidirectional flow from ecosystems to humans. Central to their model is the distinction between the biophysical environment (the supply side) that gives rise to a range of ES, and the users (the demand side) who attribute value to the same services. Recent elaborations of the ES concept, however, criticised this marked dichotomy and highlighted the multiple roles humans perform in co-producing and co-creating ES at different phases of the ES cascade (Fish et al., 2016; Fischer and Eastwood, 2016; Jones et al., 2016). As pointed out by Spangenberg et al. (2014), the 'potential' of an ecosystem or landscape to provide ES is not solely determined by their biophysical structures and functions but also by *how* these biophysical characteristics are perceived by people. In this study, we refer to the 'perceived supply of ES' as the *use potential* (Spangenberg et al., 2014) people attribute to the biophysical traits of a landscape. Hence, we distinguish people's perception of the suitability of a landscape for ES provision from the socio-cultural values people attach to realised services. Adopting a socio-cultural valuation perspective (Martín-López et al., 2014; Scholte et al., 2015), we define 'socio-cultural values' as the importance people assign to (bundles of) ES from the perspective of their own well-being.

From a landscape management perspective, studying both the perceived supply and the socio-cultural value people attribute to ES is important to obtain a differentiated understanding of the potential sources for landscape conflict. On one hand, conflicts between stakeholders can arise when different user groups express different expectations towards the landscape in terms of ES provision and mobilisation. On the other hand, conflicts can emerge when stakeholders have different needs and priorities for ES. Disentangling these potential sources of conflict from each other allows for designing and implementing more effective policy interventions for mitigation and resolution (Zoderer et al., in preparation).

3. Study area and stakeholder groups

Our study was carried out in the region of South Tyrol, the northernmost province of Italy situated in the Central Alps. With a total area of 7,400 km^2, the region is characterised by a complex topography, encompassing elevations from about 200 m to 3,895 m a.s.l., and a great variety of landscape types. Forests (47%), mountain ridges (17%) and alpine grassland (17%) are the dominant landscape types in the region, while intensively used agricultural land such as hay meadows and permanent crops (i.e. fruit orchards and vineyards) account for other 13% of the total area. In 2011, 504,643 inhabitants lived in South Tyrol, from which 69% speak German, 26% Italian, and 4.5% Ladin as their first language (ASTAT, 2012). About 12% of the inhabitants work in the agricultural sector either on a full- or part-time basis (ASTAT, 2014). In contrast to many other Alpine regions that were experiencing extensive declines in population over the past decades, South Tyrol is characterised by a prospering economy, dynamic labour market, and active agricultural sector (Tappeiner et al., 2008). In particular, the historical unique case of the region, namely its political struggle over a statute of autonomy, and the importance tourism gained for the

regional economy in the past few decades largely ensured that population decline was halted in most rural areas (Bätzing et al., 1996). Today, the region belongs to the 5% most popular tourist destinations of the European Union, during both summer and winter (Batista e Silva et al., 2018). In summer 2016 alone, a total number of 2,899,043 tourists were recorded (ASTAT, 2017), mainly being attracted by the high nature value, scenic beauty, and tourism infrastructure. Due to high tourism intensity, urban sprawl, and the increasing intensification of agricultural production on the valley floors, pressure on the resource 'land' is relatively high compared with other mountain areas in and beyond the Alps. Considering the high conflict potential arising from this demand, it is particularly important for landscape management in this region to take the often diverging perceptions and preferences of different stakeholder groups into account.

In terms of usage, three stakeholder groups are of particular relevance for the landscape development in the study area and thus at the core of this study: (1) local farmers (i.e. locals working as farmers or forest managers), (2) residents (i.e. all other locals), and (3) visitors (i.e. tourists coming from regions other than South Tyrol). These groups differ in two respects: First, stakeholders vary in terms of degree and mode of influence in the shaping of landscapes (Turkelboom et al., 2017). Property rights are unequally distributed across stakeholder groups. Whereas 94% of full-time and 69% of part-time farmers own land, only about 10% of the locals possess a property (ASTAT, 2010). This means that farmers have significantly more direct influence in the shaping of landscape, while being also more economically dependent on its outcomes (Kaur et al., 2004). The influence of other locals and visitors is largely limited to representatives in local and regional governments or in the tourism sector respectively. Second, stakeholders differ regarding their place relations. While the strength of attachment to a place may be the same, Kianicka et al. (2006) find that specific place relations depend on the activities people carry out in the landscape. According to their study, visitors tend to differ in this respect from locals, being more likely to connect to a place mainly through leisure activities and focus predominantly on the aesthetics and characteristics of a place. Locals, by contrast, define their place relations also through specific place-related investments and commitments related to childhood memories and social relationships affiliated with the place. Longer-term relationships with places are thus more likely to emerge among locals, which express themselves in different forms of place attachment, often defined by a strong sense of individual and collective identity (Smaldone et al., 2008; Lin and Lockwood, 2014).

4. Methods

4.1. Data collection

4.1.1. Photograph-based questionnaire survey

Based on landscape photographs, a questionnaire survey was conducted inquiring into the respondents' perception of ES provision and their expressed socio-cultural values towards ES. Over a three-month period in summer 2016, we interviewed a total number of 858 respondents on-site, of which 95 were local farmers, 413 residents, and 350 visitors. Respondents were recruited in public spaces and recreational sites, or approached at home in the case of farmers. Following a stratified sampling approach, a diverse sample in terms of age, gender, and language group could be achieved (see Table 1), with a representative distribution of each stakeholder group across the region's eight districts (Table A.3). In line with the statistical records (ASTAT, 2014), the sample of local farmers is further representative in terms of their main agricultural activities (i.e. dairy and livestock farming, pomi- and viticulture, arable farming, and timber production) (Table A.4). For a detailed description of the survey sample see Table A.1–3.

4.1.2. Questionnaire design and landscape photographs

The final questionnaire was divided into six sections, three of which addressed the themes relevant for this study: (1) perception of ES provision in the landscape, (2) socio-cultural values for ES, and (3) respondents' socio-demographic background and environmental behaviour. For the questionnaire we used a list of 15 ES comprising five provisioning (agricultural products, pasture and fodder, timber, water provision, and wild food), five regulating (climate regulation, air quality regulation, protection from hazards, pollination, and habitat for animals and plants), and five cultural services (leisure activities, tranquillity, aesthetics, cultural heritage, and experiential value). The selection was based on 21 semi-structured interviews with members of each stakeholder group as well as four interviews with experts in the field of nature management (i.e. forestry and nature conservation). Each interview covered two broad themes and inquired into the range of ES that people find relevant in the study area. While experts were recruited through direct contacts to relevant regional authorities, purposive and convenience sampling methods were combined for recruiting landscape users to cover a broad range of perspectives. The number of interviews reflects the level of saturation in the diversity of ES mentioned by participants. From originally more than 40 different ES, we selected the 14 ES stated most frequently (see Table A.5, including descriptions of services used in the questionnaire). An exception is the pollination service, which was not mentioned in any of the interviews, but was identified as a key service in previous studies conducted in the Central Alps and therefore added to our list.

In the main section of the questionnaire, survey participants were asked to assess the ES delivery of different landscapes (i.e. perceived ES supply potential) based on landscape photographs. Together with each questionnaire, respondents were given two randomly selected photograph sheets (A4 format) out of an overall pool of 147. Each photograph sheet represented one specific landscape type shown from three photographical perspectives (i.e. close-up, eye-level, and 360° panorama) (see Fig. 1 for an example). Based on these two photograph sheets, survey participants were asked to indicate on a five-point Likert-scale, ranging from 1 (not important) to 5 (very important), how important they think these particular landscape types are for the provision of the 15 listed ES.

The pool of 147 photograph sheets used as a basis for the questionnaire survey covered the ten most important rural landscape types found in the study region: coniferous forest, mixed forest, broadleaf forest, high mountains, alpine grassland, agroforestry, hay meadows, permanent crops, running and standing water. To facilitate the

Table 1
Socio-demographic characteristics of sample (in %).

	Local farmers N = 95	Local residents N = 413	Visitors N = 350
Gender			
Male	58.9	40.5	55.6
Female	41.1	59	44.2
Other	0	0.5	0.3
Age			
≤25	7.4	16.4	6.5
26–35	12.8	15.7	11.5
36–45	17	13.5	12.1
46–55	24.5	25.2	25.7
56–65	25.5	18.9	23.7
> 65	12.8	10.3	20.4
Mother tongue			
German	93.7	74.9	71.3
Italian	6.3	23.4	25.7
Ladin	0	1.7	0
Other	0	0	2.9
Place of residence			
Village	94.7	54.1	43.5
Small town (≤50,000 inhabitants)	4.2	18.3	26.2
City (> 50,000 inhabitants)	1.1	27.6	30.3

Fig. 1. Example of a photograph sheet as used in the survey. Landscape photograph 1 (top left) shows a close-up of the photographer's position ("at your feet"), landscape photograph 2 (top right) represents the landscape type at eye level ("at eye-level"), and the landscape photograph at the bottom a full 360° panorama.

subsequent statistical explorations of respondents' identified ES associations and their formation of ES supply bundles, each landscape type was represented along a gradient of biophysical and management conditions. Thus, instead of using only one photograph sheet per landscape type, 15 different photograph sheets (with the exception of mixed forest for which only 12 photograph sheets were used) were used for each landscape type to take variations in topography, land use intensity, and landscape context (i.e. background landscape) into account. This was important to meet the repeatability criterion stated by Raudsepp-Hearne et al. (2010), namely that ES associations can only be considered as ES supply bundles when found to be robust in space. Since all 858 survey participants assessed the ES delivery of two landscape types, a total number of 1,716 answers were collected with an average number of 150 answers per landscape type. For a more detailed description of this method see Zoderer et al. (in preparation).

In the following section of the questionnaire, respondents' sociocultural values expressed towards ES were explored to capture people's demand for ES (Wolff et al. 2015). Survey participants were asked to assess the importance of the listed ES from a self-oriented perspective (see Oteros-Rozas et al., 2014; Schmidt et al., 2017) by choosing the five ES that contribute most to their personal well-being (as done by Scholte et al., 2016). The final part of the questionnaire collected information about respondents' socio-demographic background (e.g. gender, age, mother tongue, place of residence, and education level), environmental behaviour (e.g. self-reported environmental knowledge, member of environmental or outdoor association, and support of environmental programs or activities), and about farmers' main agricultural activities.

4.2. Data analysis

4.2.1. ES associations and ES supply bundles

We first analysed associations between ES as perceived by respondents on the supply side. By taking all valid respondents' answers about their perception of ES delivery in the landscape into account (i.e. 1,494 from originally 1,716 responses after removing missing values), associations between ES were analysed across the ten landscape types covered in the survey. To determine the direction and strength of the relationship between pairs of ES, polychoric correlations were calculated. The computation of the polychoric correlations was based on Maximum Likelihood estimations, which took the observed ordinal but theorised normal distribution of our continuous Likert scale (ranging from 1 to 5) into account (Olsson, 1979). In the context of this paper, we will refer to positive associations, whenever we found a significantly positive relationship between two ES ($r \geq 0.25$), and to negative associations whenever we identified a significantly negative relationship ($r \leq -0.25$) between two services (see Lee and Lautenbach, 2016).

Based on the polychoric correlation matrix, a principal component analysis (PCA) was calculated to derive sets of associated ES that were frequently identified together in the landscape (i.e. ES supply bundles). The PCA was applied using Kaiser normalisation criterion > 1 and Varimax rotation with 999 permutations to find an optimal solution.

4.2.2. Links between ES supply bundles and landscape types

To explore the links between ES supply bundles and the ten landscape types investigated in this study, a redundancy analysis (RDA) was carried out across the whole sample. The RDA is a commonly applied analysis to explore the causal relationship between a multivariate response variable and a set of explanatory variables. Here, we performed a Monte Carlo permutation test (999 permutations) to investigate whether the ten landscape types have a significant effect on respondents' perception of the provision of the 15 ES.

4.2.3. Stakeholder differences in the identification of ES supply bundles

Following this step, we tested whether the three stakeholder groups identified the same ES supply bundles. Stakeholder-specific PCAs were first calculated for each stakeholder sample separately (compare with 4.2.1). Tucker's congruence coefficient (Φ) (Tucker, 1951) was then used to explore the factor similarity between the single PCA components (here ES supply bundles) as derived from the stakeholder-specific PCAs as well as to compare the stakeholder-specific PCA solutions with the PCA calculated across the whole sample. Lorenzo-Seva & ten Berge (2006) introduced two critical levels of congruence above which components can be considered similar: a value between 0.85 and 0.94 indicates a fair similarity between components and a value higher than 0.95 good similarity.

To analyse stakeholder differences in their perception of the landscapes' capacity to supply ES bundles, we calculated factor scores for each of the 1,494 valid observations considered in the PCA (calculated across the whole survey sample) using Thurstone's least square regression approach (Grice, 2001). Based on these factor scores, Kruskal Wallis H tests were employed to test for differences between stakeholders in relating the ES supply bundles to the ten landscape types. This analysis was further complemented by Dunn's Bonferroni post-hoc test to explore pair-wise comparisons between stakeholder groups.

4.2.4. ES demand bundles and variations across stakeholder groups

Following the identification of ES supply bundles, stakeholders'

demand for multiple ES was explored. To identify sets of ES that were frequently demanded together (i.e. ES demand bundles), we performed a multiple correspondence analysis (MCA) based on respondents' expressed socio-cultural values towards ES. We further tested whether the detected ES demand bundles were significantly linked to the three stakeholder groups, respondents' socio-demographic background, and their environmental behaviour. For this purpose, we included the respective variables as supplementary variables in the MCA. All statistical analyses were performed using R version 3.4.3 (R Core Team, 2017).

5. Results

5.1. ES associations and ES supply bundles as identified by stakeholders

We found significant associations between many of the ES perceived by respondents in the landscape (Table A.6). In particular, services within and across both the regulating and cultural services categories were positively associated with each other ($r \geq 0.25$). Strong positive associations ($r \geq 0.5$) were also observed between most regulating services as well as between most cultural services (except of cultural heritage). In contrast, only few significant positive associations were identified among provisioning services. Timber provision, for instance, was strongly related to the provision of wild food and the production of agricultural foods strongly linked to the provision of fodder and grazing land for livestock production. Notably, agricultural production was the service with the lowest number of positive associations with other services. Overall, respondents did not identify any negative associations between pairs of ES ($r \leq -0.25$).

By the use of a principal component analysis (PCA), we were able to detect three types of ES supply bundles as identified by respondents across the whole survey sample and named them according to their main characteristics: the experiential service bundle, the life maintenance service bundle, and the agroservice bundle (Table 2). The three components revealed by the PCA (eigenvalue > 1) accounted for 65.3% of the total variance in respondents' perception of ES delivery (Kaiser-Meyer-Olkin (KMO) = 0.86). The experiential service bundle (explaining 25.9% of the total variance) was characterised by a high positive loading of all cultural services (apart from cultural heritage), the provision of water, and the provision of a habitat for biodiversity. The second component, the life maintenance service bundle, explained 23.5% of the total variance and was positively related to all regulating services (except of pollination) as well as timber production and the provision of wild food. The agroservice bundle (accounting for 15.9% of the total variance) was further characterised by a mix of services including the provision of agricultural products, pasture and fodder, pollination, and cultural heritage values.

5.2. Links between ecosystem service supply bundles and landscape types

Respondents' perception of ES supply varied across the ten landscape types (Fig. 2). Forest landscapes were mainly associated with the provision of regulating services including climate and air quality regulation, high levels of timber production, the opportunity to gather wild food, and the enjoyment of cultural services such as the experiential value of the landscape. High mountains and water landscapes, in turn, were predominantly recognised as a source of water for domestic and industrial use, as a habitat for biodiversity, and for the provision of many cultural services - in particular of aesthetics and tranquillity. According to respondents' subjective perception, agricultural landscapes such as agroforestry, alpine grassland, and hay meadows provided a diverse set of ES, including services from different ES categories. Permanent crops, however, differed from these agricultural landscapes. The high potentials for agricultural production, pollination and cultural heritage values ascribed to this landscape type contrasted with the provision of most other services.

The redundancy analysis (RDA) indicated a statistical significant association between respondents' perception of ES delivery and the ten landscape types ($p < 0.001$, 999 permutations). Overall, 14.7% of the total variance in respondents' perception of the ES could be related to the ten landscape types. Fig. 3 shows the biplot of the RDA, representing the first two axes. The first axis (7.47% of the total variance) separated the agroservice bundle from the two other bundles and showed a positive relation between all agricultural landscapes and the provision of services belonging to this bundle. The second RDA axis, explaining 3.57% of the total variance, revealed a distinction of the experiential service bundle from the other two. Especially high mountains and water landscapes, but also to a lower degree forest landscapes, were regarded to have a high capacity to provide this bundle. The life maintenance service bundle, in contrast, was predominantly associated with forested landscapes and with some agricultural landscapes such as agroforestry systems.

5.3. Differences in stakeholders' identification of ES supply bundles

Factor comparisons between the single PCA components revealed that the ES supply bundles identified by the single stakeholders were very similar to each other (Table A.7) as well as to the ES supply bundles isolated across the whole survey sample. For each stakeholder, one experiential service bundle, one life maintenance service bundle, and one agroservice bundle could be identified with only slight

Table 2
Results from the principal component analysis (PCA) showing the three identified ES supply bundles. Associations between ecosystem services were analysed across the ten landscape types and the three stakeholder groups (1494 valid answers). Ecosystem services with factor loadings below a cut-off value of −0.45 and above a value of 0.45 are shown in bold and further referred to as components of the ES supply bundle.

	Experiential service bundle (component 1) 25.9%	Life maintenance service bundle (component 2) 23.5%	Agroservice bundle (component 3) 15.9%
Timber	−0.128	**0.795**	0.074
Pasture & fodder	0.247	0.041	**0.790**
Agricultural products	−0.122	0.081	**0.905**
Water provision	**0.558**	0.276	0.184
Wild food	0.203	**0.744**	0.034
Climate regulation	0.319	**0.795**	0.126
Air quality regulation	0.444	**0.668**	0.154
Protection from hazards	0.283	**0.703**	0.177
Pollination	0.248	0.435	**0.629**
Habitat for animals & plants	**0.693**	**0.504**	0.110
Leisure activities	**0.669**	0.155	0.161
Tranquillity	**0.831**	0.143	0.084
Aesthetics	**0.860**	−0.030	0.175
Cultural heritage	0.373	0.090	**0.592**
Experiential value	**0.708**	0.424	0.048

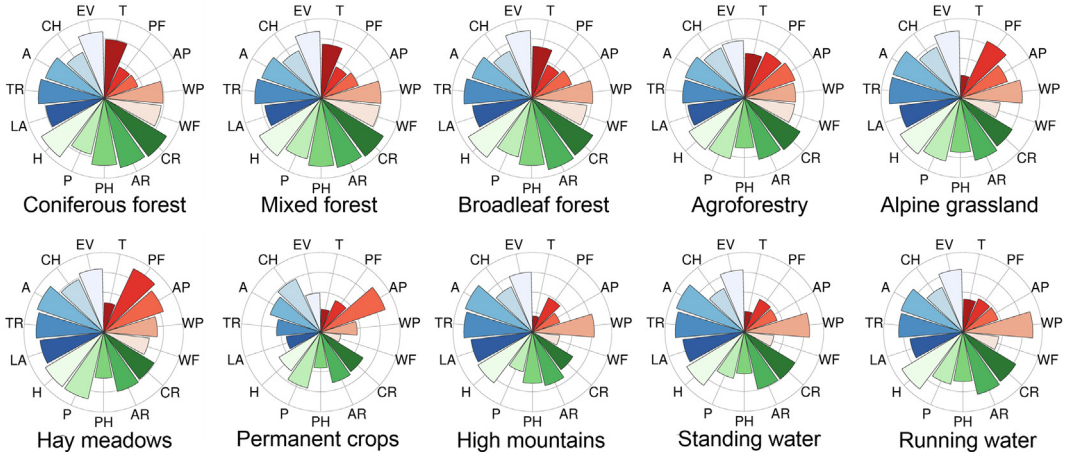

Fig. 2. Flower diagrams illustrating the respondents' perception of the landscape's capacity to supply the 15 ecosystem services. Each petal quantifies the importance of the landscape to provide the ES according to respondents' perception. Values range from 1 (not important) to 5 (very important). Provisioning services (in red): T: timber, PF: pasture and fodder, AP: agricultural products, WP: water provision, and WF: wild food; Regulating services (in green): CR: climate regulation, AR: air quality regulation, PH: protection from natural hazards, P: pollination, and H: habitat for animals and plants; Cultural services (in blue): LA: leisure activities, TR: tranquillity, A: aesthetics, CH: cultural heritage, and EV: experiential value. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

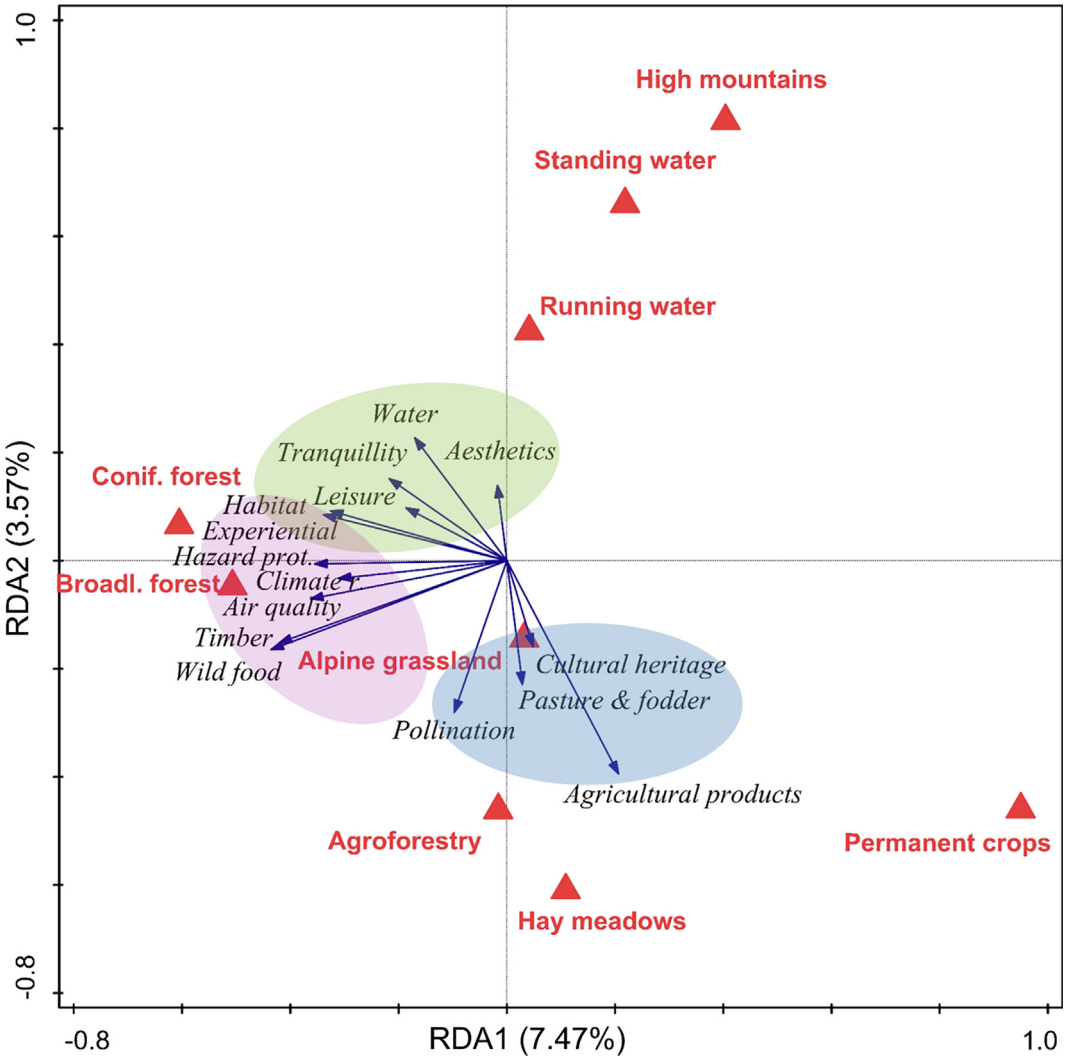

Fig. 3. Biplot of the first two axes of the redundancy analysis (RDA) illustrating the relationship between the ecosystem services (arrows) and the landscape types (symbols). Ecosystem service supply bundles are indicated by a green (i.e. experiential service bundle), pink (i.e. life maintenance service bundle), and blue (i.e. agroservice bundle) circle. Each ecosystem service (arrow) points in the direction of the steepest increase. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

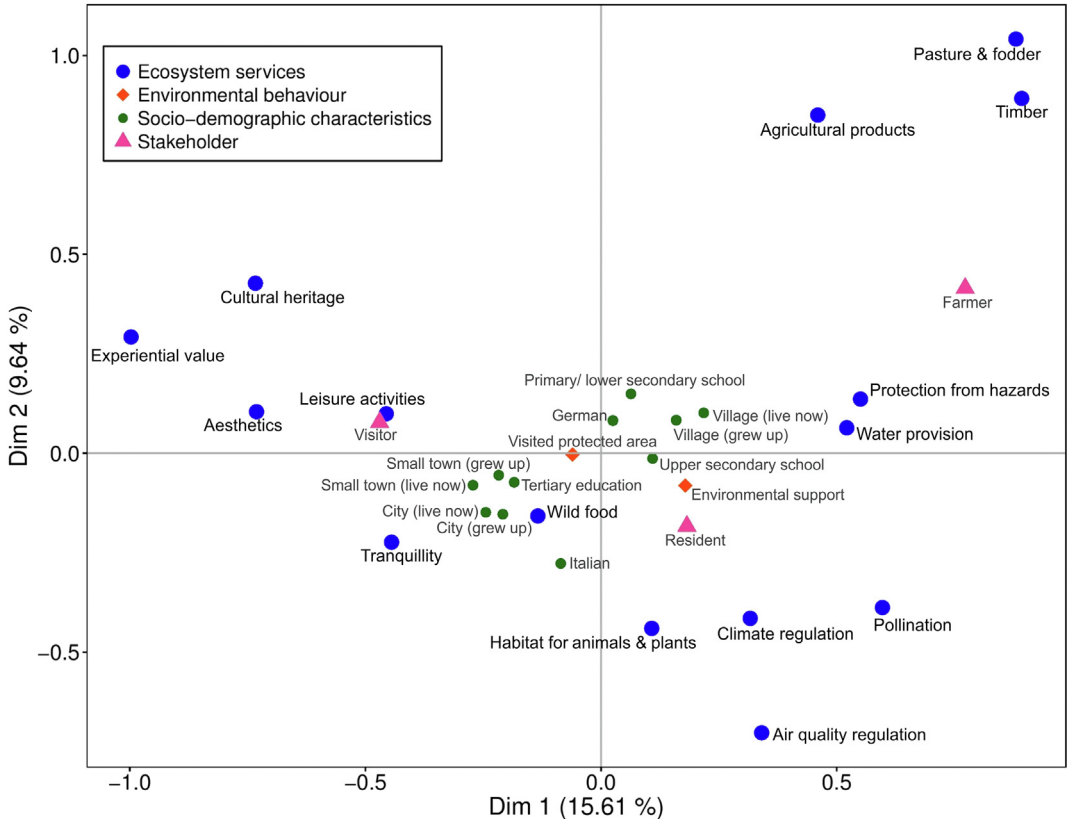

Fig. 4. Biplot of the first two axes of the multiple correspondence analysis (MCA) illustrating the identified ES demand bundles and their associations with the three stakeholder groups, respondents' socio-demographic background, and their environmental behaviour.

differences in factor loadings of the single ES on each bundle. For instance, visitors perceived the provision of cultural heritage values as not only being linked to the agroservice but also the experiential service bundle. Similarly, residents regarded the landscape's capacity for pollination to be positively loaded on both the agroservice and the life maintenance service bundle.

In addition to these findings, our analysis revealed that stakeholders did not significantly differ in relating the three ES supply bundles to the ten landscape types investigated in this study, apart from few exceptions (see Table A.8). For instance, we found that residents significantly associated the experiential service bundle less with high mountains and alpine grassland than local farmers ($Z = 22.565$, $p < 0.05$, $Z = -37.908$, $p < 0.05$, respectively). Relatedly, residents also considered alpine grassland to be less suitable for the provision of the agroservice bundle compared to local farmers ($Z = 27.224$, $p < 0.05$).

5.4. ES demand bundles and their differences across stakeholders

The multiple correspondence analysis (MCA) revealed four components accounting for 41.7% of the total variance in respondents' expressed socio-cultural values of ES (see Fig. 4 for a biplot of the first two axes). Based on the graphical depiction of ES along these four components (services closer to each other can be regarded as similar), we were able to identify four main ES demand bundles. The first component (15.61% of the total variance) showed a bundled demand for all cultural services as opposed to all other provisioning and regulating services. Component 2 (9.64% of the total variance) instead, revealed a trade-off between the demand for agricultural products, pasture and fodder as well as timber, and the demand for regulating services such as air quality regulation, climate regulation, pollination, and the provision of a habitat for biodiversity. Component 4, accounting for other 7.75% of the total variance, further showed that timber and wild food were frequently demanded together in contrast to all other services.

The MCA additionally highlighted that the ES demand bundles were significantly linked to the three stakeholder groups, and some of the respondents' socio-demographic background and environmental behaviour variables (see Fig. 4 for all significant supplementary variables). Visitors, urban respondents, and those with a tertiary education mainly preferred cultural services over other services, whereas farmers, rural respondents, and those holding a lower education degree mainly acknowledged the important role provisioning services (i.e. agricultural products, timber provision, pasture and fodder) play for their personal well-being. Residents, Italian-speaking respondents, and those supporting environmental programs and actions, in contrast, demanded regulating services more often.

6. Discussion

6.1. Characteristics and spatial distribution of ES supply bundles

Our results show that respondents distinguished between three types of ES supply bundles (i.e. agroservice, life maintenance service, and experiential service bundle) and associated each with a particular set of landscape types. Similar to previous studies that assessed ES supply bundles based on the biophysical and spatial quantification of ES provision (Raudsepp-Hearne et al., 2010; Maes et al., 2012; Turner et al., 2014; Queiroz et al., 2015a,b; Dittrich et al., 2017), we find that respondents mainly identified ES supply bundles along a gradient from forested to agriculture dominated landscapes. On one hand, respondents associated different forest habitats with the provision of multiple ES supply bundles including the life maintenance service bundle and to a lower degree the experiential service bundle, reflecting that forests can have a high combined capacity to provide timber and wild food as well as a variety of regulating and cultural services (see also Renard et al., 2015; Egarter Vigl et al., 2017). On the other hand, respondents typically perceived the provision of ES to be less diverse in

intensively used agricultural landscapes. These landscapes were commonly seen to provide few provisioning services such as food and fodder production, cultural heritage and pollination services (i.e. the agroservice bundle) at the expense of most other services. Previous assessments of ES associations have shown similar results (Raudsepp-Hearne et al., 2010; Maes et al., 2012; Howe et al., 2014; Turner et al., 2014; Lee and Lautenbach, 2016; Dittrich et al., 2017; Turkelboom et al., 2017), indicating a negative association between provisioning services such as crop and livestock production and other ES, and a positive association between different regulating and cultural services.

Exceptions from this general pattern are cultural heritage and pollination, which in the case presented here show a stronger positive association between the production of food and fodder than with the provision of other cultural and regulating services. Whereas the synergistic relationship between pollination and agricultural production was commonly reported in previous work (Boreux et al., 2013; Schulp et al., 2014; Queiroz et al., 2015a,b), the exceptional role of cultural heritage in comparison to other more interlinked cultural services is rather surprising. Interestingly, it seems that all three stakeholder groups were more likely to perceive cultural heritage values in landscapes exhibiting clear signs of human impact, as compared to other cultural services such as aesthetics or recreational values, which were more appreciated in natural or less managed landscapes. A similar behaviour was already observed in previous work carried out in the same area (Zoderer et al., 2016b), where, in contrast to prevailing expectations (Phillips, 1998), tourists associated cultural heritage values more with highly managed agricultural landscapes and rural settlements than with the traditionally used hay meadows or agroforestry systems that evolved over a long historical process.

The poor relationship between cultural heritage and other cultural services was recently also found by other scholars (Riechers et al., 2017). In their work, Riechers and colleagues observed that lay people perceived cultural heritage as a distinct concept as opposed to experts for whom this service formed strong connections with aesthetics and inspiration. Accordingly, the exceptional character of cultural heritage from the view of the general public points to the need to critically reflect on current ES classification systems, such as the newly released CICES (Haines-Young and Potschin, 2018), wherein cultural heritage is grouped together with aesthetics, nature education and the stimulation of scientific knowledge (i.e. 'intellectual and representative associations with nature').

Supporting the findings from Zoderer et al. (2016a, 2016b), our results further show that stakeholders distinguished between intensively used agricultural landscapes (e.g. permanent crops) and less managed agricultural landscapes such as different types of agroforestry systems (e.g. larch meadows, traditionally used apple orchards, and chestnut orchards) in terms of ES provision. While the intensively used agricultural landscapes were exclusively associated with the agroservice bundle, agroforestry landscapes were recognised to provide multiple ES supply bundles, including the agroservice but also the life maintenance service bundle, suggesting that stakeholders seemed to be aware of the high multifunctionality characteristic for these landscapes (Fontana et al., 2013; Torralba et al., 2016).

In addition to these findings, our study sheds light on the link between ES supply bundles and other landscape types including water landscapes and high mountains, which were less explored in previous ES bundle studies. Our respondents particularly appreciated these landscapes for the provision of water and several types of cultural services (i.e. experiential service bundle). This contradicts previous research, which found that water provisioning services and cultural services are generally unrelated (Lee and Lautenbach, 2016) and that water quality is a poor predictor for recreation-based cultural services (Ziv et al., 2016).

6.2. Spatial mismatches between ES supply and ES demand bundles

Exploring both the identification of ES supply bundles in the landscape and stakeholders' demand for ES bundles, we provide insights into how these bundles converge or diverge from each other. Contrary to previous findings that found a coherent relationship between ES bundles on both the supply and demand side (García-Nieto et al., 2013), our results reveal that the ES supply bundles identified in the landscape and the ES demand bundles requested by beneficiaries are not necessarily the same.

The mismatch can be traced back to the ES associations found on both the supply and demand side. The ES supply bundles identified by stakeholders generally encompassed ES from different ES categories, as was particularly the case for the agroservice bundle, which consisted of a mix of provisioning (i.e. food production, fodder provision), regulating (i.e. pollination) and cultural services (i.e. cultural heritage). The requested ES demand bundles, however, typically comprised a number of interlinked ES belonging to the same ES category. In fact, we found that respondents either expressed strong interests towards multiple regulating, multiple cultural or particular combinations of provisioning services (i.e. agricultural products, forage, and timber vs. wild food and timber). On a general level, our results therefore indicate that differences between ES associations on both the supply and demand side were most pronounced for the agroservice bundle. Even though the ES forming this supply bundle were perceived together in agricultural landscapes, the same services were not demanded together by any of the three stakeholder groups. This finding suggests that a spatial mismatch between respondents' demand and the capacity to supply ES is most likely expected in agricultural landscapes such as the more intensively used permanent crops, where the provision of the agroservice bundle only partially meets respondents' needs and desires.

6.3. Stakeholder differences in the experience of spatial mismatches

Spatial mismatches are particularly acute when experienced in different ways by important stakeholder groups, potentially leading to conflicts in landscape management. However, previous studies have often overlooked this issue and exclusively focused on the spatial dimension of ES mismatches. This study demonstrates the importance of the stakeholder dimension: While all local farmers, residents, and visitors identified the same three types of ES supply bundles and associated each with a similar set of landscape types, the same does not hold true for ES demand bundles.

In terms of the supply side, this finding is surprising in two respects. First of all, it contradicts related research, which identified stakeholder differences at the level of single services (e.g. López-Santiago et al., 2014; García-Nieto et al., 2015; Scholte et al., 2016; Affek and Kowalska, 2017). Second, it demonstrates that stakeholders were equally capable of identifying regulating services next to other provisioning and cultural services, assess their level of supply in the landscape, and detect associations among them and other services despite the high complexity involved (Brown et al., 2012; De Vreese et al., 2016). Looking at the demand side, our results are in line with previous research (Martín-López et al., 2012; Iniesta-Arandia et al., 2014; Oteros-Rozas et al., 2014), suggesting that each stakeholder group requested one particular ES demand bundle. Whereas local farmers expressed a strong interest towards multiple provisioning services and residents towards multiple regulating services, visitors preferred several cultural services over others. Thus, our results stress once again that stakeholders tend to express different interests towards the landscape, depending on how they engage and connect with the local landscape in their daily life (Bieling, 2014; Fagerholm et al., 2016). As set out by Buijs et al. (2006), farmers often have a more functional image of landscapes and nature, and therefore value the material and life support aspects of landscapes more. With an increasing material disconnection from local landscapes, however, other aspects such as leisure or the

regulation of ecosystem processes can become more important for people's well-being (Guo et al., 2010; Martín-López et al., 2012).

Apart from stakeholder differences, respondents' demand for ES bundles was further influenced by a complex set of factors, including respondents' place of childhood and current residence (urban vs. rural), cultural background, and formal education level (see also Castro et al., 2011; Martín-López et al., 2012; Zoderer et al., 2016a). While urban residents and those holding a higher education degree prioritised multiple cultural services, rural residents with a lower education degree typically perceived the provision of provisioning services as more valuable. In light of current urbanisation processes taking place in many municipalities located inside the European Alps and in the surrounding lowlands (Dematteis, 2009), we therefore hypothesise that while the demand for cultural services is likely to increase in the near future, the local production of agricultural foods and timber might lose its former significance for large parts of the general public.

6.4. Implications for landscape management

The findings of this study have several implications in relation to ongoing changes in land use in Alpine mountain areas. Significant changes are taking place on the less accessible, steep, and highly elevated mountain slopes, where less intensive forms of livestock farming systems are abandoned and converted into forests due to natural reforestation processes (Tasser et al., 2007). Such abandonment of land is accompanied by the specialisation and intensification of agricultural production in the most favourable locations such as the fertile valley floors (Zimmermann et al., 2010). These two opposing trends significantly and enduringly affect the capacity of the landscape for ES provision (Egarter Vigl et al., 2016). Our results show, however, that the two trends bear different potentials for conflicts among stakeholder groups.

The greatest potential for conflicts exists with regard to the increasing intensification and spread of permanent crops, where the economic benefits of intensified use of a specific bundle of services collide with the residents' demand for multiple regulating services and the visitors' demand for multiple cultural services. Indeed, the areas with the most intensively used landscapes already experience major conflicts between farmers and the other two stakeholder groups. In the municipality of Mals near the Swiss border, for instance, residents regularly protested against the negative health and environmental implications of pesticide use in permanent crop cultivation. In a referendum in 2014, 70% of the inhabitants of Mals who participated in the election expressed their concerns about the use of pesticides and voted for a ban of pesticide use on their territory (Hertoge, 2014; Scheub, 2015; The Lexicon, 2017). In contrast to permanent crops, agricultural land uses like agroforestry systems are perceived as capable of providing multiple provisioning, regulating, and cultural services and thus bear less potential for conflict. With regard to the abandonment of land on higher elevations, conflicts among stakeholders are less likely, as the processes of natural reforestation increase the residents' and visitors' perceived supply of regulating and cultural services.

Eventually, whether a potential for conflicts turns into an actual conflict crucially depends on the specific management of landscapes however. While our study indicates the potential supply of various services in landscapes, the realisation of this supply is connected to the type of management in place. Only a subset of the services and bundles that any landscape can provide may thus be realised, and access to certain services is frequently restricted to specific groups.

6.5. Methodological considerations

In this study different surveying and statistical techniques were used to quantify the single ES and their formation of consistent associations at both the supply and demand side. As pointed out by Saidi and Spray (2018), ES bundle studies are particularly sensitive to the methods chosen to quantify ES. Depending on the way data is generated, only a subset of analytical techniques can typically be applied to detect ES bundles and interpret their results. In contrast to previous studies that commonly mapped the provision of single ES and employed clustering algorithms (e.g. k-means) to spatially identify groups of consistently associated ES (Mouchet et al., 2014), this study used an a-spatial dimension reduction technique (i.e. PCA) to detect ES supply bundles based on answers from photographic questionnaires. To meet the repeatability criterion proposed by Raudsepp-Hearne et al. (2010) which demands that ES associations are regarded as consistent only when found to be robust across space, however, the questionnaire survey was carried out in combination with a large number of landscape photographs. By using multiple instead of one quasi-representative photograph per landscape type, our approach comprehensively represented the most important rural landscape types of the study area while taking their site-specific variations into account. As a result, our study provides an advancement to previous studies which investigated people's perception of ES supply using photographs of single, quasi-representative sites only (López-Santiago et al., 2014; Zoderer et al., 2016a,b). While these studies were capable of exploring respondents' perception of the multifunctionality of a particular location or landscape, their approach would not be suited for detecting the perception of consistent ES associations across different landscape types and biophysical properties.

Our approach of using multiple landscape photographs and randomly distributing them across the survey sample also bears some limitations, however. Effort and time is needed to collect a sufficient number of landscape photographs. In addition, the random distribution of landscape photographs across the sample requires the consideration of many respondents to obtain enough answers per landscape type (see Zoderer et al., in preparation for a more detailed discussion of the method). In this context, choosing an appropriate size of the study area for the identification of ES supply bundles becomes particularly important (Saidi and Spray, 2018). As stated by Marsboom et al. (2018), different ES supply bundles can be discovered for different study area sizes in case they cover part of a different landscape. In this study, the size of the study area was chosen in a way to allow the investigation of consistent ES association across the main Alpine landscape types, while simultaneously assuring that these landscape types and their topographical variations can be represented by a sufficient number of landscape photographs.

Similar to detecting of ES supply bundles, identifying and interpretating demand bundles can be influenced by the methods used to quantify socio-cultural values, the type of data they generate, as well as the sample size and sampling method (Saidi and Spray, 2018). In comparison to previous studies that used k-point rating scales to reveal socio-cultural values of ES (e.g. Ament et al., 2017; Clements and Cumming, 2017), the ranking technique chosen in our study produced a categorical instead of an ordinal data set, making the employment of a MCA instead of a PCA for the identification of ES demand bundles necessary. Whereas PCA results commonly comprise factor tables with clear thresholds useful for objectively defining ES bundle components (compare to Williams et al., 2017), results from the MCA are visually interpreted and can thus be subject to more interpretative variability. Aware that the size of the survey sample can influence the identification of ES demand bundles (Saidi and Spray, 2018), we collected a large enough number of answers to explore robust ES demand bundles across individuals with different interests and socio-demographic background. Future research, however, could complement such a quantitative survey with the use of more qualitative methods like semi-structured interviews to provide an in-depth understanding of the emergence of these bundles (see Riechers et al., 2017).

7. Conclusion

This paper set out to explore and compare stakeholders' perception

of ES bundles on both the supply and demand side of ES. The two most salient findings of this study are that (1) the ES supply bundles and ES demand bundles identified by respondents are not the same, and (2) stakeholders differed regarding their identification and characterisation of ES demand bundles, but not regarding their detection of ES supply bundles. Based on these results, we conclude that various stakeholders can experience spatial mismatches between the supply and demand of multiple ES in different ways and that these discrepancies can potentially lead to conflicts among stakeholder groups. To make such conflicts visible and promote their mitigation, our study demonstrates the need to include stakeholders' views and priorities early in the process of ES and landscape management. In particular, our study highlights that participatory approaches are needed to take account of the value pluralism associated with stakeholders' expressed demand for ES, thereby strengthening civic empowerment and the promotion of more effective, legitimate, and socially just management outcomes. To advance our understanding of stakeholder conflicts and their underlying causes and mechanisms, we encourage future studies to carry out more transdisciplinary research and to examine in greater detail how such conflicts arise among stakeholders depending on their varying values, access to ES use, and power relationships.

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Appendix A. Supplementary material

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