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Testing socio-cultural valuation methods of ecosystem services to explain land use preferences

Katja Schmidt [a,*], Ariane Walz [a], Berta Martín-López [b], René Sachse [a]

[a] University of Potsdam, Institute of Earth and Environmental Science Landscape Management Group, Karl-Liebknecht-Str. 24-25, 14476 Potsdam, Germany
[b] Leuphana University of Lüneburg, Institute of Ethics and Transdisciplinary Sustainability Research, Universitätsallee 1, 21335 Lüneburg, Germany

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ABSTRACT

Socio-cultural valuation still emerges as a methodological field in ecosystem service (ES) research and until now lacks consistent formalisation and balanced application in ES assessments. In this study, we examine the explanatory value of ES values for land use preferences. We use 563 responses to a survey about the Pentland Hills regional park in Scotland. Specifically, we aim to (1) identify clusters of land use preferences by using a novel visualisation tool, (2) test if socio-cultural values of ESs or (3) user characteristics are linked with land use preferences, and (4) determine whether both socio-cultural values of ESs and user characteristics can predict land use preferences. Our results suggest that there are five groups of people with different land use preferences, ranging from forest and nature enthusiasts to traditionalists, multi-functionalists and recreation seekers. Rating and weighting of ESs and user characteristics were associated with different clusters. Neither socio-cultural values nor user characteristics were suitable predictors for land use preferences. While several studies have explored land use preferences by identifying socio-cultural values in the past, our findings imply that in this case study ES values inform about general perceptions but do not replace the assessment of land use preferences.

1. Introduction

Ecosystems provide a variety of benefits to sustain human well-being (MA, 2003). These benefits are accounted for in the ecosystem service (ES) approach, which is set up to be used to guide land management and decision-making (Daily et al., 2009). Despite the multitude of values that can be attached to ESs as acknowledged by science and policy (Christie et al., 2012; de Groot et al., 2002; Díaz et al., 2015; MA, 2003; TEEB, 2010), the assessment of monetary and biophysical values has prevailed since the introduction of the ES concept (Gómez-Baggethun et al., 2014; Seppelt et al., 2011). Only in recent years the integration of socio-cultural values gained momentum in ES research (Nieto-Romero et al., 2014; Scholte et al., 2015).

Reasons to include socio-cultural values in landscape management and planning are manifold. They are used for instance to find feasible and acceptable solutions in land use planning (Farber et al., 2002), to set policy targets and measure progress in reaching those targets (Reyers et al., 2013), as well as "to enable a fuller characterization and representation of diverse ecosystem values in research and practice" (Chan et al., 2012).

In this context, socio-cultural valuation emerges as a methodological approach in ES research and because of its infancy, it still lacks of a consistent and widely accepted formalisation (Kelemen et al., 2014; Scholte et al., 2015). In spite of this, socio-cultural valuation is increasingly recognised in international initiatives, such as the Millennium Ecosystem Assessment (MA; MA, 2003), The Economics of Ecosystems and Biodiversity (TEEB; TEEB, 2010) and the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES; IPBES, 2015). Recent research has provided an overview of methods that are used for the assessment of non-monetary values including observation approaches, document research, expert based approaches, in-depth interviews, focus groups, and questionnaires (e.g. Arias-Arévalo et al., 2017; Kelemen et al., 2014; Scholte et al., 2015). However, the robustness of socio-valuation valuation methods is still in question, for instance, of normative approaches that enable people to rate ESs without any constraints, implying that all ESs can equally and simultaneously be provided, which is rarely the case (Horne et al., 2005; Scholte et al., 2015). Further, Martin-Lopez et al. (2014) show that the choice of methodological approach determines which values and trade-offs of ESs are addressed in the assessment, hence not only uncovering but also constructing value. Furthermore, Kenter et al. (2015) emphasise that different dimensions of social value yet seek routine integration into ES

* Corresponding author.
E-mail address: schmikat@uni-potsdam.de (K. Schmidt).

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assessments. Within this study, we test two techniques (i.e. rating and weighting) and two intentions (i.e. self- and other-oriented) of socio-cultural valuation of ESs and examine their quality to predict preferences in land use.

In the light of rapid land use transitions (Antrop, 2005; Pearson and McAlpine, 2010), sustainable land management has become a central challenge in environmental policy (Garcia-Llorente et al., 2012). Several European as well as national policies recognise people's preferences in land use and management as a crucial element to determine land use policies (ELC, 2000; EC, 2001). For instance in Scotland, the Land Use Strategy (SG, 2016) and the Scottish Biodiversity Strategy (SG, 2013) both aim to increase public involvement in land use and ecosystem management and decision-making while also introducing the ecosystem approach in policies. In Scotland, public participation in management planning is currently implemented in the Pentland Hills regional park, which is the research site of the present study. After an informative public survey in 2014, several stakeholders have engaged in a workshop to contribute to the understanding of land use preferences in the area.

In Europe, several studies have explored land use preferences by identifying socio-cultural values in the past. For example, Garcia-Llorente et al. (2012) explored social preferences toward semi-arid rural landscapes in south-eastern Spain by assessing social preferences towards 20 representative Andalusian landscape views based on photographs. López-Santiago et al. (2014) used photographs to assess social perceptions of ecosystem services in a transhumance landscape in Spain and Zoderer et al. (2016) explored how socio-cultural value changes with different landscape types in the Central Alps also based on photographs. These studies use landscape perception to detect socio-cultural values of ESs.

In this study, we use the Pentland Hills Regional Park, Scotland as a case study to understand to what extent socio-cultural values of ESs can be used to predict land use preferences. In doing so, we specifically aim to (1) identify clusters of land use preferences by using a novel visualisation tool based on trade-offs in land use management, (2) test if socio-cultural values of ESs elicited by different valuation techniques (i.e. rating and weighting) and different value intentions (i.e. self- and other-oriented well-being) are associated with the different clusters of land use preferences, (3) test if user characteristics are linked with the different clusters of land use preferences, and (4) determine whether both socio-cultural values of ESs and user characteristics are able to predict land use preferences.

2. Methods

2.1. Study area: Pentland Hills Regional Park

Located to the south-west of Edinburgh and covering areas in Midlothian, West Lothian and the City of Edinburgh Councils, the Pentland Hills comprise a variety of land uses and provide an important recreational asset to the region. The northern part of the Pentland Hills is designated as a Regional Park since 1986 under the provisions of the Countryside (Scotland) Act 1981 and covers an area of 9200 hectares (Fig. 1). The vision statement of the Pentland Hills Regional Park (PHRP) Plan recommends "To guide and assist all stakeholders in the sustainable management of the Pentland Hills Regional Park's changing environment in a way which supports communities living and working within the Pentland Hills Regional Park, promotes responsible access for all, develops public understanding of the mixed land use resource and conserves and enhances the Pentland Hills Regional Park's landscape, cultural and natural heritage features" (PHRP, 2007).

The land within the Pentland Hills Regional Park is mostly privately owned by over 30 landowners and farmers, smaller sections are owned by the City of Edinburgh Council, Midlothian Council, West Lothian Council and Scottish Water. The Regional Park is designated as an Area of Great Landscape Value and comprises a landscape of hills (up to 580 m a.s.l.), upland heather moorland, small pockets of woodland, Military of Defense firing ranges and reservoirs. The main land use of the hills is sheep farming on upland and lowland areas, agricultural farming on lower sections and liv-

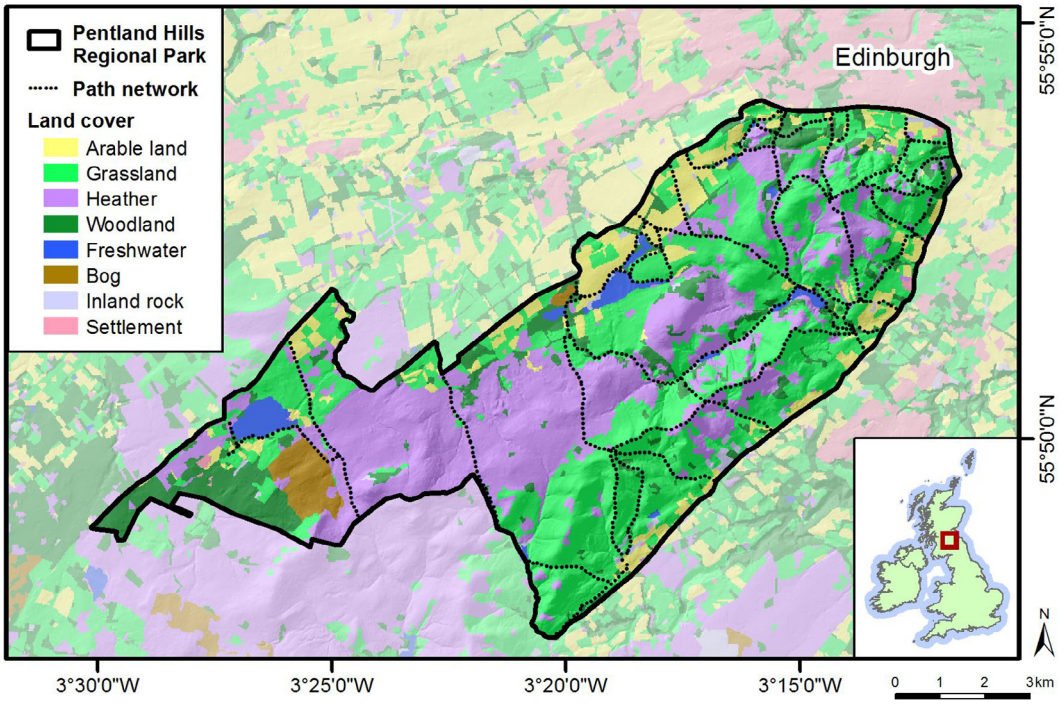

Fig. 1. Location, land cover and paths of the Pentland Hills Regional Park. The shaded areas indicate elevations.

ery. Further traditional land uses include bird shooting and fishing. The Regional Park is managed on behalf of the partner local authorities by the City of Edinburgh Council Natural Heritage Service aiming to conserve and enhance the environmental quality and public enjoyment of the area.

2.2. Data collection

2.2.1. User survey

The analysis is based on a user survey conducted in the summer and autumn of 2014. Tablet-based, on-site face-to-face visitor questionnaires were conducted over a 4-week period in June and July 2014. Respondents, who were mostly visitors, were randomly selected and approached on one of five car parks around the Regional Park before or after their trip ($n = 454$). Additionally, an online survey was available from August until October 2014 ($n = 109$), which link was widely distributed across stakeholders of the regional park, the project's website and social media. The online survey invited respondents to express their perceptions of ecosystem-based benefits provided to residents of the adjacent Councils. For the online survey we adapted the questionnaire slightly on account of technical limitations. Clarity and suitability of the questionnaire used for the survey were pre-tested on-site in February 2014 ($n = 18$).

2.2.2. Questionnaire and selection of ecosystem services

The final questionnaire (see Appendix A) consisted of four sections: The first section derives general information on the respondent's use of the park, the motivation of their visit, activities they took part in and general attitudes toward the management of the Regional Park; the second section assesses non-monetary values that the Pentland Hills generate via rating and weighting techniques; the third section asks the respondents to interactively visualise a future land use scenario for the Pentland Hills reflecting their personal preferences by using a novel visualisation tool, namely LANDPREF; the fourth section derives socio-demographic information of the respondents.

We derived the list of ecosystem services (Table 1) in cooperation with the Regional Park Management and selected members of the Councils based on the Common Classification of Ecosystem Services (Haines-Young et al., 2013). It was agreed that it represents all significant ESs provided by the regional park at a meeting with the Consultative Forum which included members from the regional park management, Councils, private landowners and other stakeholders.

The first section of the questionnaire was based on questions that were initially retrieved in the Pentland Hills Regional Park Visitor Survey of 2006 and that the Regional Park Management had expressed particular interest in updating, such as visitor characteristics or level and pattern of usage. We included people's activities in the park and motivations to visit the park in the further analysis of this manuscript.

In the second section of the questionnaire, we explored the socio-cultural values of ESs. We later used rating and weighting values in order to test if they could explain the choice of land use preferences. In the rating exercise, we asked respondents to assess the importance of the nine ESs by using a Likert scale (Likert, 1932): 1 = not important at all, 2 = not very important, 3 = of medium importance, 4 = quite important, and 5 = very important. Likert scales are a common tool for the assessment and rating of stakeholder values and attitudes in environmental research (Calvet-Mir et al., 2012; de Chazal et al., 2008; Petrosillo et al., 2007; Ruiz-Frau et al., 2013). We asked all respondents first to rate the list of ESs from a self-oriented perspective, indicating if they personally felt they benefited from the services, and subsequently asked to rate each ES from an other-oriented perspective, suggesting how much they felt others benefit from them (see also Chan et al., 2012; Oteros-Rozas et al., 2014; Kenter et al., 2015). By including these two value intentions in the rating exercise, i.e. self- and other-oriented, we explored whether different sets of values are important for land use preferences. Next, respondents were asked to weight the ESs by allocating a total of 100 points across the listed services. Respondents were free to distribute the points according to their preferences, allowing them to distribute points evenly or in favour of only a few or even one ES. We adapted the weighting approach from a study by Brown and Reed (2000), who conducted a similar assessment of forest values using the allocation of 100 US dollars as a payment instrument. In this study, we chose to substitute 'dollars' with 'points' to keep the allocation exercise as straightforward as possible and not to introduce a monetary metric.

In the third section, we aimed to assess respondents' land use preferences by using a novel visualisation tool for the assessment of land use preferences (LANDPREF, www.landpref.org). Respondents were asked to adjust a virtual landscape indicating their desired vision of the Pentland Hills in the future. LANDPREF's novelty lies in its interactive character which advances the frequently used photographic visualisations by enabling users to indicate their preferences freely without set outcomes or visions and providing real-time visual feedback of the implications of their choice

Table 1
Ecosystem services according to the Common Classification of Ecosystem Services (CICES) classes, associated benefits that were used in the user survey and abbreviated names used in the analysis.

Ecosystem services (according to CICES class)	Benefit it provides to users	Abbreviated names
Cultural ecosystem services		
Experiential use of plants, animals and land−/seascapes in different environmental settings	It enables to experience nature by watching it	Experiential use of nature
Physical use of land−/seascapes in different environmental settings	It enables to use nature by biking, hiking, walking in it	Physical use of nature
Educational	It enables to learn about and investigate the environment (education, research)	Education
Heritage, cultural	It holds places and things of natural and human history (landscape, farming traditions)	Cultural and natural history
Aesthetic	It provides inspiration and conveys a sense of place (aesthetics)	Aesthetics/Sense of place
Provisioning ecosystem services		
Provision of reared animals and their outputs	It provides agricultural products (food, wool)	Food provision
Regulating ecosystem services		
Filtration/sequestration/storage/accumulation by micro−organisms, algae, plants, and animals	It cleans and renews air, water and soils	Mediation of pollutants
Global climate regulation by reduction of greenhouse gas concentrations	It regulates the climate as a carbon sink	Carbon sequestration
Maintaining nursery populations and habitats	It provides habitat for wild plants and animals	Habitat/biodiversity

on the landscape. The images are based on rich pictures, resembling the Pentland Hills' existing landscape, still providing a level of abstractness to avoid an explicit spatial context. Whereas the landscape visualisation with photographs (e.g. López-Santiago et al., 2014) or photo-realistic montages (e.g. van Berkel et al., 2014) have been applied in ES research on various occasions, the interactive landscape visualisation based on rich pictures is a novel technique in the ES context and in landscape visualisation studies in general. See Fig. 3A for some examples of LANDPREF output.

LANDPREF allows respondents to interactively combine competing land uses at six intensity levels (on a scale from 0 to 5), namely sheep farming, restoration of native woodland, conservation of birds habitat, wind farming, carbon storage, and recreation. These land use options are restricted based on an algorithm, indicating the potential impact of every land use on each of the other land uses in order to represent trade-offs and synergies. These trade-offs and synergies were based on current research findings and guidelines of practice (e.g. Dramstad et al., 2006; Pavel, 2004; SNH, 2012). However, several simplifications have been made in regard to the land uses to allow for a speedy comprehension and execution of the exercise as well as to account for practical limitations that lie in the nature of the visual approach. For instance, we used the image of different birds to represent the conservation of birds' habitat and diversity. In addition, we used the number of visitors as well as an increase in recreational infrastructure to represent recreation, without differentiating between the intensity of the uses. Further, we directly linked carbon sequestration with the amount of woodland without accounting for additional carbon sinks. For a detailed description and the impact matrix of the land use trade-offs see Appendix B. Initially, we had developed an option to rate the inspiration provided by the landscape on a scale from 0 to 5 after having adjusted the virtual landscape to the desired extent. As suspected during the survey phase and confirmed during analysis, the concept of inspiration was misinterpreted by a large number of respondents. We therefore decided to omit the "inspiration" category from the analysis.

In the fourth section of the questionnaire, we collected socio-demographic data of the respondents, such as age, gender, level of education and postcode of residence. We used age and level of education for further analyses.

2.3. Data analysis

We applied a mixed analytical approach that includes different steps (Fig. 2). First, we performed Welch's Two-sample *t*-test to test if the online and on-site samples of respondents revealed any significant differences in their landscape preferences, ESs valuation, or user characteristics. The results indicated no significant differences between the samples that were collected through either the on-site and online surveys (*p*-value: 0.89) in regard to land use preferences, ESs valuation, and user characteristics. Thus we used a combination of both samples ($n = 563$) for all of our further computations.

To identify groups of users with similar land use preferences, we conducted Hierarchical Cluster Analysis (HCA) with the data collected through LANDPREF. We used Ward's linkage method as agglomerative technique (Ward, 1963) to minimise within-cluster variance and Bray-Curtis dissimilarity (Bray and Curtis, 1957) to eliminate the consideration of joint absences of preferences. We analysed median values of land use preferences for

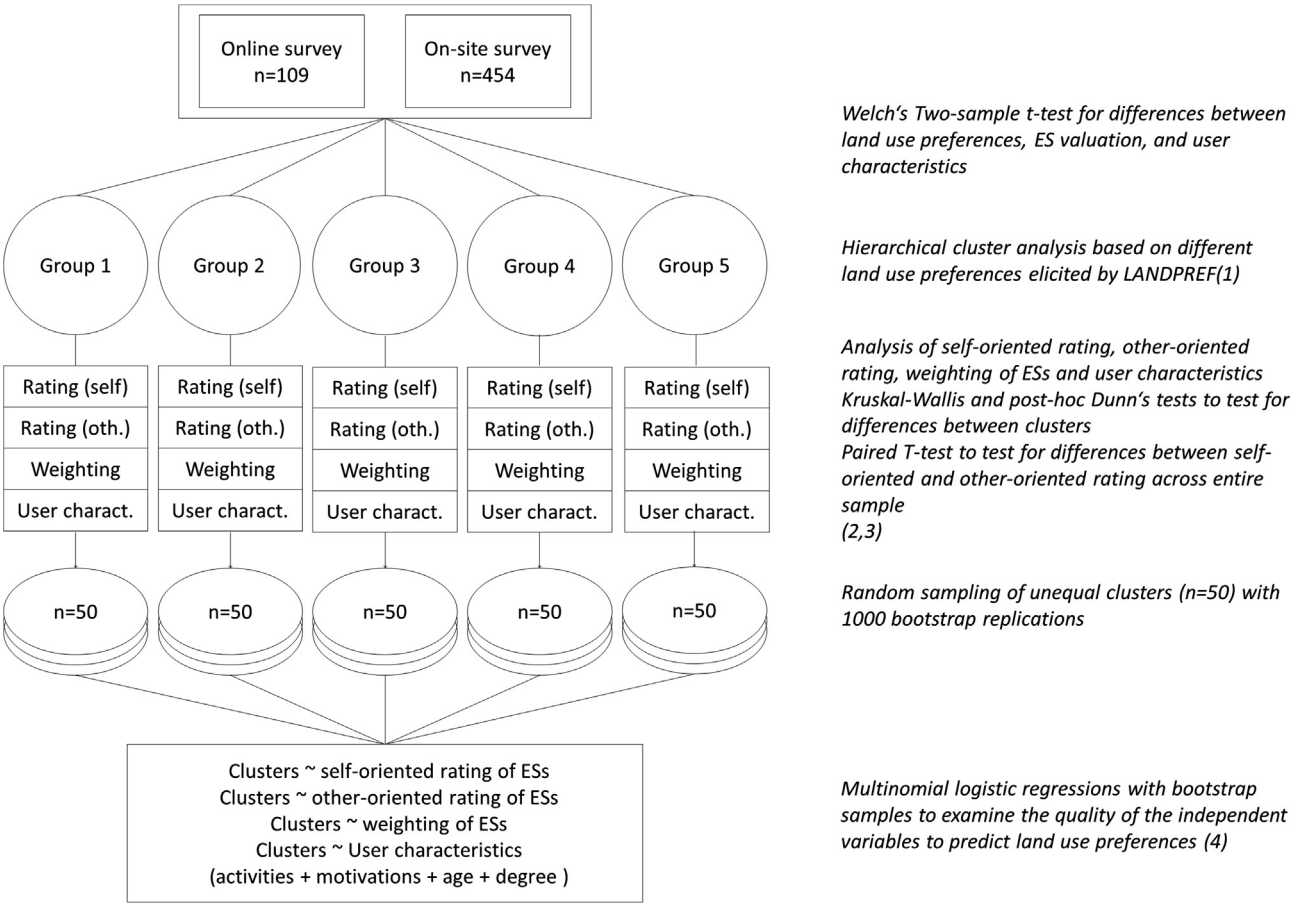

Fig. 2. Graphical flow chart of the data analysis in this study. Numbers in parentheses refer to the specific objectives of this research (see section 1).

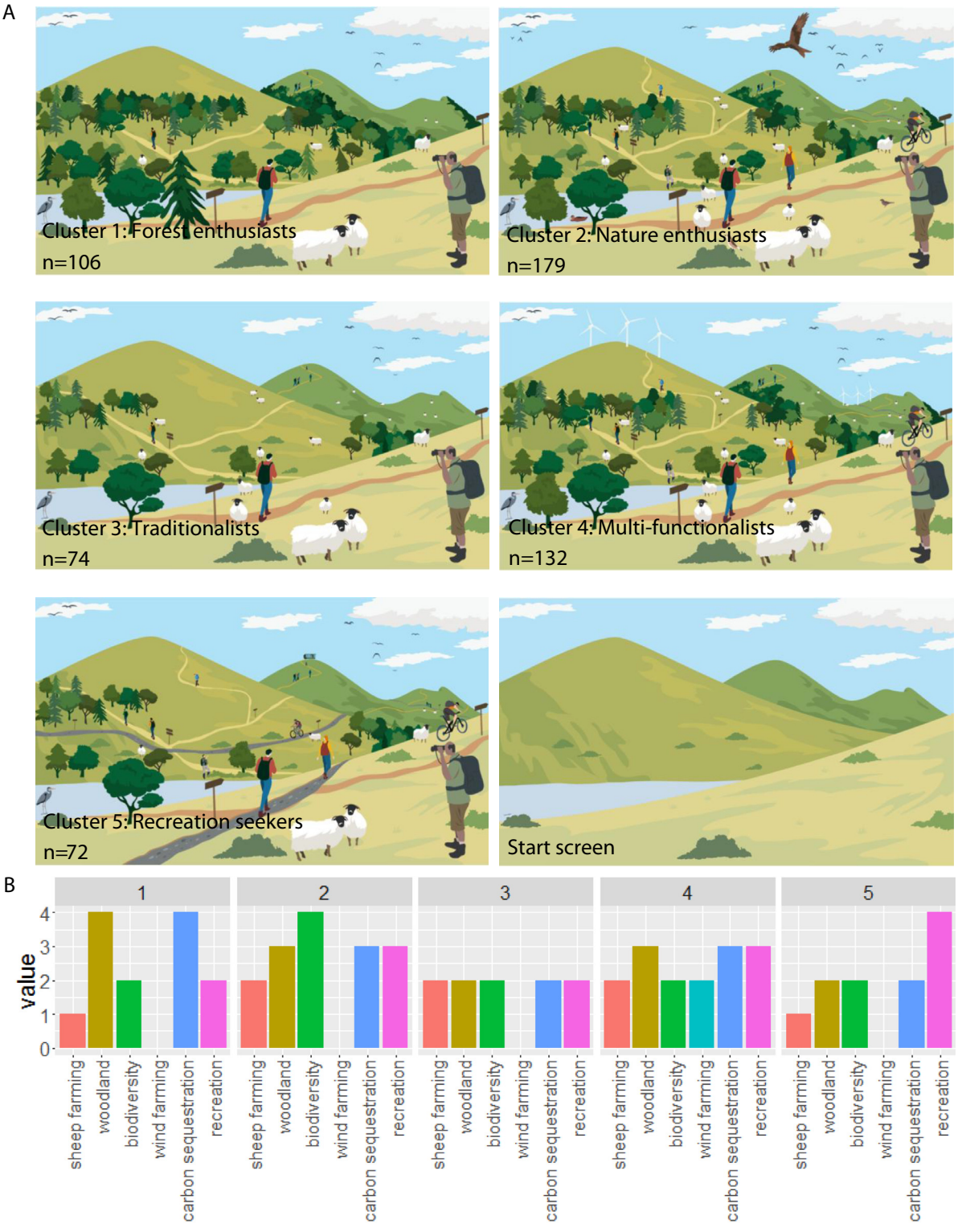

Fig. 3. Preference clusters for future land use management within the Pentland Hills Regional Park. (A) Composition of the future landscape settings visualised for each of the five clusters with attributed cluster name and size and the start screen of LANDPREF, (B) Median rating of each of the land use options for the five clusters.

the returned clusters and identified five distinguishable groups of people that were named accordingly.

To get an overview of the socio-cultural values of ESs, we calculated median values of respondents' rating for their individual well-being, rating for social well-being, and weighting of ESs per cluster. We used the non-parametric Kruskal–Wallis rank sum test (Kruskal and Wallis, 1952) to test if socio-cultural values of ESs elicited by different valuation techniques or value intentions differed between the different clusters of land use preferences. Post-hoc Dunn's test was performed to reveal which clusters differed by

pairwise comparison using rank sums (Dunn, 1964). To explore if there is a general difference between self-oriented and other-oriented rating irrespective of land use preferences, we also tested the entire sample (not cluster specific) using a paired *t*-test.

We calculated mean values of the socio-demographic variables (i.e. age and level of education) and visit characteristics (i.e. performed activities, motivations to visit) per cluster of landscape preferences. Then, we tested differences of these variables between the clusters by using Kruskal–Wallis rank sum test and post hoc Dunn's test.

We used multinominal logistic regression models to investigate how well the given ES values and user characteristics can predict land use preferences, namely the membership to a certain land use preference cluster. Because the obtained clusters were unequal in size, we generated random subsets of 50 respondents for each cluster. We re-sampled the observed context to produce 1000 bootstrap data sets for each group to ensure balanced sampling. For each of these bootstrap data sets, we then computed individual multinomial logistic regressions based on (1) self-oriented rating, (2) other-oriented rating or (3) weighting of ESs, and (4) user characteristics. We used the sensitivity (true positives) of each model to assess the quality of the prediction.

Further, we examined which regression coefficients showed the strongest links between predictors and land use preference clusters in each model. We calculated the median, 25th, and 75th percentiles of the regression coefficients from 1000 bootstrapped models for (1) self-oriented rating, (2) other-oriented rating or (3) weighting of ESs, and (4) user characteristics. These coefficients describe the change in log odds for one of the predicted classes, with cluster 1 "forest enthusiasts" being the reference cluster that all other clusters are compared with. A one-unit increase in the respective explanatory variable is associated with the increase (or decrease) in the log odds of being in that particular cluster. Such a comparison is meaningful, because the models for (1) self-oriented rating, (2) other-oriented rating or (3) weighting of ESs, and (4) user characteristics have the same value range across explanatory variables. All calculations were performed with the statistical software R version 3.3.3 (2017-03-06). Multinomial logistic regressions were fit with the multinom function in the package nnet (nnet package version 7.3–12).

3. Results

3.1. Identification of clusters of land use preferences

We identified five clusters of respondents with different land use preferences. The output of the LANDPREF tool and thus the landscape setting for each group is visualised in Fig. 3A based on the median values of land use preferences of each cluster as shown in Fig. 3B. People in cluster 1 (19% of respondents) whom we named "Forest enthusiasts", indicated a high preference for woodland development and low medium preferences for bird habitat/diversity and recreation. People in cluster 2 (32%), the largest cluster, favoured bird habitat and diversity for future land use and expressed medium interest for woodland development and recreation. We named them "Nature enthusiasts". Cluster 3 (13%) is characterised by people with low medium preference for all proposed land uses except for wind farming. These preferences resemble the current setting of the landscape in the Pentland Hills, hence we named people in cluster 3 "Traditionalists". People in cluster 4 (23%) tolerate all proposed land uses to a moderate extent ("Multifunctionalists"). People in cluster 5 (13%) indicated a strong preference for recreational use and infrastructure with low to medium interest in the other land uses ("Recreation seekers"). Despite different priorities in their landscape settings, the five clusters of respondents are characterised by rather gradual differences in their land use preferences. With the exception of wind farming, respondents in all five clusters desire each of the proposed land uses but to a different extent.

3.2. Socio-cultural values of ESs

Results of the socio-cultural valuation revealed various values of ESs depending on the respective socio-cultural valuation method (Fig. 4). The self-oriented rating of ESs unveiled particu-

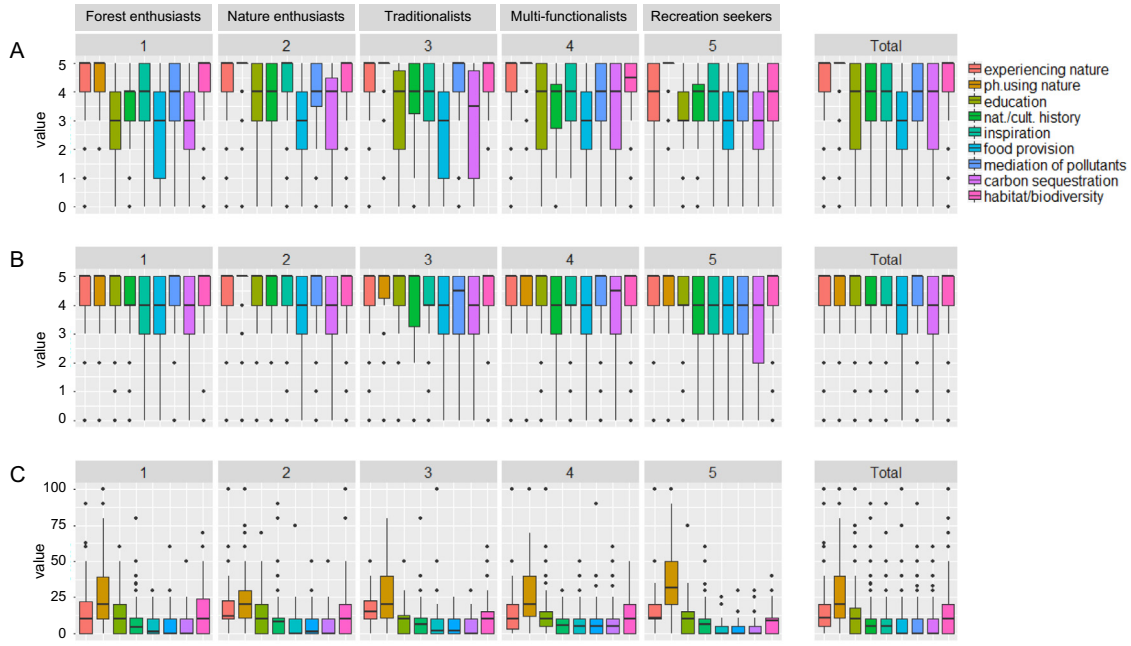

Fig. 4. Median, 25th, and 75th percentiles of the (A) self−oriented rating of ecosystem services (ESs) on a Likert−scale, (B) other−oriented rating of ESs on a Likert−scale, and (C) weighting by allocating 100 points across all ESs. The last group of boxes in each row labelled "Total" indicates the median, 25th, and 75th percentiles for the entire sample for each valuation exercise.

larly high values for cultural and regulating ESs and lower values for provisioning ESs. The experiential and physical use of nature as well as habitat and biodiversity were given the highest importance by all clusters. In contrast, food provisioning was given the lowest importance by all clusters. Several ESs were valued differently between the clusters with education and carbon sequestration receiving the widest range of values within the groups.

We found significant differences between the results of self-oriented and other-oriented rating (paired *t*-test, *p*-value: <0.001). In the other-oriented rating exercise, respondents collectively attributed higher values to all ESs and median values range between 4 and 5. Cluster 5 (Recreation seekers) indicated the lowest importance for carbon sequestration. Across the entire sample, the 25th and 75th percentiles of ESs values range between 4 and 5, only for food provisioning and carbon sequestration they range between 3 and 5. Other-oriented value was hence distributed more equally than self-oriented value.

Whereas the (self-oriented) rating exercise revealed information on the general importance of ESs, the weighting of ESs allowed drawing conclusions on the priorities and relative importance of ESs. Physical use of nature (median 20 points, 75th percentile 40 points) was identified as the most important ESs provided by the Regional Park across the entire sample, followed by experiencing nature (median 11 points, 75th percentile 20 points) and habitat/biodiversity (median 10 points, 75th percentile 20 points). In this valuation exercise, education received high importance as it ranked fourth, closely behind habitat/biodiversity (median 10 points, 75th percentile 17.5 points). The provision of food, mediation of pollutants and carbon sequestration received the lowest scores (median all 0 points, 75th percentile 10 points).

Kruskal–Wallis rank sum test revealed that several ESs were associated with different clusters of respondents (Table 2, see Appendix C. for Dunn's test results). In the self-oriented rating, except for education and food provision, at least one cluster of respondents valued ESs significantly different from the other clusters. Other-oriented rating uncovered fewer differences between the clusters (Table 2, Appendix C). The importance that people attributed to education, cultural history, aesthetics, and the mediation of pollutants significantly differed in between the clusters. Weighting of ESs revealed differences between the clusters (Table 2, Appendix C), but only for the physical use of nature (which nonetheless received the highest number of points in all clusters), the mediation of pollutants and carbon sequestration.

3.3. Socio-demographic and visitor characteristics of users

We found little socio-demographic differences between the clusters (Table 3, see Appendix C. for Dunn's test results). In fact, only age differed significantly between clusters. Cluster 4 (Multifunctionalists) were younger on average, whereas cluster 2 (Nature enthusiasts) were older. The level of education was similar across the clusters.

Activities performed in the Pentland Hills differed between the clusters (Table 3). Statistical differences between the five groups were evident for the activities of running, mountain biking, bird watching, nature observation and fishing. Motivations to visit the Pentland Hills regional park also presented differences between the clusters, in particularly for dog walking, exercise, inspiration, learning about nature, view, and scenery. Whilst walking was the most established activity in the regional park across all clusters, Recreation seekers (cluster 5) presented the highest percentage of people who performed physical training such as running and mountain biking (Table 3). In line with their land use preferences, Nature enthusiasts (cluster 2) contain the highest percentage of people who indicated they visited the Pentland Hills to observe nature, who come to watch birds or to fish.

Regarding motivations to visit the Pentland Hills, Cluster 5 (Recreation seekers) was the group that least indicated "exercise" as a motivation to visit the park, despite being the group that indicated most physical activities during their visit. Fifty-seven percent of people in cluster 2 (Nature enthusiasts) indicated they came to the regional park to walk their dogs. Consistent with their preferred land use setting, 25% of Nature enthusiasts also denoted "learning about nature" as one of their motivations to visit (Table 3).

3.4. Testing predictors for landscape preferences

The ranges of probability to correctly predict land use preference groups by the four bootstrapped regression models based on self-oriented and other-oriented rating of ESs, weighting of ESs, and user characteristics are shown in Fig. 4. The boxplots indicate that neither self-oriented rating (median 0.36) nor other-oriented rating (median 0.30) nor weighting of ESs (median 0.32) were suitable predictors of land use preferences. Despite providing the best model to predict the clusters (median 0.46), user characteristics did not qualify as fit predictors either.

The comparison of the median coefficients of the bootstrapped multinomial logistic regressions of the tested valuation techniques and value intensions indicates that none of the given ES values enable us to identify particular land use preferences (Appendix D). Because all median coefficients are ranging close to 0, the log odds of being in clusters 2, 3, 4 and 5 are very similar to the log odds of being in the reference cluster 1.

For the user characteristics, the median coefficients of the bootstrapped multinomial logistic regressions disclose differences in performed activities in the Pentlands in between clusters of land use preferences (Appendix E). For instance, mountain biking is an activity similarly important in all clusters, except for cluster 3 (Traditionalists; median log-odds by −14.5). Fishing is a particularly rare activity in cluster 5 (Recreation seekers; median log-odds of

Table 2
Results of Kruskal–Wallis rank sum test of self–oriented rating, other–oriented rating and weighting of ecosystem services for the five clusters. Significant values at $p \leq 0.05$ are in bold.

Ecosystem service	Self–oriented rating		Other–oriented rating		Weighting	
	p–Value	Chi^2	*p*–Value	Chi^2	*p*–Value	Chi^2
Experiential use of nature	**0.005**	14.7	0.3	4.8	0.09	8.1
Physical use of nature	**<0.001**	28.3	0.07	8.7	**0.02**	11.9
Education	0.13	7.1	**0.01**	13.0	0.33	4.6
Cultural and natural history	**<0.001**	21.5	**0.003**	15.9	0.8	1.6
Aesthetics/Sense of place	**0.006**	14.4	**0.01**	13.0	0.4	4.1
Food provision	0.16	6.5	0.3	4.9	0.17	6.4
Mediation of pollutants	**0.001**	18.2	**0.006**	6.2	**0.02**	11.3
Carbon sequestration	**0.048**	9.6	0.18	6.2	**0.002**	16.5
Habitat/biodiversity	**0.005**	14.7	0.08	8.4	0.11	75

Table 3
Socio–demographic and visitor characteristics of respondents (proportion within clusters). The last column indicates proportions of total sample.

	Chi^2	p–Value	Cluster 1 Forest enthusiasts	Cluster 2 Nature enthusiasts	Cluster 3 Traditional–ists	Cluster 4 Multi–functional–ists	Cluster 5 Recreation seekers	Total sample
Socio–demographic variables								
Proportion of visitors according to age and degree								
Age group	40.4	<0.01						
25			0.13	0.03	0.07	0.19	0.10	0.10
25 – 34			0.19	0.12	0.23	0.23	0.14	0.17
35 – 44			0.17	0.16	0.16	0.22	0.21	0.18
45 – 54			0.21	0.25	0.22	0.17	0.17	0.21
55–64			0.14	0.18	0.15	0.08	0.20	0.15
65 +			0.16	0.26	0.18	0.11	0.18	0.18
Degree	4.7	0.32						
GCSE or equivalent			0.07	0.10	0.07	0.06	0.06	0.07
A–levels or equivalent			0.13	0.14	0.07	0.07	0.12	0.11
Technical/vocational degree			0.08	0.15	0.13	0.11	0.11	0.12
Undergraduate degree			0.30	0.29	0.41	0.35	0.34	0.33
Graduate degree			0.36	0.30	0.32	0.40	0.35	0.34
Other			0.06	0.01	0	0.02	0.02	0.02
Characteristics of visit								
Proportion of visitors indicating activities and motivations if indicated by respondents (multiple choice possible)								
Activities								
Walking	4.6	0.33	0.71	0.76	0.80	0.70	0.81	0.75
Hillwalking	6.1	0.19	0.50	0.39	0.39	0.45	0.51	0.44
Running	22.1	<0.01	0.10	0.12	0.12	0.20	0.33	0.16
Mountain biking	32.0	<0.01	0.09	0.12	0.03	0.20	0.32	0.15
Bird watching	16.1	<0.01	0.09	0.18	0.07	0.08	0.04	0.11
Photography	8.0	0.1	0.09	0.13	0.12	0.20	0.10	0.13
Picnicking	4.7	0.3	0.11	0.13	0.12	0.20	0.17	0.15
Observing nature	11.7	0.02	0.14	0.27	0.12	0.18	0.18	0.2
Working	0.6	0.9	0.03	0.03	0.01	0.03	0.03	0.03
Horse riding	2.0	0.7	0.01	0.02	0.00	0.02	0.01	0.01
Fishing	15.3	<0.01	0.03	0.09	0.03	0.03	0.00	0.05
Motivations to visit								
Fresh air	2.8	0.6	0.63	0.64	0.69	0.58	0.60	0.63
Dog walking	21.8	<0.01	0.24	0.41	0.36	0.44	0.57	0.4
Exercise	9.8	0.04	0.65	0.72	0.78	0.64	0.57	0.67
Inspiration	14.1	<0.01	0.25	0.45	0.34	0.31	0.31	0.35
Solitude	3.1	0.5	0.25	0.26	0.20	0.20	0.19	0.23
Learning about nature	11.5	0.02	0.16	0.25	0.08	0.17	0.17	0.2
Enjoying company of others	5.5	0.2	0.16	0.20	0.19	0.16	0.08	0.17
View	13.3	0.01	0.44	0.65	0.53	0.53	0.49	0.55
Scenery	15.4	<0.01	0.57	0.72	0.68	0.53	0.54	0.62
Proximity work/home	7.1	0.1	0.70	0.76	0.85	0.73	0.81	0.76
Accessibility	5.6	0.2	0.42	0.51	0.38	0.51	0.49	0.47
Facilities	3.1	0.5	0.11	0.17	0.12	0.17	0.11	0.14

−13.5). Finally, all clusters show higher frequencies in swimming than the reference cluster 1 (Forest enthusiasts) which is evident as clusters 2–5 have median log-odds >10.5 compared to the reference cluster. In contrast to activities, motivations to visit the Pentland Hills as well as socio-demographic factors made little difference between clusters (Appendix E).

4. Discussion

4.1. Land use preferences and socio-cultural value of ESs

Including people's preferences in land use and management has become a crucial element in land use policies. In this study, we present an approach to assess land use preferences and compare the explanatory value of two socio-cultural valuation approaches and two value intentions for ESs valuation in general and for the determination of these land use preferences.

We derived five groups of respondents with different land use preferences. Whereas the support of woodland development, recreation and bird habitat/diversity varies widely in between the groups, the development of wind farms within the park received little, if any, tolerance in all groups. Over half of the respondents opted for desired scenarios that enhance the conservation of biodiversity and nature (Forest and Nature enthusiasts). Almost one quarter (23%) of the respondents related to all of the proposed land uses (Multi-functionalists) and smaller groups opted either for very little quantities of the proposed land uses (Traditionalists) or a strong focus on recreational use and infrastructure (Recreation seekers) each with about 13%. Though we found gradual differences between the clusters in regard to land use preferences, the overall desired landscape in the Pentland Hills can be characterised as multi-functional. The five assessed land use scenarios did not imply that a dramatic change in land use was required, rather an upkeep of the current one and a general tendency to more natural structures and biodiversity. Similar findings were obtained in recent studies that find people favour more structured heterogeneous landscapes over ones in which one land use dominates over the others (Arnberger and Eder, 2011; Van den Berg and Koole, 2006).

We showed that rating and weighting of ESs as performed in the current study revealed different levels of importance of ESs. Whereas rating allowed for an unlimited distribution of points which led to high values for several ESs, weighting by allocating a total of 100 points across all ESs prompted respondents to priori-

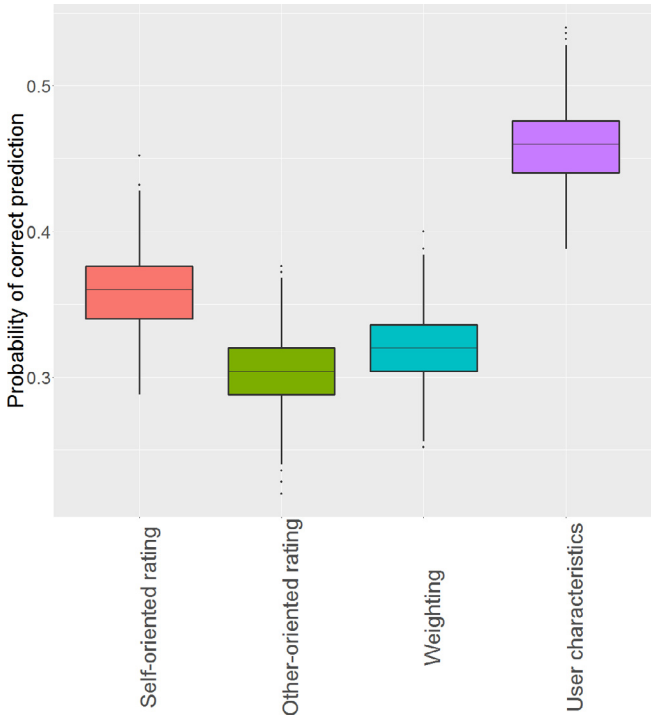

Fig. 5. Results of the multinomial logistic regressions, indicating the probability of each predictor model to correctly predict cluster membership. Computations are based on 1000 bootstrap data sets.

tise their preferences. Horne et al. (2005) experienced a similar outcome of nearly all respondents indicating that all of the suggested elements were important in an "open" rating, when investigating the importance people assign to different elements in a recreational environment. Because all ESs usually cannot be provided simultaneously, our results emphasise the need to carefully select a suitable technique for valuation, i.e. using a relative measure, such as dividing a total number of points in between all services (weighting) to compare importance between services and a normative measure, such as a Likert-scale for each service (rating) to examine general importance of the ES.

In regard to the two value intentions, we found that generally other-oriented values of ESs were given higher rates than self-oriented values. In self-oriented rating, food provision, carbon sequestration, and education received the lowest number of points, which are activities that were least exercised or, as asserted in the conversations with users, least known about by visitors of the Pentland Hills. This outcome is different to Oteros-Rozas et al.'s (2014) finding, that ES categories were valued differently in a transhumance cultural landscape, i.e. provisioning ESs were given higher other-oriented values and cultural ESs were given higher self-oriented values. In line with Oteros-Rozas et al.'s argument, the lack of knowledge of agricultural practices and products and climate regulation by many respondents in the Pentland Hills may have led to a lower personal valuation of the relating services. These ESs may however still have been found valuable to fulfill general needs and preferences of others. This assumption is backed by Herzog et al.'s (2002) results whereby ratings for nature were higher for a best friend than for the participants themselves. Also, Oteros-Rozas et al. (2014) assessed values for a broad range of provisioning, regulating, and cultural services, enabling them to draw conclusions on ES categories, whereas the selection of ESs in the Pentland Hills focuses on cultural ESs and thus limiting comparability between ES categories.

We investigated whether different groups of land use preferences can be predicted by ESs values. Our results suggest that in the observed regional, multi-functional context, socio-cultural valuation of ESs only poorly predicts preferences for future land use. Whereas, for instance, Zoderer et al. (2016) show that socio-cultural values of ESs could be attributed to different given landscape types as well as socio-demographic information, we were unable to find a reliable model to predict our five groups of different land use preferences based on respondents' values of ESs elicited by different methods. Surprisingly, ESs values were distributed fairly equally across the groups with diverging land use preferences. A possible explanation for this might be, that whereas the provision of many ESs relies directly on a particular land use, one type of land use is capable to supply multiple ESs (Metzger et al., 2006). Hence, even with the selection of diverse land use scenarios, the provision of the desired ESs by respondents is not necessarily jeopardised. For example, the value attributed to the experiential interactions with nature is almost equally high in either of the valuation exercises among cluster 1 (Forest enthusiasts) and cluster 4 (Multi-functionalists). It can therefore be assumed that to respondents in these two groups, landscapes with a variety of land uses and despite including technical structures like wind turbines, are deemed capable to provide experiential interactions with nature.

4.2. Methodological implications

As indicated previously, there is a need to incorporate socio-cultural values in ES assessments. The present study aimed to examine the explanatory power of ES values for land use preferences while testing three methods of socio-cultural valuation of ESs in a multi-functional landscape, namely the Pentland Hills regional park. Our results show that different techniques to elicit socio-cultural values reveal different information of value (normative rating, relative weighting), can vary between different value intentions (self-oriented, other-oriented), and that in our case study, ESs values cannot be used interchangeably with land use preferences.

A few limitations of our approach remain. LANDPREF, despite its comprehensible and engaging nature within the survey, is based on the developers' choices of trade-offs. In this case study, we adopted simplified relationships between land uses to assist a prompt understanding followed by a quick completion of the exercise to match the on-site survey setting. A different calibration of land use intensities and trade-offs as well as the integration of more complex (non-visual) impacts could well lead to different clusters of land use preferences. Generally, interactive landscape visualisation can draw audiences but can also sacrifice data accuracy and representativeness with increasing degrees of artistic style and interpretation (Newell et al., 2016). Daniel and Meitner (2001) find that the perception and valuation of landscapes depend on the degree of realism-abstraction, thus questioning the representational validity of computer-generated landscape visualisations. Our intention was to explore visitors' visions of different land uses in the future, rather than to accurately communicate environmental conditions as would be needed in the context of a formal participation process. Within the scope of this study, LANDPREF serves as a suitable instrument for the assessment of land use preferences.

There are some limitations based on the methods used in our study. Though tested negative for difference in both samples, we used two different methods for data collection (online, on-site survey) which may have had implications for the survey results. Also, our analysis of land use preferences is not capable to provide spatially explicit information for future management, though it can

help to identify preferred trends in land use. Likewise, as demonstrated, ES valuation as performed in this study, i.e. isolated from a spatial context or landscape features, is not capable to explain land use preferences. In a different spatial context, however, different land use preferences could emerge that could potentially stronger relate to ES values. Howley (2011) showed that environmental value orientations as well as socio-demographic variables were fitting predictors of landscape preferences. Our study was unable to demonstrate that socio-demographic variables or attributes of the respondent's visit were suitable predictors of landscape preferences and we did not assess environmental value orientations.

Another limitation is that despite including a wide range of provisioning, regulating and cultural ESs in our assessment, we expect a bias towards recreational ESs due to our chosen sample of respondents. Whereas food provisioning was found to be of medium importance in the rating and low importance in the weighting exercise, we would expect results to be higher if we had asked local farmers instead of visitors. We assume differences between user groups because preferences can be explained by the way people interact with and the extent they know about the landscape (Bradley and Kearney, 2007). It was indicated in conversations with several visitors who took part in the survey that they were unaware of regional produce activities in the Pentland Hills. Naturally, they deemed the provision of food less important for them personally. Having collected insight on values and land use preferences from visitors, an objective for future research would be to investigate which ecosystem services deemed important by other stakeholder groups and where these are located. Given the proximity to Edinburgh and the current structure and management of the park, we expect recreational ESs to be found very important by most stakeholder groups.

A further limitation of the study is that the five land use preferences that were derived by hierarchical clustering are based on a range of landscape configurations that can all be considered multifunctional, i.e. sheep farming, restoration of native woodland, bird habitat conservation, wind farming, carbon storage, and recreation. In this study, the multi-functionality of the depicted land uses corresponds with the character of the Pentland Hills. However, other studies of socio-cultural valuation of ESs demonstrated that people value ESs differently when intensification or land abandonment were compared to multi-functional landscapes (Garcia-Llorente et al., 2012; Iniesta-Arandia et al., 2014).

4.3. Implications for land use management

Bridging the gap between ES science and land use management and decision-making is a central research priority (Laurans et al., 2013; Opdam et al., 2013). Previous studies have identified the need to go beyond monetary metrics to inform practitioners and include socio-cultural values to understand which ESs are supplied at which locations and to whom they are delivered (Albert et al., 2014; Ruckelshaus et al., 2015). Furthermore, including public values in decision-making can have significant benefits by increasing public trust and support in decision-making (Raymond and Brown, 2011). However, as people's preferences become increasingly important in land use management, there is a need for a comprehensible methodological approach to assess them. Our study gives insight into the limitations of socio-cultural valuation methods of ESs for explaining landscape preferences. It also provides insight about the differences between ES values elicited by people in a particular landscape and their land use preferences.

Our results show that ES values in certain landscape contexts should not be equated with land use preferences. In our regional case study, ESs were not valued differently (to the extent that they could explain membership to a group) in between groups with different land use preferences. One possible explanation for this is that each of the prompted land use attributes supply a variety of ESs. Thus, if one land use is disregarded in the preference scenario, the "lost" ESs can likely be replaced by another land use with the capacity to provide similar ESs. It could however also mean, that on a general level ESs are found equally important in all groups but when describing future land use more explicitly, trade-offs became clear and respondents prioritised their choices. Our findings emphasise the complementary nature of both approaches which enable a fuller characterization of people's preferences. Understanding the opportunities as well as limitations of valuation approaches is crucially important to successfully communicate and implement landscape management strategies in practice.

Recently, scholars have emphasised that conservation plans should recognise ESs values by different users as well as note conflicting perceptions (García-Llorente et al., 2016). In this context, the Pentland Hills Management Plan (PHRP, 2007) provides a framework to conserve and enhance the Pentland Hills, their heritage and environment, to develop public understanding of the PHRP, to provide responsible access for all, and to support communities living and working within the PHRP. The current Park Plan ends in 2017 and the subsequent Plan aims to adopt the ecosystems approach to include ESs. Our findings provide a broad overview of socio-cultural values of ESs and more specific land use preferences of visitors which can be used to inform future objectives on public preferences.

5. Conclusions

Although recent ES research used landscapes and their configuration as a visualisation instrument to derive socio-cultural values of ESs (Garcia-Llorente et al., 2012; López-Santiago et al., 2014; van Zanten et al., 2016), we demonstrated that socio-cultural values of ESs are not suitable to describe land use preferences in the Pentland Hills regional park. In the current study, none of the socio-cultural valuation methods (rating, weighting) or value intentions (self-oriented, other-oriented) considered explained landscape preferences. In fact, socio-cultural values of ESs similarly span across the land use preferences of Forest enthusiasts, Nature enthusiasts, Traditionalists, Multi-functionalists, and Recreation seekers. Our results indicate that socio-cultural values of ESs should not be equated with land use preferences in all landscape contexts. These findings strengthen the idea that in a multifunctional landscape, one land use has the capacity to provide multiple ESs, so that different landscape configurations may lead to the provision of similar ESs. Continued efforts are needed in landscape management, to include socio-cultural perspectives in planning and decision-making. The challenge now is to conserve multifunctional landscapes that allow people to recognise the value of multiple ESs regardless of the specific land use configuration.

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Appendix A

Questionnaire as used in survey

1) What describes your role in the Pentland Hills today? (multiple choice)
Visitor
Farmer
Conservationist
Other
2) Which of the following statements best describes your visit to the PH today?
On a short trip (of less than 3 h) from home
On a day out (for more than 3 h) from home
On a holiday or short break away from home
On a business trip – staying away from home
Other (specify)
3) Who accompanies your visit to the PH today?
Alone
Dog(s)
Spouse
Children
Friends
A group
Family
Colleagues
4) Is this your first visit to the Pentland Hills?
No
Yes
5) If no, what year did you first visit the PH?
6) If no, have you ever participated in a recreational event (e.g. mountain bike race, run, guided tour) in the Pentland Hills?
No
Yes
7) If no, how often, on average, during the past calendar year do you visit the Pentland Hills?
Only been once
Less often than once a month
Once a month
2–3 times a month
Once a week
More than once a week but not daily
Every day
Other (specify)
8) What best describes your motivation to come here (nature-based motivations)?
To get some fresh air
To take out my dog
To get exercise
To be inspired by nature
To enjoy solitude/peace and quiet
To learn about nature
To enjoy the company of others:
To enjoy the view
To enjoy the scenery
Other (specify)
9) What **other** factors determined your choice to visit the Pentland Hills today (non-nature-based motivations)?
Existing facilities (ski slope, golf course, Visitor/Information Centre, toilets, Pub/restaurant)
Proximity to work/home
Accessibility (buses, car park)
Other (specify)
10) Which of the following activities have you taken part in, or intend to take part in, today?
Walking
Hillwalking
Running
Cycling
Mountain biking
Bird watching
Photography
Picnic/barbeque
Nature/natural history observation
Climbing
Work
Horse riding
Fishing
Sponsored walk
Orienteering
Geo-caching
Sailing
Other (specify)
11) Which areas in the Pentland Hills are of special importance to you?
Hills
Heathlands
Woodland
Reservoirs/ wetlands
Other (specify)
None
12) This map illustrates eleven different paths/walking routes in the Pentland Hills Regional Park. Which of these routes, if any, have you or do you expect to use today?
13) In general, how interested are you in what happens to the Pentland Hills Regional Park in the next 10–15 years (e.g. land use, recreational events, conservation planning)?
Very interested, I would want to get involved/ I am involved
Moderately interested, I follow the news and revisit the website to get information on that
Somewhat interested, I follow the local press
Not interested
14) We would like to find out more about what benefits the Pentland Hills provide for you personally, what benefits you think they provide for other people, or for nature itself. Please rate the following benefits provided by the Pentland Hills regarding their importance on the following scale:

0: I don't know
1: not important at all
2: not very important
3: of medium importance
4: quite important
5: very important

No.	Benefits provided by the Pentland Hills	Importance for myself (self-oriented value)	Importance for society and future generations (other-oriented value)
1	Experience: It enables to experience nature by watching it		
2	Physical Use: It enables to use nature by biking, hiking, walking in it		

Appendix A (*continued*)

No.	Benefits provided by the Pentland Hills	Importance for myself (self-oriented value)	Importance for society and future generations (other-oriented value)
3	Education: It enables to learn about and investigate the environment (education, research)		
4	Natural and cultural history: It holds places and things of natural and human history (landscape, farming traditions)		
5	Aesthetics: It provides inspiration and conveys a sense of place (aesthetics)		
6	Food and biomass provision: It provides agricultural products, food, wool		
7	Mediation of pollutants: It cleans and renews air, water and soils		
8	Carbon storage: It regulates the climate as a carbon sink		
9	Habitat: It provides habitat for wild plants and animals		

15) Please name the benefit you consider most important for the overall society.
Experience
Physical Exercise
Education
Natural and cultural history
Inspiration
Food and biomass provision
Mediation of pollutants
Carbon Storage
Habitat/Biodiversity
16) Within this map, please identify up to 3 places that you personally benefit from.
17) Imagine you could spend 100 Points to ensure that the Pentland Hills Regional Park keeps its existing benefits. You may allocate the 100 points in any way you like, but your total spending may not exceed 100 points. You might spend all 100 points on one value (and 0 on all others), or you might spend 50 points on one value, 25 on another and 25 on yet another value. Remember the total points you allocate should equal 100.
Experience __ points
Physical use __points
Education __points
Natural and cultural history __points
Inspiration __points
Food and biomass provision __points
Mediation of pollutants __points
Carbon storage __points
Habitat __points
18) What key changes have occurred in the PH over the past 10–15 years? What has changed?
Changes in the landscape
Changes in visitor density
Changes in recreational infrastructure
Other
19) Ideally, which combination of benefits will be provided by the Pentland Hills Regional Park in the next 10–15 years?
Please note that certain combinations are limited as some land uses interact and you may not be able to adjust all buttons to the desired level. Please prioritise your preferences. (LANDPREF)
20) What would you like to be different?
21) Have you been to the southern part of the Pentland Hills that extends beyond the Regional Park boundary?
Yes, once or twice
Yes, I go there sometimes
Yes, I go there frequently
No
22) Are you in favor of extending the Regional Park boundary so that it covers the entire area of the Pentland Hills, and why?
Yes
No
23) Can you please tell me
a) your post code
b) your age group

-24
25–34
35–44
45–54
55–64
65+

c) your gender

Male
Female

d) If you would like to be informed about the results of the study, your email address
e) How long have you lived in the Edinburgh area?

I don't live in the Edinburgh area
Less than 5 years
5–10 years
10–20 years
More than 20 years
I was born here and moved back after a time of being away
My whole life

f) What is the highest level of education you have completed?

GCSE or equivalent
A-levels or equivalent
Technical/vocational degree
Undergraduate Degree (Bachelor's)
University higher degree (e.g. Master's, PhD)
Other

g) Any comments?

Appendix B

Detailed matrix of land uses and their impact as used for LANDPREF. −1∗ indicates a relative dependency to the other levels and subtracts one point from the current value instead of indicating a set value.

Land use	Impact	Maximum possible level due to trade-off 0 1 2 3 4 5	Reference(s)
Impact of sheep farming on other land uses			
Woodland development	*More sheep farming, less habitat for wild plants and trees.*We assume that sheep farming and afforestation are land uses that in limited space directly oppose each other as grazing animals suppress tree generation.	5 4 3 2 1 1	Thompson and Brown (1992), Pollock et al. (2005), SNH (2012)
Habitat (birds)	*Very little or more intensive sheep farming, less habitat diversity for wild animals.*Grazing pressure through sheep farming can cause reduction in habitat quality for ground nesting birds. The lack of sheep farming is thought to leave less habitats for ground-nesting birds as the landscape will inevitably change if not further managed. Bird habitats are thought to be most diverse in a mix of open (lightly grazed) and woodland landscape providing nesting options for multiple habitat preferences/requirements.	3 4 5 5 3 2	MacArthur and MacArthur (1961), Fuller and Gough (1999), Pavel (2004), Brak et al. (2004)
Wind farming	*No scientific evidence found of an impact of sheep farming on wind farming.*	5 5 5 5 5 5	
Carbon sequestration	*More sheep farming, less forest thus less carbon sequestration.*This trade-off is based on the assumption that woodland allows for more carbon sequestration than farmed grassland. Therefore, as sheep farming threatens tree generation, it also compromises carbon sequestration.	5 4 3 2 1 1	Lal (2004), Liao et al. (2006)
Recreation	*Little to moderate sheep farming, no impact. More intensive sheep farming, less visitors/ infrastructure.*The Scottish Outdoor Access Code, allows the responsible use of private lands for recreational purposes. Thus, formally sheep farming has no impact on responsible recreational uses of landscapes. However, intensive sheep farming limits access for specific user groups (e.g. dog walkers, mountain bikers) which we argue is a trade-off in land uses.	5 5 5 5 4 2	Scottish Outdoor Access Code (2005)
Impact of woodland development on other land uses			
Sheep farming	*More habitat for plants and trees, less sheep farming.*Afforestation supports only light sheep stocks, thus an increase in woodland limits in sheep farming.	5 5 5 4 3 1	Mather (1971)
Habitat (birds)	*Little habitat for plants and trees, medium forest; medium habitat for plants and trees, much (diverse) habitat for wild animals; much habitat for plants and trees, medium habitat for wild animals.*Habitat requirements widely vary among bird species. In this study, we assume that the largest variety of breeding and nesting habitats are provided by a diversified landscape composition consisting of a mix of heather moorland and woodland areas.	2 3 5 5 4 3	Robbins et al. (1989), Murray et al. (2008)
Wind farming	*Much habitat for plants and trees, less wind farms.*Woodland and forests are not desirable areas for wind farm siting, therefore an increase in woodland limits the availability of wind farm sites.	5 5 5 4 3 2	Tegou et al. (2010), SNH (2014)
Carbon sequestration	*More forest, more carbon sequestration.*As carbon is stored in trees, an increase in habitat for wild plants and trees leads to an increase in carbon sequestration, based on the assumption that the long-lived trees are being planted.	0 1 2 3 4 5	Willis et al. (2003), Bateman and Lovett (2000), Cannell and Milne (1995)

Recreation	*Much habitat for plants and trees, less visitors/ infrastructure.*Woodland generally is found to have a positive effect on landscape preferences. However, heterogeneity and diversity in landscape structure is found to have a positive effect as well. We therefore assume that little to moderate habitat for plants and trees allows for the maximal amount of physical and experiential interactions with landscapes, which gradually declines with above average-average woodland plantations.	5 5 5 5 4 3	Willis et al. (2003), Dramstad et al. (2006)
Impact of habitat (birds) on other land uses			
Sheep farming	*No scientific evidence found of an impact of birds on any other land use.*	5 5 5 4 3 2	
Woodland development		5 5 5 5 4 3	
Wind farming		5 5 3 2 1 0	
Carbon sequestration		5 5 5 5 4 3	
Recreation		5 5 5 4 4 3	
Impact of wind farming on other land uses			
Sheep farming	*No scientific evidence found of an impact of wind farms on sheep farming.*	5 5 5 5 5 5	
Woodland development	*More wind farming, less woodland.*Though we found no scientific evidence that wind farming limits woodland expansion, we assume that both are conflicting land uses as wind turbines need access tracks for service and maintenance and are thus unlikely areas for woodland expansion.	5 4 3 2 2 2	SNH (2014)
Habitat (birds)	*More wind farming, less bird habitats.*Wind farms can affect birds by direct habitat loss, collision mortality, displacement or barrier effects.	5 4 3 2 1 1	Madders and Whitfield (2006), Drewitt and Langston (2006)
Carbon sequestration	*More wind farming, less carbon sequestration by woodland.*Because carbon sequestration in this study is interlinked with woodland expansion (habitat for wild plants and animals), it is likewise limited by the establishment of wind farms.	5 4 3 2 2 2	
Recreation	*More wind farming, less visitors/infrastructure.*Despite a wide public acceptance of wind farm developments in Scotland, a recent wind farm survey revealed that Scottish landscapes have become and are thought to increasingly become less appealing for walking and climbing tourists.	5 5 5 5 4 3	Warren et al. (2005), Gordon (2014)
Impact of carbon sequestration on other land uses			
Sheep farming	*No scientific evidence found of an impact of carbon sequestration on any other land use. As carbon*	5 5 5 4 3 1	
Woodland development	*sequestration, in this study, directly correlates with woodland expansion, the same trade-offs apply as for habitat for wild plants and trees.*	0 1 2 3 4 5	
Habitat (birds)		2 3 5 5 4 3	
Wind farming		5 5 5 4 3 2	
Recreation		5 5 5 5 4 3	
Impact of recreation on other land uses			
Sheep farming	*Many visitors/much infrastructure, less sheep farming.*Physical and experiential interactions (e.g. off-track dog walkers, recreational events, etc.) add pressure to sheep farms, particularly during lambing season.	5 5 5 5 4 3	PHRP (2014)
Woodland development	*Many visitors/much infrastructure, less woodland expansion.*Pressure is imposed upon woodland when visitors or group of visitors (e.g. recreational event) don't remain on access tracks and damage sensitive habitats for wild plants and trees.	5 5 5 5 5 −1*	Burden and Randerson (1972)

(*continued on next page*)

Appendix B (*continued*)

Land use	Impact	Maximum possible level due to trade-off	Reference(s)
		0 1 2 3 4 5	
Habitat (birds)	*Many visitors/much infrastructure, less bird habitats.*Human-induced disturbance can have negative effects on bird populations, namely by causing nest abandonment, increased predation and habitat loss.	5 5 5 5 4 2	Hockin et al. (1992), Gill (2007)
Wind farming	*No scientific evidence found of an impact on wind farming.*	5 5 5 5 5 5	
Carbon sequestration	*Many visitors/much infrastructure, less carbon sequestration.*As carbon sequestration in this study directly correlates with woodland expansion, it is reduced with an increase in visitors/ infrastructure which has a negative effect on afforestation.	5 5 5 5 5 −1*	

Appendix C

Results of Kruskal Wallis rank sum test and post hoc Dunn's test to examine how self-oriented, other-oriented rating and weighting of ecosystem services differ between clusters. In the output of Dunn's test, common characters indicate groups that are not significantly different.

Ecosystem services	Chi^2-Test		Groups according to Dunn's Test				
			Cluster 1 Forest enthusiasts	Cluster 2 Nature enthusiasts	Cluster 3 Traditionalists	Cluster 4 Multi-functionalists	Cluster 5 Recreation seekers
	P-Value	Chi^2	Groups				
Self-oriented rating of ESs							
Experiential use of nature	0.005	14.7	AB	A	A	AB	B
Physical use of nature	<0.001	28.3	B	A	A	A	A
Education	0.13	7.1	A	A	A	A	A
Cultural and natural history	<0.001	21.5	B	A	A	B	B
Aesthetics/Sense of place	0.006	14.4	B	A	AB	AB	B
Food provision	0.16	6.5	A	A	A	A	A
Mediation of pollutants	0.001	18.2	AB	A	A	A	B
Carbon sequestration	0.048	9.6	AB	AB	AB	A	B
Habitat/biodiversity	0.005	14.7	AB	A	AB	B	B
Other-oriented rating of ESs							
Experiential use of nature	0.3	4.8	A	A	A	A	A
Physical use of nature	0.07	8.7	A	A	A	A	A
Education	0.01	13.0	B	A	AB	AB	B
Cultural and natural history	0.003	15.9	AB	A	AB	B	B
Aesthetics/Sense of place	0.01	13.0	B	A	AB	AB	B
Food provision	0.3	4.9	A	A	A	A	A

Mediation of pollutants	0.006	6.2	A	A	AB	A	B
Carbon sequestration	0.18	6.2	A	A	A	A	B
Habitat/biodiversity	0.08	8.4	AB	A	AB	AB	B
Weighting of ESs							
Experiential use of nature	0.09	8.1	A	A	A	A	A
Physical use of nature	0.02	11.9	A	A	AB	A	B
Education	0.33	4.6	A	A	A	A	A
Cultural and natural history	0.8	1.6	A	A	A	A	A
Aesthetics/Sense of place	0.4	4.1	A	A	A	A	A
Food provision	0.17	6.4	A	A	A	A	A
Mediation of pollutants	0.02	11.3	AB	AB	AB	A	B
Carbon sequestration	0.002	16.5	AB	A	AB	B	A
Habitat/biodiversity	0.11	75	A	A	A	A	A

Appendix D

Median and 25th and 75th percentiles of regression coefficients of the multinomial logistic regression models of self-oriented rating, other-oriented rating and weighting of ecosystem services. All quartiles of coefficients relate to the baseline cluster, which is cluster 1 (Forest enthusiasts).

Percentiles	Cluster 2 Nature enthusiasts									Cluster 3 Traditionalists									Cluster 4 Multi-functionalists									Cluster 5 Recreation seekers								
	Self-oriented rating			Other-oriented rating			Weighting			Self-oriented rating			Other-oriented rating			Weighting			Self-oriented rating			Other-oriented rating			Weighting			Self-oriented rating			Other-oriented rating			Weighting		
	25th	Median	75th	25th	Median	75th	25th	Median	75th	25th	Median	75th	25th	Median	75th	25th	Median	75th	25th	Median	75th	25th	Median	75th	25th	Median	75th	25th	Median	75th	25th	Median	75th	25th	Median	75th
Intercept	−4.88	−3.49	−2.10	−2.42	−1.28	−0.50	−3.03	1.84	3.95	−3.76	−2.94	−2.18	−0.58	0.01	0.59	0.97	2.40	4.72	−3.28	−2.28	−1.48	−0.79	−0.14	0.48	−1.19	0.74	4.22	−1.85	−1.29	−0.70	0.39	0.88	1.36	−516.09	−0.99	1.28
Experiential use of nature	−0.03	0.09	0.21	−0.20	−0.07	0.07	−0.04	−0.01	0.04	−0.07	0.03	0.14	−0.20	−0.07	0.04	−0.05	−0.02	0.00	−0.28	−0.16	−0.06	−0.13	−0.01	0.12	−0.05	−0.02	0.01	−0.24	−0.13	−0.05	−0.11	0.02	0.13	−0.02	0.01	5.16
Physical use of nature	0.11	0.35	0.61	−0.28	−0.10	0.09	−0.05	−0.02	0.03	0.29	0.42	0.58	−0.33	−0.19	−0.06	−0.05	−0.02	−0.01	0.50	0.67	0.86	−0.11	0.05	0.20	−0.04	−0.01	0.02	0.50	0.63	0.75	−0.34	−0.20	−0.05	0.00	0.02	5.18
Education	0.07	0.17	0.26	0.06	0.23	0.42	−0.03	0.00	0.04	−0.03	0.05	0.14	0.19	0.34	0.51	−0.06	−0.03	−0.01	0.13	0.22	0.31	0.16	0.34	0.51	−0.03	0.01	0.03	0.13	0.22	0.30	0.03	0.19	0.34	−0.01	0.02	5.16
Cultural and natural history	0.07	0.18	0.28	0.09	0.24	0.39	−0.04	−0.01	0.04	0.26	0.35	0.46	−0.06	0.06	0.18	−0.05	−0.02	0.00	−0.25	−0.14	−0.05	−0.30	−0.17	−0.05	−0.06	−0.03	0.00	−0.02	0.07	0.16	−0.04	0.10	0.21	−0.01	0.02	5.17
Aesthetics/ Sense of place	0.07	0.17	0.27	0.07	0.21	0.36	−0.03	0.00	0.05	−0.17	−0.08	0.01	−0.10	−0.01	0.09	−0.03	−0.01	0.02	−0.11	−0.01	0.09	−0.08	0.04	0.15	−0.04	−0.01	0.03	−0.21	−0.13	−0.05	−0.05	0.05	0.14	0.00	0.03	5.17
Food provision	−0.03	0.06	0.15	−0.01	0.09	0.20	−0.08	−0.04	0.01	−0.08	−0.01	0.07	−0.07	0.02	0.11	−0.05	−0.02	0.00	0.15	0.25	0.35	−0.10	0.00	0.10	−0.07	−0.03	0.01	0.26	0.34	0.41	0.00	0.09	0.18	−0.04	0.00	5.13
Mediation of pollutants	−0.06	0.05	0.15	−0.16	−0.01	0.12	−0.03	0.01	0.06	0.05	0.15	0.24	−0.27	−0.14	−0.03	−0.04	−0.01	0.03	−0.15	−0.04	0.06	−0.15	0.00	0.12	−0.02	0.02	0.06	−0.29	−0.20	−0.12	−0.40	−0.29	−0.17	−0.02	0.01	5.17
Carbon sequestration	−0.23	−0.14	−0.05	−0.25	−0.14	−0.04	−0.08	−0.04	0.01	−0.25	−0.18	−0.10	−0.13	−0.03	0.05	−0.08	−0.05	−0.02	0.10	0.20	0.30	−0.05	0.05	0.16	−0.03	0.01	0.05	−0.14	−0.07	0.01	−0.14	−0.05	0.04	−0.05	−0.02	5.12
Habitat/ biodiversity	−0.24	−0.09	0.07	−0.31	−0.12	0.05	−0.05	−0.02	0.03	−0.20	−0.08	0.02	−0.08	0.06	0.20	−0.06	−0.04	−0.01	−0.49	−0.35	−0.22	−0.39	−0.23	−0.07	−0.06	−0.02	0.01	−0.45	−0.35	−0.23	−0.23	−0.08	0.07	−0.04	−0.01	5.13

Appendix E

Median and 25th and 75th percentiles of regression coefficients for the multinomial logistic regression model of user characteristics (activities, motivations to visit, socio-demographic characteristics of visitors). All quartiles of coefficients relate to a baseline cluster, which is cluster 1 (Forest enthusiasts).

	Cluster 2 Nature enthusiasts			Cluster 3 Traditionalists			Cluster 4 Multi-functionalists			Cluster 5 Recreation seekers		
Percentiles	25th	Median	75th	25th	Median	75th	25th	Median	75th	25th	Median	75th
Intercept	−1.95	−1.43	−0.85	−1.76	−1.28	−0.80	−0.18	0.33	0.80	−1.28	−0.83	−0.41
Activities in Pentland Hill												
Walking	−0.38	0.00	0.34	−0.35	−0.05	0.25	−0.57	−0.26	0.08	0.29	0.61	0.88
Hillwalking	−0.97	−0.68	−0.38	−0.87	−0.64	−0.42	−0.67	−0.40	−0.14	−0.37	−0.14	0.10
Running	−0.56	−0.08	0.40	−0.42	0.01	0.44	−0.13	0.25	0.63	0.74	1.13	1.52
Mountainbiking	−0.82	−0.23	0.25	−18.55	−14.43	−2.95	−0.20	0.25	0.69	0.75	1.11	1.57
Bird watching	0.32	0.76	1.26	−0.81	−0.33	0.13	−0.48	−0.03	0.54	−1.72	−1.18	−0.68
Photography	−0.12	0.32	0.74	−0.22	0.14	0.51	0.67	1.05	1.45	−0.19	0.19	0.56
Fishing	0.47	1.20	2.07	−1.01	−0.23	0.56	−0.74	0.33	1.11	−17.09	−13.51	−11.00
Swimming	10.22	11.91	13.47	13.45	22.27	28.96	9.60	10.84	12.30	9.28	10.41	11.66
Motivations to visit Pentland Hills												
Fresh air	−0.68	−0.39	−0.07	−0.01	0.27	0.55	−0.54	−0.24	0.02	0.66	−0.33	−0.08
Dog walking	0.18	0.50	0.80	0.39	0.62	0.86	0.66	0.98	1.28	−0.64	0.92	1.21
Exercise	−0.16	0.18	0.50	0.23	0.47	0.70	−0.25	0.03	0.28	−0.22	−0.38	−0.15
Inspiration	0.15	0.51	0.86	0.19	0.45	0.78	−0.20	0.16	0.48	−0.33	0.10	0.42
Solitude	−0.89	−0.54	−0.20	−0.80	−0.48	−0.15	−0.67	−0.33	−0.01	−0.77	−0.05	0.24
Learning about Nature	−0.27	0.15	0.56	−1.65	−1.30	−0.90	−0.76	−0.34	0.06	−0.83	−0.44	−0.09
Company of others	−0.36	0.01	0.40	0.05	0.34	0.66	−0.35	0.02	0.41	0.25	−0.45	−0.11
Enjoy view	0.60	0.95	1.26	−0.31	0.00	0.29	0.38	0.71	1.03	−0.95	0.53	0.84
Enjoy scenery	−0.43	−0.11	0.23	0.09	0.40	0.68	−1.01	−0.69	−0.35	0.00	−0.65	−0.36
Proximity to home	−0.11	0.22	0.55	0.74	1.01	1.30	−0.20	0.09	0.37	0.29	0.27	0.54
Accessibility	0.22	0.50	0.77	−0.32	−0.11	0.13	0.29	0.51	0.77	−0.61	0.51	0.75
Facilities	−0.07	0.29	0.71	−0.10	0.25	0.64	−0.14	0.25	0.65	0.66	−0.24	0.12
Socio−demographic information												
Age	0.16	0.25	0.34	−0.07	0.01	0.08	−0.23	−0.15	−0.06	0.09	0.16	0.23
Degree	−0.23	−0.14	−0.05	−0.06	0.02	0.10	−0.13	−0.04	0.05	−0.24	−0.15	−0.08

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