Assessing, testing, and implementing socio-cultural valuation methods to operationalise ecosystem services in land use management

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Main abbreviations

CBD	Convention on Biological Diversity
EC	European Commission
ES	Ecosystem service
GIS	Geographical information system
IPBES	Intergovernmental Platform of Biodiversity and Ecosystem Services
LANDPREF	Tool for the assessment and visualisation of land use preferences
MA	Millennium Ecosystem Assessment
PHRP	Pentland Hills Regional Park
PPGIS	Public participation GIS
TEEB	The Economics of Ecosystems and Biodiversity
UN	United Nations

1. Introduction

1.1 Background

The relationship between humans and nature is increasingly being investigated by using the ecosystem services (ESs) approach (Carpenter et al., 2009; Chaudhary et al., 2015). Ecosystems contribute to human wellbeing in several ways. Humans benefit from ecosystems because they provide resources, generate ways to mediate or moderate the ambient environment affecting human performance, and have the potential to impact physical and mental states of people (Haines-Young and Potschin, 2013b). They are commonly characterised in three types of ES categories: provisioning, regulating, and cultural services. For instance, ecosystems provide water, food, raw materials, and energy resources, i.e. provisioning services. Ecosystems maintain essential ecological processes that are beneficial to humans, such as the regulation of geochemical cycles, the mediation or prevention of environmental disturbances, and climate regulation, i.e. regulating services. Furthermore, ecosystems provide the environmental settings for physical, intellectual, and spiritual interactions with ecosystems and landscapes, i.e. cultural services (Haines-Young and Potschin, 2013b).

The notion of humans depending on ecosystems has a long history within environmental sciences. The awareness of humans depending on ecosystems is much older than the scientific analysis of ESs, and can be dated back to Plato in 400 BC and perhaps even earlier (Daily, 1997, p. 5f.). The origins of the concept of ESs have been traced back to the late 1970s when ecosystem functions were framed as utilitarian services to increase public interest in biodiversity conservation (Costanza et al., 2017; Gomez-Baggethun et al., 2010). After the publication of two milestone studies in the 1990s (i.e. Costanza et al., 1997; Daily, 1997), the ESs approach received rapidly increasing attention in environmental sciences and was henceforth put more and more on the policy agenda. The Millennium Ecosystem Assessment (MA, 2005) and The Economics of Ecosystems and Biodiversity (TEEB, 2010) provided important conceptual frameworks as well as empirical results to raise the scientific interest in ESs. The most recent conceptual framework and assessment was developed by the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES), an initiative established in 2012 as an independent intergovernmental body for all member countries of the United Nations to strengthen the science-policy interface for biodiversity and ecosystem services (Díaz et al., 2015). A recent literature review revealed that until today there are a total of over 17.000 papers published with the term "ecosystem services" in the title, abstract or keywords (Costanza et al., 2017) with a clear rise in the years following the publications of the MA and TEEB.

In spite of the substantial amount of research around the ESs approach that includes reviews, conceptual underpinnings as well studies applying the approach, different interpretations of the concept are still debated (Nahlik et al., 2012). In this thesis, ESs are defined as the "contributions that ecosystems make to human well-being [that] retain a connection to the underlying ecosystem functions, processes and structures that generate them" (Haines-Young and Potschin, 2013b). Whereas certain ESs retain a direct link to their underlying ecosystems (e.g. micro climate regulation by trees in urban environments), the use of other ESs requires human management (e.g. to provide access to environmental settings that enable the experience of nature) or harvesting of services (e.g. provision of cultivated crops). It is inherent to this definition that the ESs approach is anthropocentric, i.e. that "it is the presence of human beings as valuing agents that enables the translation of basic ecological structures and processes into value-laden entities" (de Groot et al., 2002). Consequently, values are central to ESs research.

Values in ESs research are commonly associated with three value domains: the socio-cultural, monetary, or biophysical domains (de Groot et al., 2002; MA, 2005). Socio-cultural values can generally refer to cultural ideas about what are desirable goals and appropriate standards for judging actions (i.e. held values) or to the relative importance that people assign to objects on a non-monetary scale (i.e. assigned values; Brown, 2002; Brown, 1984; Rokeach, 1973). Monetary values account for the relative importance of ESs to people similar to socio-cultural values but adapt a market-based approach and use monetary expressions of value (Gomez-Baggethun et al., 2010). Biophysical, or ecological, value refers to how well an ES contributes to the sustainability of an ecosystem, using indicators like diversity, complexity, rarity, and resilience (de Groot et al., 2002). In the light of many drawbacks of monetary valuation of ESs (see e.g., Gomez-Baggethun and Ruiz-Perez, 2011; Jax et al., 2013; Luck et al., 2012; McCauley, 2006; Spangenberg and Settele, 2010) and because previously it has been underrepresented in ES assessments, socio-cultural valuation has recently explicitly been put on the research agenda in the field of ES science (Christie et al., 2012; Quintas-Soriano et al., 2016; Scholte et al., 2015; Walz et al., 2016).

Although value plurality has been recognised long before the MA and the coinciding mainstreaming of ESs research (e.g., Bingham et al., 1995; de Groot et al., 2002), the importance of an integrated valuation of diverse values within ESs assessments has only in the past few years gained attention in the research community and related policy field (Jacobs et al., 2016; Martín-López et al., 2014; Pascual et al., 2017). Because of this novelty, so far there are only few applications of integrated value assessments in ESs research (e.g., Bark et al., 2016; Kenter et al., 2016; Martín-López et al., 2014). In the past, ESs research adopted a utilitarian perspective with a scientific focus on ecosystem functions and environmental economics and only from approx. 2010 onwards has the framing eventually changed towards an emphasis of the importance of cultural structures for sustainable interactions between humans and nature with a more interdisciplinary underpinning and the integration of social sciences (Mace, 2014). Consequently, valuation studies in ESs research have focused mostly on either the economic or the biophysical value domains leaving the socio-cultural domain largely underrepresented (Nieto-Romero et al., 2014; Seppelt et al., 2011; Vihervaara et al., 2010).

The notion of an integrated approach to ESs valuation and the importance of socio-cultural values in particular have been picked up by several policy initiatives with the objective to counteract sustainability challenges by integrating nature's values into ecosystem management (Diaz et al., 2015; Jacobs et al., 2016; Pascual et al., 2017). Ecosystem management within this research, because of its regional character, is mostly referred to as 'land use management'. Examples for such policies include global initiatives, such as the Convention on Biological Diversity's Ecosystem Approach (CBD; Raum, 2017), and the Aichi 2020 Targets (Shepherd et al., 2016) that aim to support sustainable development and protect biodiversity. On the European level, the European Biodiversity Strategy aims to halt the loss of biodiversity and ecosystem services in the EU and contribute to stopping global biodiversity loss by 2020 (European Commission, 2011). These goals are adopted by various national policies (e.g. Scottish Biodiversity Strategy, Scottish Land Use Strategy). Furthermore, integrated ESs valuation has become a focus in the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES; Díaz et al., 2015; Pascual et al., 2017), which is an intergovernmental body established to strengthen the science-policy interface for biodiversity and ESs for the preservation of biodiversity, human well-being, and sustainable development. Despite the recent advances of ESs and nature's values in several policy initiatives, they are accompanied by calls for further operationalisation of ESs in land use management (Daily et al., 2009; Lautenbach et al., 2015; Martinez-Harms et al., 2015; Russel et al., 2016).

In this research, I focus on socio-cultural valuation of ESs in terrestrial ecosystems on a regional scale. I use the concept of assigned values while acknowledging the central role that held values have as a determinant for assigned values (Brown, 1984). Although I will not further address biophysical valuation approaches and discuss monetary valuation critically albeit briefly in chapter 3, I advocate the notion of an integrated valuation approach with complementary consideration of all three value domains because they are fundamental to safeguard the ecological integrity (i.e. biophysical values), provide a measure of comparability (i.e. monetary values), and allow to include important social objectives (i.e. socio-cultural values). It is a lengthy undertaking from the simple notion that ESs provide value to people, to the measurement of values of ESs on to the implementation of these values in decision-making. For further advancing the socio-cultural value domain of ESs and their operationalisation in land use management several challenges need to be addressed. Examples for some of these challenges are the unbalanced consideration of value domains, conceptual and methodological uncertainties, investigating the relationship between ESs values and land use preferences, the lack of management implications in ESs research, and exploring approaches to implement ESs research in land use management. These challenges are outlined below and provide the background for the objectives and research questions of this dissertation (section 1.3).

1.2 Challenges of SCV of ESs for being operationalised in land use management

1.2.1 Assessing the current role of socio-cultural valuation in ESs research

Unbalanced consideration of value domains: Despite the recognition of value plurality throughout various conceptual underpinnings of the ESs approach (Cowling et al., 2008; de Groot et al., 2002; Díaz et al., 2015; MA, 2005; TEEB, 2010), socio-cultural values are underrepresented in ESs assessments. The assessment of socio-cultural values has only recently started to increase steadily (Iniesta-Arandia et al., under review; Nieto-Romero et al., 2014). A literature review found that 2012 was the first year in which there were more than 10 studies published that assess socio-cultural values of ESs with rises in the subsequent years (Iniesta-Arandia et al., under review). In the past, valuation studies often focused on a single ES category (frequently provisioning, rarely cultural services; Nieto-Romero et al., 2014) and a single or only few ESs (Seppelt et al., 2011). Nieto-Romero et al. (2014) revealed a significant association between the methodological approach of valuation (i.e. biophysical, socio-cultural, or monetary) and the type of ESs: regulating services were most often assessed with biophysical analysis, cultural services with socio-cultural analysis, and provisioning services either with biophysical or monetary approaches. Thus, the deficit of analyses considering cultural services has negative implications for the application of the socio-cultural value domain. Further, it is recognised that the engagement with stakeholders is a suitable means to include socio-cultural values in ESs assessments (Cowling et al., 2008; Plieninger et al., 2013) and help to operationalise ESs research to address real-world management needs (Martinez-Harms et al., 2015; Dick et al., 2017). However, ESs assessments frequently did not include stakeholders in the valuation process (Nieto-Romero et al., 2014; Seppelt et al., 2011).

Conceptual uncertainties: As socio-cultural values have only recently gained traction in ESs research, they were lacking a theoretical and methodological basis for a long time (Scholte et al., 2015). Despite a rich background of knowledge in other research disciplines, such as psychology, social sciences, and geography, there are still a considerable amount of uncertainties when characterising cultural dimensions and addressing socio-cultural values of ESs (Chan et al., 2012a; Oteros-Rozas et al., 2014). Within ESs assessments, the concept of socio-cultural value is frequently conflated with the notion of cultural ESs (Chan et al., 2012b). Though both may be intangible in nature (Chan et al., 2012a; Chan et al., 2012b), I argue that there is a clear difference between the service category and value domain. Whereas cultural services refer to a particular type of ESs, namely a broad realm of human interactions and understandings of the natural environment (Fish et al., 2016), the socio-cultural value domain applies to all ESs categories (Chan et al., 2012a; Scholte et al., 2015). Consequently, the value of provisioning, regulating, and cultural services can be expressed through socio-cultural terms (e.g., Kelemen et al., 2013; Oteros-Rozas et al., 2014). A deeper knowledge regarding the patterns of socio-cultural values in ESs literature could add to the scientific foundation for the practical implementation of socio-cultural values into ESs assessments.

1.2.2 Testing socio-cultural valuation methods of ESs and their relevance for land use preferences: exploring methodological opportunities and limitations

Methodological uncertainties: Because socio-cultural valuation methods have only recently entered the ESs research domain (Jacobs et al., 2016; Mace, 2014), they have less frequently been tested and bear various uncertainties regarding their opportunities and limitations. For instance, studies have outlined how certain values have been overlooked in ESs research, how valuation can highlight the importance of certain underappreciated ESs, and how deliberation can improve the appreciation of positions of citizens at odds (Chan et al., 2012b). Others warned of methodological implications of socio-cultural valuation methods (i.e. socio-cultural values may not only uncover but also construct values; (Martín-López et al., 2014). Within the context of socio-cultural valuation, the normative consideration of acceptable trade-offs (e.g., Martín-López et al., 2014; Oteros-Rozas et al., 2013) as well as the promotion of synergies was identified as a central challenge to steer land use management towards multifunctionality (Martín-López et al., 2012; Plieninger et al., 2013). A better understanding of the implications of individual valuation methods and the development of new tools to account for trade-offs could advance and promote socio-cultural valuation in ESs assessments.

Relationship between ESs values and land use preferences: Because it facilitates a wide range of applications, such as the valuation of multiple benefits and tradeoff assessment, and it has the potential to inform land use management, the ESs approach has become a focus in cultural landscape research (Hermann et al., 2014; Hermann et al., 2011; Schaich et al., 2010). Several studies have explored land use preferences by identifying socio-cultural values, frequently by using photorealistic landscape visualisations within surveys (Garcia-Llorente et al., 2012; López-Santiago et al., 2014; van Zanten et al., 2016; Zoderer et al., 2016). However, the relationship between ESs values and land use preferences has not been sufficiently explored. So far, little attention has been paid to the ability of ESs values to translate into preferences for land use management. From a methodological perspective, the use of photorealistic images has received criticism because the level of photorealism has important implications for the validity of the participant's responses (Daniel and Meitner, 2001). It is thus a challenge of socio-cultural valuation studies not only to explore limitations and opportunities of existing methodologies but also to understand how methods complement each other and to develop new tools for the assessment of land use preferences and test their boundaries to ESs assessments.

1.2.3 Implementing ecosystem services research into land use management through socio-cultural valuation

ESs research lacks implications for land use management: Although socio-cultural valuation is characterised as a promising approach towards the integration of a multitude of values of ESs (Chan et al., 2012a; Oteros-Rozas et al., 2014), an important challenge is to implement these values into land use management. Though it is generally emphasised that the ESs approach has the ability to assist decision-making and ultimately guide land use management towards a more sustainable future, early conceptual underpinnings such as the MA did not include the necessary methods to make ESs operational (Armsworth et al., 2007). As a result, ESs research addresses widely diverging topics, for instance, conceptual classifications, valuation, modelling, and governance (Costanza et al., 2017). However, recently calls for the operationalisation of the ESs approach in land use management have surfaced (Chan et al., 2011; Daily et al., 2009; Sitas et al., 2014). A large body of literature creates ESs knowledge but only few studies also contain clear implications of such knowledge for land use management (Martinez-Harms et al., 2015). As a consequence, the utilisation of ESs research in practical decision making is found under-researched (Cowell and Lennon, 2014; Jordan and Russel, 2014; Russel et al., 2016).

Finding ways to implement transdisciplinary, spatially explicit research: There are several challenges to be addressed in order to integrate the ESs approach into practical land use management. Because of the lack of pragmatic approaches towards the integration of scientific knowledge into decision making processes (Nassauer and Opdam, 2008), it is a challenge to transcend disciplinary boundaries and use different forms of knowledge to address complex socio-ecological problems (Lang et al., 2012; Sitas et al., 2014). To achieve this, it is advised to go beyond assessing multidisciplinary perspectives from social sciences, natural sciences, and the humanities and in addition also to integrate local knowledge with other sources of information (Bennett et al., 2015). Social values are found particularly suitable to integrate diverse disciplines and views (van Riper et al., 2017). Further, ESs have a spatial dimension. The location of benefits that ecosystems supply to people can be used to inform site prioritisation in spatial planning and management (Chan et al., 2006; Egoh et al., 2011; Schröter et al., 2014). Thus, another challenge towards the operationalisation of the ESs approach is to improve the understanding of how spatial and participatory approaches can be linked to optimise the multifunctional use of ecosystems (de Groot et al., 2010). It is recognised that stakeholder engagement can help to operationalise ESs research to address real-world management needs (Dick et al., 2017; Martinez-Harms et al., 2015). Participatory mapping is a method that links spatial and participatory approaches by assessing the spatial distribution of ESs according to the knowledge and perceptions of stakeholders. Previous studies suggest that supplementary valuation exercises yielded no added analytical benefit compared to the investigation of the frequency of mapped benefits for the assessment of socio-cultural value of an area (Brown, 2013; Nielsen-Pincus, 2011). Therefore, participatory mapping has proven an appropriate method to address the challenge of integrating socio-cultural values of ESs into practical land use management (Brown and Fagerholm, 2015; Jacobs et al., 2017).

1.3 Research objectives and questions

As has been outlined above, several challenges should be addressed in order to further operationalise the ESs approach to account for socio-cultural values in land use management. The main ambition of this research is **to explore the ability of socio-cultural valuation methods for the operationalisation of ESs research in land use management.** In doing so, I seek to advance and promote the application of socio-cultural valuation of ESs in order to ultimately take into account people's values, preferences, and knowledge in land use management. To address this main objective, I formulated three objectives that comprise a total of five research questions (RQs; Figure 1.1):

Objective I: Assessing the current role of socio-cultural valuation in ESs research

RQ 1: To what extent have socio-cultural values been addressed in ESs assessments?

Objective II: Testing socio-cultural valuation methods of ESs and their relevance for land use preferences: exploring methodological opportunities and limitations

RQ 2: What are the implications of applying different socio-cultural valuation methods for ESs values?

RQ 3: To what extent are land use preferences explained by socio-cultural values of ESs?

Objective III: Implementing ecosystem services research into land use management through socio-cultural valuation

RQ 4: Which landscape features with particular relevance to ESs supply are explicitly considered in land use management?

RQ 5: How can participatory approaches accounting for ESs be operationalised in land use management?

Addressing these objectives and research questions will help to operationalise the ESs approach to account for socio-cultural values in land use management in several ways. Assessing the current role of socio-cultural values in ESs valuation studies can improve the conceptual basis of the approach. Exploring patterns under which socio-cultural values have been elicited in the past can facilitate and improve future applications by demonstrating the wide range of opportunities of the application of the approach. Furthermore, an improved understanding of the implications and limitations of socio-cultural valuation methods can enhance their credibility and facilitate their application in other studies. A rich knowledge base of socio-cultural valuation methods of ESs can help to account for people's values of nature more effectively. Additionally, knowledge on which landscape features underpinning ESs supply are considered in land use management can suggest which landscape features should be the focus of future management with regard to the desired ESs supply. Finally, this research demonstrates how socio-cultural valuation can be operationalised in practical land use management.

1.4 Outline

This thesis consists of seven chapters (Figure 1.1). Chapters 3 to 5 are written as three individual research papers, preceded by this general introduction (chapter 1) and the methodological approach (chapter 2). To address the research questions, I gain an understanding of the current role of socio-cultural values in ESs assessments by systematically reviewing publications in the study field (chapter 3). Then, I assess socio-cultural values of ESs and their relationship with land use preferences (chapter 4). To this end, I develop and apply a new tool to assess land use preferences and their related ESs. Finally, I use a participatory mapping approach to investigate landscape features underpinning ESs supply and to what extent these landscape features are considered in land use management (chapter 5). The research in Chapters 4 and 5 were based on studies conducted in a case study area south of Edinburgh, Scotland (UK), the Pentland Hills Regional Park. In the final chapters, I provide a discussion of this research (chapter 6) and present main conclusions (chapter 7).

In line with other research (Abson et al., 2014; Brink et al., 2016; ProClim, 1997), I distinguish between three types of knowledge that are needed to explore the ability of socio-cultural valuation methods for the operationalisation of ESs research into land use management: systems knowledge, normative knowledge, and transformative knowledge. Figure 1.1 shows the connection of my five RQs in relation to these three knowledge types. *Systems knowledge* generally relates to a descriptive understanding of social and ecological systems, in this thesis it refers to an understanding of the role of socio-cultural valuation in ESs research and its methodological implications. *Normative knowledge* comprises knowledge related to value judgements associated with alternative potential states of the system (Jax et al., 2013; Wiek et al., 2011). Here, I translate it to the knowledge gained by the assessment of socio-cultural values of ESs and land use preferences, both of which are inherently normative. *Transformative knowledge* generally relates to the formulation of strategies based on an understanding of the system and normative goals. Within the context of my thesis, it describes the knowledge obtained by implementing ESs research on socio-cultural valuation into land use management. Systems knowledge such as the understanding of socio-cultural values of ESs in contemporary ESs research provides the methodological foundation to acquire normative knowledge such as socio-cultural values of ESs. In turn, socio-cultural values of ESs are used for the implementation of the ESs in land use management. This transformative knowledge feeds back and changes our current understanding of socio-cultural valuation in ESs research (systems knowledge).

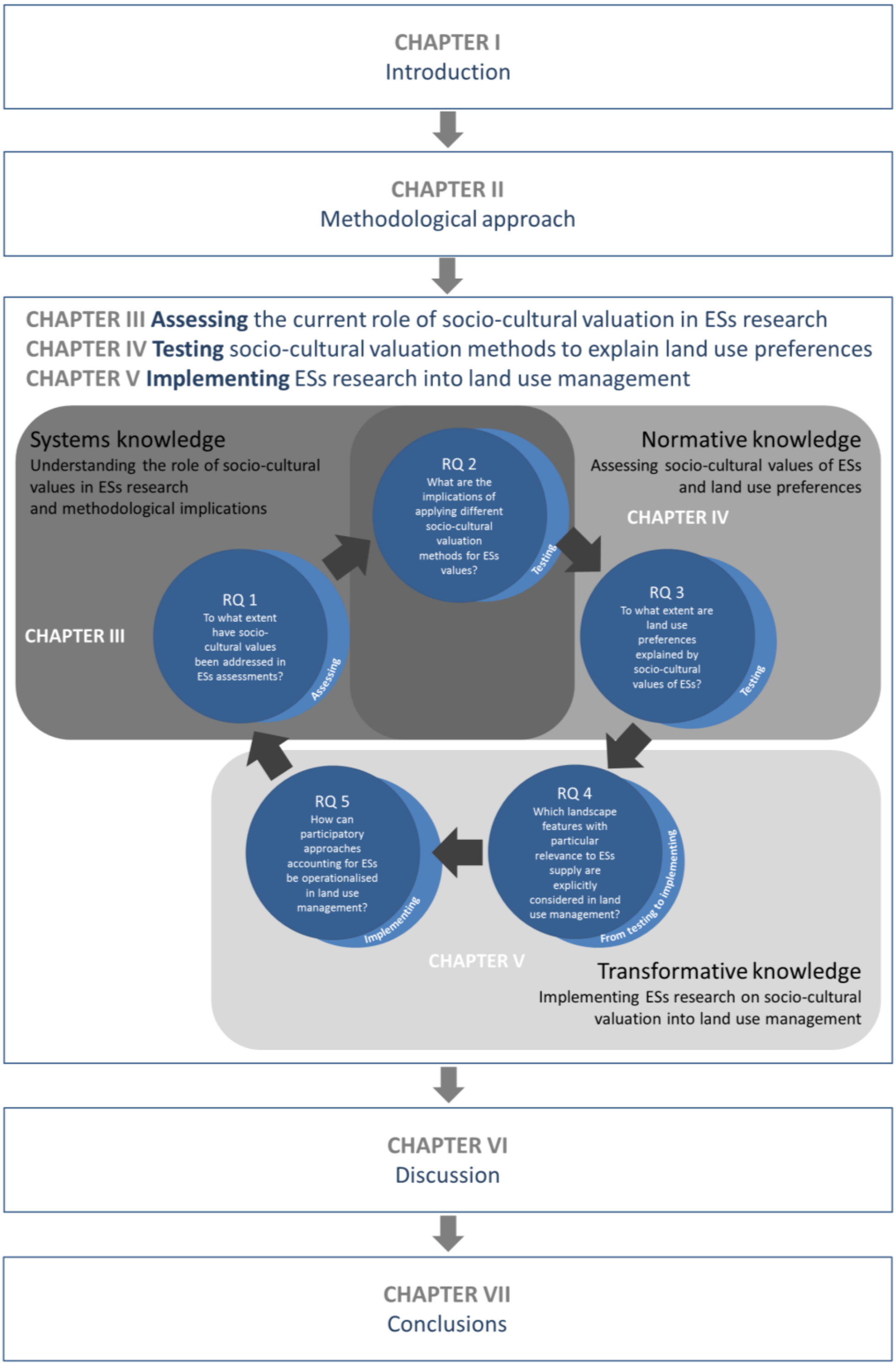

Figure 1.1. Outline of this thesis and the classification of knowledge types related to ESs research (Brink et al., 2016). The specific research questions (RQs) are described in blue bubbles, with a reference to the objective of the corresponding chapter in the shadow area

2. Methodological approach

In line with the current literature (Jacobs et al., 2017), I adopted a methodological approach that combines different methods (Table 2.1) which enabled me to respond to my research objectives and research questions (section 1.3). First, a systematic literature review of empirical valuation studies was conducted in chapter 3 to quantitatively *assess the current role of socio-cultural valuation in ESs research* (Objective I). In order to *test socio-cultural valuation methods of ESs and their relevance for land use preferences: exploring methodological opportunities and limitations* (Objective II), I applied existing methods of socio-cultural valuation and statistically compared them to land use preferences elicited by a newly developed tool for the assessment and visualization of land use preferences (LANDPREF). In order to *implement ESs research into land use management through socio-cultural valuation* (Objective III), I adapted a mixed methods approach using participatory mapping, geospatial analysis, and document analysis to show the potential of ESs knowledge for land use management. Table 2.1 synthesises the methodological approach used in each of the chapters comprising the results.

For the assessment of the current role of socio-cultural valuation, I analysed empirical ESs assessment studies in regard to their concurrent consideration of social benefits and ESs categories, cultural services, valuation methods, and stakeholder participation. I reviewed a total of 115 studies that were published in between 2005, i.e. the year of the publication of the MA reports and mainstreaming of ESs research, and May 2014. I targeted studies that conducted a primary valuation of ecosystem services using biophysical, monetary, or non-monetary approaches, excluding studies that employed value transfer.

To explore methodological opportunities and limitations of valuation methods, I employed a user survey that comprised different non-monetary methods (i.e. rating and weighting) and value dimensions (i.e. self-oriented value and others-oriented value), as well as land use preferences. The survey was pre-tested and facilitated in the Pentland Hills Regional Park, Scotland (UK). To investigate the potential of the area to its users, target respondents were visitors to the park. In 2014, a total of 563 questionnaires were collected during an on-site and subsequent online survey. The tablet based on-site survey (n=454) was carried out by myself and undergraduate students from the University of Edinburgh, School of GeoSciences during June and July 2014. Appendix 2 delineates the questionnaire used for this research.

For the purpose of implementing socio-cultural values of ESs into land use management, I used participatory mapping data collected at a workshop of stakeholders of the Pentland Hills Regional Park, Scotland (UK) to assess the spatial location of ESs hotspots. These ESs hotspots were the basis for the geospatial analysis of landscape features underpinning the supply of ESs. Subsequently, those landscape features were compared to management priorities as derived by content analysis of the current management plan. Table 2.1 shows the variety of methods applied in this dissertation, the rationale of their application, and how the data was collected and analysed. Specific information regarding data collection and data analysis as well as implications of the methodologies can be found in the respective chapters.

Table 2.1. Methods applied in this research

Chapter	Methodological approach	Rationale	Data collection	Data analysis
3	Systematic literature review Case survey method	To assess to what extent socio-cultural values have been addressed in ESs assessments in regard to ESs categories, cultural services in particular, monetary valuation techniques, and stakeholder participation.	Document analysis	Multiple logistic regressions
4	Quantitative assessment of preferences and values of ESs and land use Statistical testing of socio-cultural values of ESs and land use preferences	To identify clusters of land use preferences in the study area. To test if user characteristics are associated with land use preferences. To test if socio-cultural values of ESs derived by different valuation techniques and value intentions are associated with land use preferences. To determine whether socio-cultural values of ESs of user characteristics are able to predict land use preferences	Survey – questionnaire	Hierarchical cluster analysis Kruskal-Wallis / post-hoc Dunn's test Kruskal-Wallis / post-hoc Dunn's test Bootstrapped sampling and multinomial logistic regressions
5	PPGIS GIS analysis Content analysis Ranking	To identify hotspots of cultural, provisioning, and regulating ESs. To explore landscape features that underpin ESs supply. To investigate current land use management priorities. To uncover mismatches to allow for a better understanding of the required focus of future land use management to account for ESs.	Workshop, document analysis	Participatory mapping and intensity analysis Geospatial analysis / Redundancy analysis Quantitative content analysis Ranking of importance of landscape features for the supply of ESs and management priorities

3. Current role of social benefits in ecosystem service assessments

Abstract: Ecosystem services have a significant impact on human wellbeing. While ecosystem services are frequently represented by monetary values, social values and underlying social benefits remain underexplored. The purpose of this study is to assess whether and how social benefits have been explicitly addressed within socio-economic and socio-cultural ecosystem services research, ultimately allowing a better understanding between ecosystem services and human well-being. In this paper, we reviewed 115 international primary valuation studies and tested four hypotheses associated to the identification of social benefits of ecosystem services using logistic regressions. Tested hypotheses were that (1) social benefits are mostly derived in studies that assess cultural ecosystem services as opposed to other ecosystem service types, (2) there is a pattern of social benefits and certain cultural ecosystem services assessed simultaneously, (3) monetary valuation techniques go beyond expressing monetary values and convey social benefits, and (4) directly addressing stakeholders views the consideration of social benefits in ecosystem service assessments. Our analysis revealed that (1) a variety of social benefits are valued in studies that assess either of the four ecosystem service types, (2) certain social benefits are likely to co-occur in combination with certain cultural ecosystem services, (3) of the studies that employed monetary valuation techniques, simulated market approaches overlapped most frequently with the assessment of social benefits, and (4) studies that directly incorporate stakeholder's views were more likely to also assess social benefits.

Based on:

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3.1 Introduction

The ecosystem services approach has initially been established to recognise the central role that ecological processes and natural capital play in supporting human well-being and to integrate their values into decision-making (Daily et al., 2009; MA, 2005). Assessments of ecosystem services aim to evaluate the impact of policy decisions and identify benefits as well as trade-offs within environmental management (de Groot, Alkemade, Braat, Hein, & Willemen, 2010; Hauck, Görg, Varjopuro, Ratamäki, & Jax, 2013). Ecosystem service assessments have been found useful in communicating benefits of environmental conservation among stakeholder groups and particularly effective in extending biodiversity conservation beyond its extent of protected areas (Hauck et al., 2013). They could potentially contribute largely to environmental planning and management (von Haaren & Albert, 2011).

The valuation of these benefits bears various challenges and to date remains controversial within the research community. Though the Millennium Ecosystem Assessment (2003) proclaims very broad terms of ecosystem service value as "the contribution of an action or object to user-specified goals, objectives, or conditions", allowing for ecological, economic or social interpretations (de Groot et al., 2010, Chapter 1; Gomez-Baggethun & Groot, 2010), the ecological and economic value domains prevail over social implications in ecosystem services valuation applications (Nieto-Romero, Oteros-Rozas, González, & Martín-López, 2014; Sherrouse, Semmens, & Clement, 2014; Vihervaara, Rönkä, & Walls, 2010).

The monetary valuation of ecosystem services, often referred to as "economic valuation", is found to be limited due to methodological uncertainties. Not all services provided by ecological systems are marketable goods that directly imply a monetary value. Non-utilitarian benefits (mostly provided by regulating and cultural services) are often assessed with indirect valuation approaches (Chan et al., 2012). These methods are commonly applied where there are no explicit markets for services (de Groot, Wilson, & Boumans, 2002). Methods of indirect revealed preferences often fail to reveal the full value of ecosystem services or provide only lower bound value indications respectively, especially if the service lacks an adequate proxy (cf. Daily et al., 2000). Also the validity of stated preference methods (Hausman, 2012; Kahneman & Knetsch, 1992), incommensurability, and the dynamics of people's values (Satz et al., 2013) are discussed critically. Several authors point out the limitations of monetary valuation of ecosystem services and suggest to explore different valuation methods to match the broad diversity of values (Baveye, Baveye, & Gowdy, 2013; Chan, Satterfield, & Goldstein, 2012; Kumar & Kumar, 2008; Martín-López et al., 2012; Quintas-Soriano et al., 2016).

Though it may not be the focus of the better part of valuation endeavors, the consideration of social benefits of ecosystem services is subject to a variety of studies. Chan et al. (2012) propose a framework that allows for the valuation of ecosystem services in general and that is particularly attentive to complications originating from cultural values and benefits, e.g. the intangibility of values, ecological and social change, etc. Other studies confirm the correspondence of social benefits and cultural ecosystem services (Daniel et al., 2012; Sherrouse et al., 2014). Bryan, Raymond, Crossman, and Macdonald, (2010) conduct a study on environmental management and identify areas with social values for ecosystem services of high abundance, diversity, rarity and risk. Furthermore, Sherrouse, Clement, and Semmens (2011) provide a GIS-based tool, i.e. Social Values for Ecosystem Services (SolVES), to assess, map, and quantify the perceived social values of ecosystem services by deriving a non-monetary Value Index from responses to a public attitude and preference survey. Scholte, van Teeffelen, and Verburg (2015) provide an overview of methods which assess socio-cultural values of ecosystem services in recent studies. Other research directly addresses current policy implementation, such as the European Landscape Convention, where the social valuation of residents largely contributes to the landscape character assessment (Baas, Groenewoudt, & Raap, 2011). Terminology of ecosystem benefits and values has previously been applied inconsistently, using the terms “cultural values and benefits”, “social values”, and “cultural ecosystem services”.

In this study, we aim to provide very clear definitions and interpretations of benefits, values, social valuation, and human well-being. Benefits, here also referred to as social benefits, represent the final outputs from ecosystems that directly affect human well-being (Haines-Young & Potschin, 2013b), see Chapter 3.4.1. Values can either refer to cultural ideas about what are desirable goals and appropriate standards for judging actions (held values) or to the relative importance that people assign to objects (in this study: to benefits provided by ecosystem services) by rating or ranking them (assigned values) (Brown, 2002; Rokeach, 1973). In this study, we refer to ecosystem service values in terms of the latter interpretation, namely the relative importance that people assign to benefits provided by ecosystem services, typically in monetary units, rating or ranking schemes. Social valuation describes the act of the valuation by people as opposed to using extant proxies, such as market values or costs. Benefits and values of ecosystem services are the key focus of the study. Human well-being is generated by access to the basic materials of a good life required to sustain livelihoods, sufficient food, shelter and access to goods, as well as health, good social relations and freedom of choice and action (MA, 2003), all of which social benefits of ecosystem services contribute to. Thus, benefits link ecosystem services closely to human well-being, because they specify in what ways humans benefit from ecosystem services (e.g. therapeutic benefits, economic benefits, see Table 3.1). In the next step, which has commonly been conducted in ecosystem service research without necessarily referring to individual benefits, the value assigned to these benefits is quantified. These values are described in either monetary (e.g. costs, willingness to pay (WTP), market prices) or non-monetary (e.g. rating, ranking) measures of relative importance to individuals or society. Identification of benefits as well as the quantification of their value is frequently referred to as the process of valuation in ecosystem service research, with benefits often only indirectly addressed. We aim to contribute to a better link between ecosystem services and human well-being that essentially will lead to an equal integration of economic, ecological and social issues within environmental management and planning.

Table 3.1: Social benefit types considered in this study

Social benefit type	Description	Examples	Literature
Therapeutic	The provision of medicines, clean air, water and soil, space for recreation and outdoor sports and general therapeutic effects of nature on people's mental and physical well-being	- Health services - Restorative and regenerative effects on people - Socio-economic benefits from reduced health costs and conditions	De Groot et al. (2003), Brown (2005; Turner et al., 2003)
Economic opportunities	to provide a work place, income, economic opportunities	- Provision of work place, income, economic opportunities	Brown and Reed (2000)
Amenity	Importance of nature for cognitive development, mental relaxation, artistic inspiration, aesthetic enjoyment and recreational benefits	- Aesthetic quality of landscapes - Recreational use - Artistic use	De Groot et al. (2003), Brown and Reed (2000)
Heritage	Importance of nature as reference to personal or collective history and cultural identity, also for educational purposes	- Historic sites and features - Role in cultural landscapes - Cultural traditions and knowledge - Education	De Groot et al. (2003), Brown and Reed (2000)
Spiritual	Importance of nature in symbols and elements with sacred and religious significance	- Sacred sites and features - Role of nature in religious ceremonies and sacred texts	De Groot et al. (2003), Brown and Reed (2000)
Existence	Importance people because they obtain moral satisfaction by conservation of biodiversity (intrinsic value)	- Expressed (through donations, voluntary work, etc.) or stated preference for nature protection - Moral satisfaction through conservation and the "warm glow effect"	De Groot et al. (2003), Brown and Reed (2000) Turner et al. (2003) Kahneman and Knetsch (1992)
Option	Importance people attach to having the option to use ecosystem services in the future, within their own lifetime	- Comfort of having the option to use ecosystem services at a later time in their lives	De Groot et al. (2010b)
Bequest	Importance people attach to nature for inter-generational equity	- Comfort of knowing ecosystem services will be available for future generations	Brown and Reed (2000)

In order to tie the benefits of ecosystem services better to human-wellbeing, this study explores how social benefits have been addressed in ecosystem service valuation studies published since the release of the Millennium Ecosystem Assessment in 2005. What typical benefits have been identified for ecosystem services? Have these been explicitly addressed in valuation studies? What ecosystem services, valuation techniques and research designs are they usually associated with? To this effect, we develop a typology for ecosystem service benefits adapted from conceptual ecosystem services literature that we found to cover all social benefits derived from the subsequently reviewed primary valuation studies. Further, we develop hypotheses on the relationship between social benefits and the assessment practice of ecosystem services based on conceptual and empirical ecosystem service literature. These hypotheses are then tested based on the coded evaluation of 115 valuation studies published between 2005 and 2014. To do so, we phrased four hypotheses that arise from current research opinions and their implications for social benefits in ecosystem service valuation (Section 3.2). We lay out our methods (Section 3.3) to establish a clear link between ecosystem services and human well-being. We tested how social benefits are linked to ecosystem service types, cultural ecosystem services, valuation techniques and directly addressing stakeholders (Section 3.4). Finally, the results of the analysis, together with implications of the used method and conclusions for further research are drawn (Section 3.5).

3.2 Hypotheses

Considering conceptual and empirical insights from recent ecosystem service research, we put forward four hypotheses regarding the relationship between social values, ecosystem service types, particularly cultural ecosystem services, valuation techniques and directly approaching stakeholders.

H 1

Social benefits (see Section 3.1) are mostly considered in studies that assess cultural ecosystem services, as opposed to provisioning, supporting or regulating ecosystem services.

Whereas social constructs by definition underlie all ecosystem services, it is argued that cultural ecosystem services rely on them to a greater degree (Daniel et al., 2012). Moreover, non-marketed cultural ecosystem services are associated with intangibility, incommensurability and scaling issues (Chan, Satterfield et al., 2012; Satz et al., 2013) and are considered less susceptible for economic indicators (Carpenter et al., 2009; Martín-López, Gómez-Baggethun, Lomas, & Montes, 2009). These studies are bound to employ alternative valuation approaches in order to assess cultural ecosystem services that leave more room for the assessment of social benefits. It is thus assumed that studies are more likely to value social benefits when cultural ecosystem services are assessed than when provisioning, regulating or supporting services are reviewed.

H 2

There is a typical pattern of social benefits and cultural ecosystem services explored in combination (see Section 4).

It is further observed, that cultural ecosystem services, which essentially assemble cultural values, benefits and services in numerous classifications, frequently overlap with social and cultural benefits, e.g. aesthetics contribute to recreational leisure experiences, recreation and tourism can trigger physical exercise and intellectual stimulation, both contributors to health (Chan, Satterfield et al., 2012; Daniel et al., 2012). Referring to Haines-Young and Potschin (2013b), we support the distinction between cultural ecosystem services and social benefits with cultural services “covering all non-material outputs of ecosystems that affect physical and mental states of people” whereas social benefits relate to “things that people create or derive from final ecosystem services (e.g. products, experiences)”. Hence, we argue that the assessment of social benefits co-occur in studies that derive non-material, cultural ecosystem services, in this study based on the TEEB typology (2010). We expect to identify pairs of cultural ecosystem services and social benefits that frequently appear together.

H 3

Monetary valuation techniques go beyond expressing monetary values and also convey social benefits.

Recent ecosystem service research emphasizes that the valuation of ecosystem services is heavily dependent upon the valuation method employed and that ecosystem service value is not a robust figure (Spangenberg & Settele, 2010). Valuation approaches, including monetary techniques, reflect “perceived realities, worldviews, mind sets and belief systems” and thus are thought to be heavily dependent on social, cultural and economic contexts (Kumar et al., 2013). Some authors find the results of monetary assessments (i.e. willingness to pay) to a bigger extent resemble attitudes or social preferences than economic preferences (Castro et al., 2011). We assume that monetary values derived by monetary valuation methods, such as contingent valuation, choice experiments, replacement costs and even hedonic prices and market prices have potential to go beyond expressing monetary measures and also convey social benefits expressed in monetary terms.

H 4

Directly incorporating the view of stakeholders supports the consideration of social benefits in ecosystem service assessments

Ecosystem service assessments typically rely on stakeholder engagement to inform on critical management decisions, to develop scenarios to estimate future change or to derive stakeholder preferences and values (Daily et al., 2009). It is assumed that representative individuals as well as small groups of citizens can pass informed judgments about public goods and services not merely in terms of personal utility, but representing widely held social values (Wilson & Howarth, 2002). In this study, we distinguish between studies that address stakeholders within case study regions to assess their (stated) values (e.g. surveys, workshops, interviews), and studies that rely on extant data (e.g. market prices, costs) as a proxy for social value. In the following, we subsume experts, land managers, decision-makers, sensu stricto stakeholders, users and the affected public under the term “stakeholders”. Thus, we hypothesise that the assessment of social benefits correlates with directly addressing stakeholders to elicit their views.

3.3 Methods

3.3.1 Development of an integrated classification for social benefits of ecosystem services

Human well-being has been found to be linked to five key components: the necessary material for a good life, health, good social relations, security and freedom and choice (MA, 2003). Whereas good social relations (social cohesion, mutual respect, good family relations, etc.) and freedom and choice (having control over what happens, etc.) are less attributable to social benefits provided by ecosystems, material for a good life, health and security are dimensions that generate multiple benefits supplied by ecosystems and their services.

Building on current classifications of benefits of ecosystem services (Brown, 2005; Brown and Reed, 2000; De Groot, Van der Perk, Chiesura, & van Vliet, 2003; Kahneman and Knetsch, 1992; Turner et al., 2003), we developed a typology of benefits to describe how ecosystem services improve human well-being. We reviewed the range of benefits covered by the existing classifications, each of them with their specific foci, and combined them to an integrated typology of social benefits of ecosystem services. Brown and Reed (2000) and Brown (2005), for instance, classify forest values to assess preferences and attitutes towards forest management, clearly associating a social benefit with each value type. Then, De Groot et al. (2003) classify social criteria to measure the criticality of natural capital while largely overlapping with Brown's forest values, while Turner et al. (2003) and Kahneman & Knetsch (1992) provide insight into mostly economic concepts of existence value. While these classification schemes frequently refer to the term social "values", we adapt and use them for our classification of social benefits of ecosystem services. As explained above, we refer to the term "value" as an assigned measure of relative importance (monetary, rating, ranking) of a benefit rather than to the effect on human well-being itself. Merging the existing classification schemes allowed us to broaden the scope of benefits to be identified.

3.3.2 Case survey method

We make use of the case survey method, which combines qualitative and quantitative techniques and has been employed for meta-analyses in policy research for several years (Larsson & Finkelstein, 1999; Newig & Fritsch, 2009; Yin & Heald, 1975). The method is used to review primary research and its significant findings and is thought to work well when the research consist of a heterogeneous collection of case studies (Yin & Heald, 1975). As case survey method allows to aggregate individual case studies' characteristics with scientific rigour, without necessarily comprising their conclusions, it provides a suitable approach to review which characteristics of ecosystem service valuation studies determine the comprehension of social benefits.

The case survey method draws on existing published case studies according to following procedure (Larsson, 1993): first, a group of existing case studies relevant to previously determined research questions is selected (Section 3.3). Next, a coding-scheme for the systematic recording of case study variables is designed (Section 3.4) which is then applied to the group of selected studies. Whereas Larsson (1993) suggests to measure interrater reliability of multiple raters, we had two raters discuss discordant cases. The coded information was subsequently statistically analysed in regard to the research questions (Section 3.5). As case surveys review several individual case studies, they are thought to combine advantages of both case-based and cross-based research (Newig & Fritsch, 2009).

3.3.3 Selection of studies

To evaluate the consideration of social benefits within ecosystem service valuation research, we conducted a literature search using Thomson Reuters' search engine Web of Knowledge mid May 2014 (cut-off date 13 May, 2014). Keywords were defined to select studies regarding the valuation of ecosystem services (topic: "ecosystem service*" AND "valuation"). In total, 1089 publications were retrieved from the Web of Knowledge database published between 2005 and 13 May 2014. These studies were qualitatively reviewed in terms of their content, selecting empirical; primary studies in which the authors performed an assessment of ecosystem services for further review. Studies using value proxies derived by meta-analysis or benefit/value transfer as well as conceptual contributions and reviews were discarded. Duplicates; grey literature and non-English studies were also omitted from the review. Ecosystem services of the reviewed studies had to roughly comply with the classifications of the MA, TEEB or CICES classification of ecosystem services (Haines-Young & Potschin, 2013a; MA, 2003; TEEB, 2010). The valuation of ecosystem services did not have to be the main focus of the study. As a result, of the initially retrieved studies, 115 studies were found to contain a self-consistent primary valuation of ecosystem services and were therefore selected for the detailed analysis (see Appendix 1).

3.3.4 Coding scheme to evaluate primary studies

Information was extracted from these 115 papers. They were screened individually in terms of basic information on the year of publication, the study area and several features that relate to our hypotheses (ecosystem service categories, cultural ecosystem services, valuation approaches, consideration of social benefits, involvement of stakeholders; see Table 3.2).

Table 3.2: List of variables considered in this research and the corresponding codes

Variables	Description	Codes (binary)
Year of Publication	Year that study was published	
Study area	Continent and country that the study area was located in	
Ecosystem services categories	Ecosystem services were derived from the reviewed studies and subsequently divided into the ES categories (MA, 2003)	Provisioning services, regulating services, supporting services, cultural services
Cultural ecosystem services	To examine the correlation between social benefits and the assessment of cultural ecosystem services (TEEB, 2010)	Recreation and tourism, spiritual experience, aesthetic appreciation, inspiration, cultural heritage, sense of place
Valuation techniques	Valuation methods contain monetary and non-monetary methods (Christie et al., 2012)	Market price, cost-based methods, hedonic pricing, travel cost analysis, contingent valuation methods (CVM), choice experiments, deliberative methods, social ranking, social rating
Social benefit types	Social benefits, the final outputs from ecosystems that directly affect the well-being of people, were derived from the reviewed studies (see section 4.1 for a closer description).	Therapeutic, economic opportunities, amenity, heritage, spiritual, existence, option, bequest benefits
Involvement of stakeholders	We distinguish between studies that engage the public or stakeholders in their valuation (e.g. surveys, workshops) and studies that rely on existing data (e.g. market prices, costs)	Stakeholders, experts, land managers, decision-makers, users, affected public

3.3.5 Data analysis

In our analysis, one study corresponds to one dataset. One dataset may therefore assess multiple ecosystem services, value multiple benefits and use numerous valuation techniques.

In order to test the hypotheses and to explore the likeliness that social benefit types were determined in the studies, four types of general linear models (GLM) were fitted to the data using the R environment for statistical computing (R Core Team, 2013). The models aimed at predicting the conditional probability for each of the social benefit types that have been investigated in the studies in dependency of (i) the ecosystem service types, (ii) the cultural ecosystem services, (iii) the used monetary and non-monetary valuation techniques, and (iv), whether or not stakeholders had been directly addressed in the studies.

Since all dependent variables and explanatory variables were binary (present or not present in the study) the GLMs were calculated with binomial error distribution and a logit link function resulting in multiple logistic regressions for the first three models and logistic regression for the investigation of directly addressing stakeholders. Relevant predictors which should be included in the models were identified by applying stepwise backward model selection according to Venables and Ripley (2002), choosing the models with the smallest AIC as best model. Peng, Lee, and Ingersoll (2002) found logistic regressions appropriate for testing hypotheses about relationships between a categorical outcome variable and one or more categorical or continuous predictor variables. Since the logit is calculated as the logarithm of the odds: $logit(p) = \log\left(\frac{p}{1-p}\right)$, the logistic regression models calculate the log-odds:

$\log\left(\frac{p_i}{1-p_i}\right) = \beta_0 + \beta_1 x_{i1} + \cdots + \beta_n x_{in}$. For easier interpretation of the regression coefficients (β_i) the equation has been exponentiated to retrieve odds ratios:

$\frac{p_i}{1-p_i} = e^{\beta_0} e^{\beta_1 x_{i1}} \ldots e^{\beta_n x_{in}}$. The exponentiated coefficients (the odds ratios) can be read as how much the odds of the social benefit types increased multiplicatively with the presence of the predictor variables (x_i) compared to their absence.

3.4 Results

3.4.1 Integrated classification of social benefits of ecosystem services

Our classification of social benefits includes 8 benefit types that have previously been discussed in literature (Brown, 2005; Brown and Reed, 2000; De Groot et al., 2003; Kahneman & Knetsch, 1992; Turner et al., 2003) and extracted from the reviewed valuation studies according to Table 2. The included benefits are thought to specify in what ways the ecosystem services improve human well-being. Knowledge about these effects therefore strengthens the understanding of the link between human-wellbeing and ecosystems. They range from palpable effects like therapeutic (e.g. health through outdoor activities) and economic benefits (e.g. sustaining one's livelihood by providing an income through fishing) to less tangible benefits like amenity (e.g. mental relaxation through a hike), heritage (e.g.

cultural identity by passing along knowledge and traditions), spiritual (e.g. religious awareness through sacred sites), existence (e.g. moral satisfaction people obtain from conserving a local ecosystem they themselves may never experience) to rather abstract categories like existence, bequest and option benefits. The latter three are often referred to as values rather than benefits. As they describe the moral satisfaction derived from knowing that ecological systems or species are existent (existence), will be available for future generations (bequest) and possibly available for people to experience in the future (option), we include them in our typology of benefits.

Social benefits in the reviewed valuation studies have been assessed through a wide range of monetary and non-monetary methods, i.e. market prices, cost-based methods, hedonic pricing method, travel cost analysis, contingent valuation, choice experiments as well as deliberative, social ranking and social rating approaches.

3.4.2 Overview over primary valuation studies

The number of the selected valuation studies rose exponentially after 2005 with 2 articles published in 2005 and 28 articles in 2013. Three quarters of the reviewed case studies originate in Europe (37%), Asia (24%) and North America (17%). While Africa accounted for 8%, Australia, New Zealand and the Pacific Islands for 7% and South America for 6%. One study was a global assessment. In terms of study areas, most case studies were conducted in the USA (15%) and China (14%), followed by Spain (10%).

Of the reviewed studies, cultural ecosystem services were assessed most frequently (65%), followed by regulating (62%), and provisioning services (56%). Supporting services were assessed by roughly one third (34%) of the studies (Figure 3.1a). Studies that explored cultural, provisioning and regulating services had increased significantly since 2009 and 2010, the number of studies that assessed supporting services was on the rise since 2012. The majority of studies conducted an assessment of more than one ecosystem service type (63%). If a study focused on only one type of ecosystem service, they most frequently focused on cultural ecosystem services (17%), followed by regulating (11%), provisioning (6%) and supporting (2%) services. 13% of the reviewed articles accounted for all four ecosystem services types and 12% assess provisioning, regulating and cultural ecosystem services in their case studies.

The selected studies valued a broad range of cultural ecosystem services (Figure 3.1b). More than half of the studies assessed values for recreation and tourism services (57%) while one quarter assessed values for the aesthetic appreciation of landscapes (26%). Less often assessed were science and education services (16%), cultural heritage (12%), sense of place (9%), spiritual experience (7%) and inspiration (4%).

Regardless of the ecosystem service type assessed, 76 of the selected studies (66%) explicitly refer to social benefits (Figure 3.1c). The remaining 34% of the studies assessed values for ecosystem services without associating them in the wider context of human-wellbeing, thus

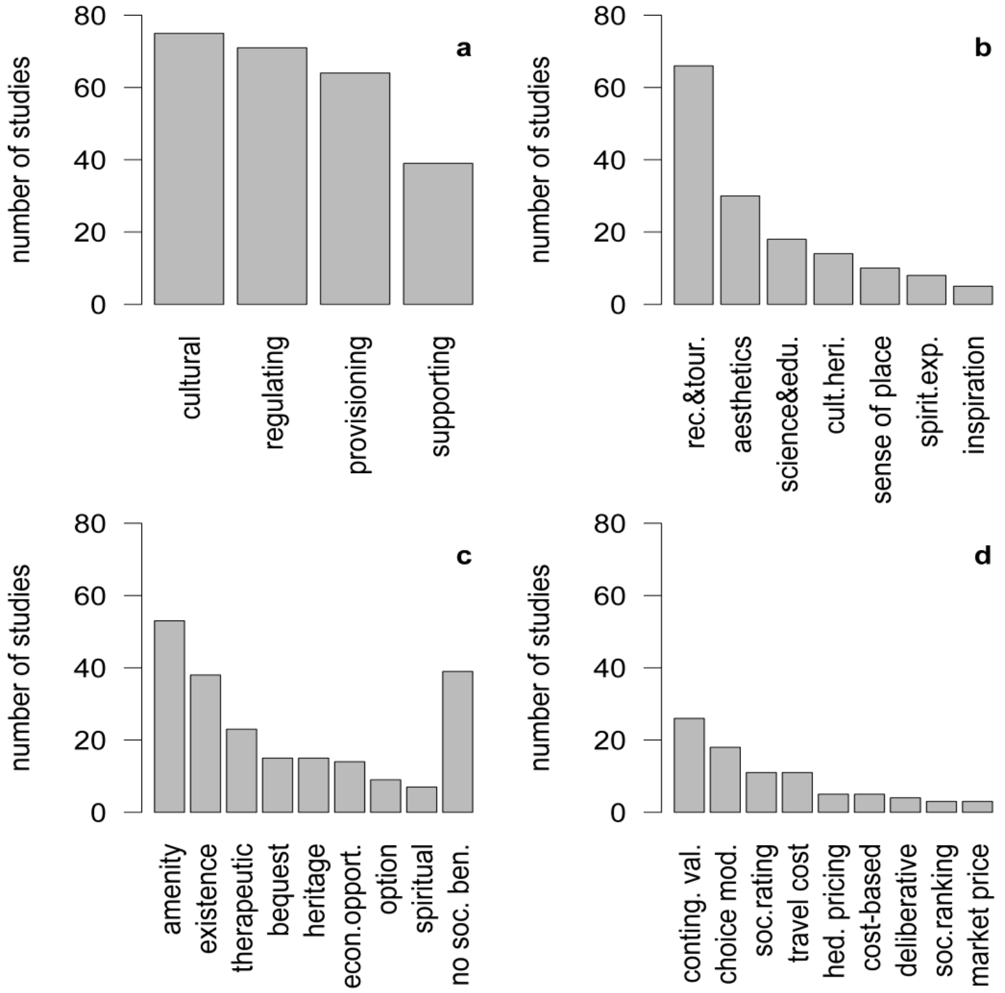

Figure 3.1 Number of studies a) per ecosystem service types, b) per cultural ecosystem services, c) per social benefits and d) per valuation techniques to derive social benefits.

without specifically addressing social benefits. Almost one half of the 115 reviewed studies derived amenity benefits (46%) and nearly one third evaluated existence benefits (29%). Therapeutic benefits (20%), heritage benefits and bequest benefits (both 13%) as well as the benefit of economic opportunities (12%) were evaluated less often. Option values (8%) and spiritual benefits (6%) were assessed in less than 10 articles each. Most articles derived only one social benefit in their case studies, the most frequent combination of social benefits derived being amenity and existence benefits that were explored in seven of the reviewed studies.

To derive values for these social benefits, 79% the social benefit deriving studies used monetary approaches, only 16% made use of non-monetary social approaches, 5% mixed monetary and non-monetary methods. When taking a closer look at the types of valuation methods (Figure 3.1d), contingent valuation methods (willingness to pay, willingness to invest, etc.) were employed most frequently (34%), followed by choice experiments (24%), social rating approaches (14%) and travel cost analysis (14%). Methods that were less often employed were hedonic pricing (7%), cost-based approaches (7%), deliberative approaches (5%), social ranking (4%) and market price approaches (4%).

3.4.3 Case-survey of the integration of social benefits

Hypothesis 1

Social benefits are mostly considered in studies that assess cultural ecosystem services, as opposed to provisioning, supporting or regulating ecosystem services.

In an attempt to explore the link of ecosystem service types and the valuation of social benefits, we found that social benefits are abundant across provisioning, regulating, supporting and cultural ecosystem services, yet vary under the ecosystem service type assessed (Figure 3.2).

The results suggest that social benefits were mainly assessed within studies that value cultural ecosystem services, particularly amenity benefits. Spiritual benefits are inextricably linked to the valuation of cultural ecosystem services, as they only appear in studies that also examine cultural ecosystem services. The number of studies that assess social benefits is altogether lower in studies that do not assess cultural ecosystem services.

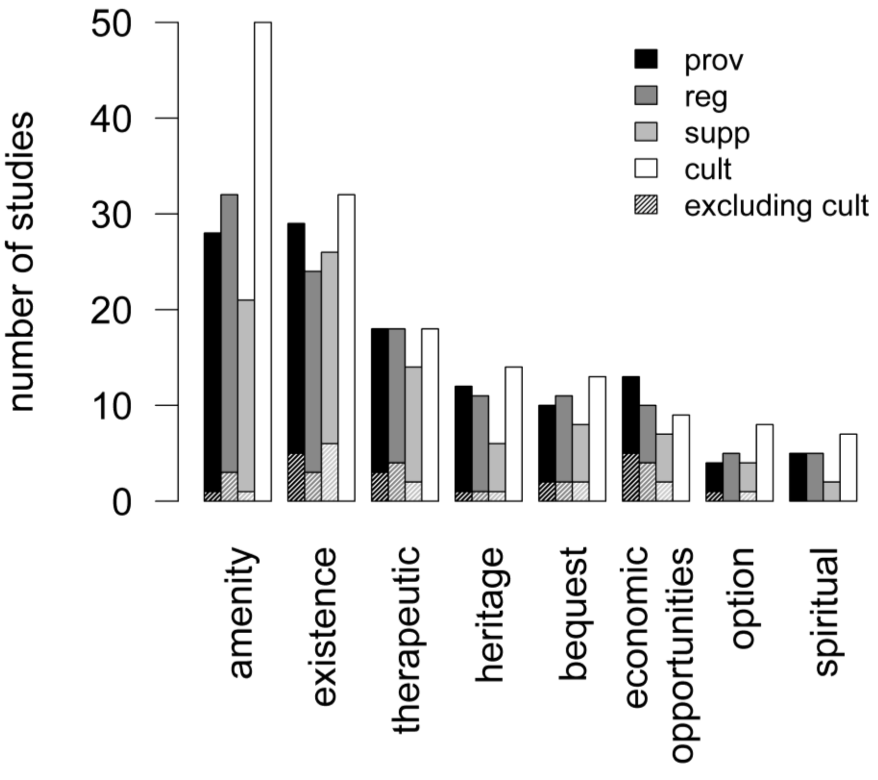

Figure 3.2 Number of studies that assess social benefits according to ecosystem service type. Bars with cross-hatching represent a subset of the studies that do not include the assessment of cultural ecosystem services (no cult).

Similarly the logistic regression shows (Table 3.3) that four social benefits types are significantly related to the assessment of cultural ecosystem services. Studies addressing supporting and provisioning services show significant results for two types of benefits each. Chances that therapeutic benefits were derived were 3.3 times higher when supporting services were valued ($p < 0.05$) and additionally 6 times higher when also provisioning and regulating services were valued (Table 3.3). The odds to assess heritage benefits were just over 9 times higher for studies when cultural ecosystem services were explored and collectively 36.3 times higher when also provisioning services were assessed ($p \leq 0.05$). Results further indicate that the assessment of amenity benefits were more likely with the valuation of only cultural ecosystem services (odds ratio = 24.7, $p < 0.05$). Chances to derive existence values increase with simultaneous consideration of cultural, provisioning and supporting ecosystem services, altogether odds = 195 ($p < 0,05$). Our findings further suggest a significant link between the assessment of economic opportunities and cultural ecosystem services (odds ratio = 12.7, $p < 0.05$). For instance, Butler, Radford, Riddington, and Laughton (2009) estimate the economic impact of recreational rod fisheries for four salmon and trout species in north-east Scotland. In our analysis, we found no significant influence between ecosystem service type and spiritual, option and bequest benefits.

Table 3.3. Odds ratios of the best logistic regression models of social benefits and ecosystem service types after stepwise backward model selection. Each line represents a model for the social benefit type in the first column. The following columns represent the predictors. Empty cells indicate that the predictor was not included in the best model. Coefficients in bold font were significant with p<0.05.

Ecosystem service types / Social benefit types	cultural Odds ratios	provisioning Odds ratios	supporting Odds ratios	regulating Odds ratios	Intercept Odds ratios	AIC
therapeutic		2,68	**3,32**	2,24	**0,04**	108,35
heritage	**9,35**	**3,88**			**0,01**	82,96
amenity	**24,67**				**0,08**	120,79
spiritual	3,2E+07				3,2E-03	50,53
existence	**5,80**	**3,05**	**11,06**		**0,03**	108,60
economic opportunities	**12,74**				**0,02**	78,45
option	4,66				**0,03**	64,28
bequest	3,85		2,45		**0,04**	88,59

The model with maximal possible number of predictors was:

$$\mathbf{logit}(\boldsymbol{social\ benefit\ type}) = \boldsymbol{\beta_1 cultural + \beta_2 provisioning + \beta_3 supporting + \beta_4 regulating + \beta_0}$$

Our results provide evidence that social benefits are linked to the assessment of cultural ecosystem services to a greater degree than to provisioning, supporting or regulating services. Significant influence was found for 4 of the 8 social benefit types analysed. However, significant correlations could also be found in respectively two combinations of social benefit types and provisioning and supporting ecosystem services. These findings indicate that the assessment of social benefits is not only significantly linked to cultural ecosystem services but that social benefits are abundant across three ecosystem service types. Only the valuation of regulating services revealed no significant link to the elicitation of social benefits. Furthermore, high odds to derive social benefits when only one or two ecosystem service types were assessed suggest that certain social values are linked to the assessment of certain ecosystem services. This will be further explored within the next section.

Hypothesis 2

There is a typical pattern of social benefits and cultural ecosystem services explored in combination.

We analysed whether studies that contained individual cultural ecosystem services show a higher probability to consider certain social benefits than others. We included recreation/tourism, spiritual experience, aesthetics, science and education, inspiration, cultural heritage and sense of place as cultural ecosystem services according to TEEB (2010).

Table 3.4 Odds ratios of the best logisitic regression models of social benefits and cultural ecosystem services (after TEEB, 2010) after stepwise backward model selection. Each line represents a model for the social benefit type in column one. The following columns represent the predictors. Empty cells indicate that the predictor was not included in the best model. Coefficients in bold font were significant with p<0.05.

Cultural ecosystem services / Social benefit types	recreation/ tourism	spiritual experience	aesthetics	science/ education	inspiration	cultural heritage	sense of place	Intercep t	AIC
	Odds ratios	Odds ratios	Odds ratios	Odds ratios	Odds ratios	Odds ratios	Odds ratios	Odds ratios	
therapeutic				**3,98**	**16,67**			**0,16**	106,96
heritage			10,94			8,3E+09	1,2E-02	**0,007**	28,973
amenity	**4,08**		**6,23**				3,87	**0,22**	133,51
spiritual				7,8	**60**	**29,11**		**0,003**	27,76
existence	**3,25**						2,77	**0,21**	141,1
ec. opportunities						3,64		**0,11**	85,98
option	4,87					**10,18**	2,2E-02	**0,02**	57
bequest						**7,67**		**0,1**	83,82

The model with maximal possible number of predictors was:

$$\mathbf{logit}(\boldsymbol{social\ benefit\ type}) = \boldsymbol{\beta_1 recr} + \boldsymbol{\beta_2 spirit} + \boldsymbol{\beta_3 aest} + \boldsymbol{\beta_4 science} + \boldsymbol{\beta_5 insp} + \boldsymbol{\beta_6 cult} + \boldsymbol{\beta_7 place} + \boldsymbol{\beta_0}$$

In our analysis, we found that a number of social benefit types are more often investigated when the reviewed studies also assessed cultural ecosystem services (Table 3.4). The assessment of amenity benefits was found 6 times more likely if aesthetic appreciation was valued and collectively even 25 times more likely if also recreation and tourism were valued. Sherrouse et al. (2011) for instance derived amenity benefits for the aesthetic appreciation of an area by having survey respondents first allocate points and then map areas where they see these provided. Liu, Crossman, Nolan, and Ghirmay (2013) performed a social rating exercise estimating the amenity benefits of recreation and tourism, sense of place as well as aesthetic appreciation in a sub-catchment of the Murray–Darling Basin in Australia.

Therapeutic benefits co-occured in studies that assessed science/education (odds ratio = 4) and inspiration (odds ratio 16.7; both $p < 0.05$). Larson, Stoeckl, Neil, and Welters (2013) for instance used a mail-out survey to assess therapeutic benefits of the provision of drinking water next to teaching/learning benefits and inspiration benefits of the Australian tropical rivers. Another study conducted a valuation of therapeutic benefits (flood prevention, enhanced water quality and pest control) provided by home gardens in the Catalan Pyrenees, while also assessing the social benefits of inspiration for culture, art and design and the maintenance of traditional ecological knowledge (Calvet-Mir, Gómez-Baggethun, & Reyes-García, 2012).

Our results suggest, that existence values are 3 times more likely to be derived when recreation and tourism is being assessed ($p = 0.05$). Wakita et al. (2014) for instance measured the indispensability of marine ecosystem services by assessing existence values ("Because the sea exists, life continues and nature is sustained") next to amenity values for recreation ("Without recreational opportunities such as swimming, diving, and surfing, our recreation opportunities would be far less interesting").

We found that the assessment of spiritual benefits is more likely when science and education, inspiration ($p < 0.05$) and cultural heritage ($p < 0.05$) are valued as ecosystem services. As an example, one study assessed spiritual benefits for spiritual services and sense of place provided by the water resources of the Murray-Darling basin in Australia, while also assessing aesthetic appreciation and cultural inspiration (Liu et al., 2013).

Further we found that the odds to assess bequest and option benefits rose within the valuation of cultural heritage. Zander and Straton (2010) for instance used the condition of waterholes and their importance to aboriginal people as a proxy to assess the existence and bequest value of Australia's tropical rivers for urban Australians. We were unable to identify any of the tested cultural ecosystem services as significant predictors for the elicitation of heritage benefits and the benefit of deriving economic opportunities.

Hypothesis 3

Monetary valuation techniques go beyond expressing monetary values and also convey social benefits.

Next, we tested the co-occurrence of social benefits and the employment of monetary valuation techniques. Monetary valuation techniques include market prices, cost-based approaches, hedonic pricing, travel cost analysis, contingent valuation and choice experiments if they include monetary measures. Non-monetary valuation techniques comprise deliberative techniques next to social rating and social ranking approaches.

Table 3.5 Odds ratios of the best logistic regression models of social benefits and monetary and non-monetary valuation techniques after stepwise backward model selection. Each line represents a model for the social benefit type in column one. The following columns represent the predictors. Empty cells indicate that the predictor was not included in the best model. Coefficients in bold font were significant with the predictors.

Val. techniques / Social benefit types	Market-based approaches		Surrogate market approaches		Simulated market approaches		Non-monetary approaches			Intercept	AIC
	Market price	Cost based	Hedonic pricing	Travel costs	Contingent valuation	Choice experiment	Delibe-rative	Social rating	Social ranking		
	Odds ratios	Odds ratios	Odds ratios	Odds ratios	Odds ratios	Odds ratios	Odds ratios	Odds ratios	Odds ratios	Odds ratios	
Therapeutic					**11.06**	**12.44**		**343.16**	11.65	**0.03**	78.89
Heritage	6.1E-02	16.02			**24.48**	**27.61**		**370.93**	38.98	**5.4E-03**	65.31
Amenity	9.6E-11		6.6E+09	5.4E+09	**27.32**	**21.07**	1.1E+09	3.8E+09		**0.05**	85.92
Spiritual					1.1E+08			4.9E+08		1.2E-03	39.02
Existence	2.1E-02	18.71			**125.09**	**130.84**		**108.85**	9.2E-03	**0.02**	88.83
Ec. opportunities	3.8E+09	20.17			**14.13**	**29.08**		**184.75**		**0.0054**	60.51
Option					4.76	**5.91**			9.27	**0.03**	63.51
Bequest					**18.23**	**22.69**		**40.21**		**0.01**	76.55

In our analysis we found that simulated market approaches such as contingent valuation and choice experiments correlate significantly with a wide range of social benefits (see Table 3.5). Contingent valuation derives indirect monetary values (passive use values) of environmental services by estimating people's willingness to pay, or the cost of actions they are willing to accept, to avoid the unfavourable effects that would occur if these services were suspended. Studies that employed contingent valuation frequently derived existence values, e.g. for marine biodiversity and species conservation (Chen, Chuang, Jan, Liu, & Jan, 2013), to improve coral reef quality (Madani, Ahmadian, Khalili, Araghi, & Rahbar, 2012), for the protection of a special protected area (Cruz, Benedicto, & Gil, 2011). Other studies assessed therapeutic benefits, e.g. by eliciting people's WTP for health benefits provided by a project that prevents a local lake from further degradation and enhancement of basic environmental infrastructure (Wang, Shi, Kim, & Kamata, 2013), maintained by the UK Biodiversity Action Plan via a choice experiment (Colombo, Christie, & Hanley, 2013), or economic opportunities, e.g. by measuring the value of an area of agricultural land change required to keep agricultural provision as a basic industry in the Kushiro watershed in Japan (Shoyama, Managi, & Yamagata, 2013).

In our analysis, market-based (market price, cost-based methods) as well as surrogate market approaches (travel cost analysis, hedonic pricing) did not or without significant frequency occur in studies that address social benefits. In contrast, we found that all of the 16 studies that used non-monetary approaches also assessed social benefits, social rating being the method connected with highest odds ratios to the most social benefit types.

Hypothesis 4

Directly incorporating the view of stakeholders supports the consideration of social benefits in ecosystem service assessments.

In order to determine whether methods that include public engagement lead to a more frequent consideration of social values in ecosystem service assessments, we compared studies that directly addressed stakeholders or the public in their study design and studies that used proxy-based methods.

We found that social benefits were assessed in studies that included stakeholders a lot more frequently than in studies that applied proxy-based methods (e.g. market based and hedonic pricing methods) (Figure 3.3). Of the 66% of the studies that assessed social benefits, 84% addressed the views of stakeholders directly in their valuation by employing travel cost analysis, deliberative methods, contingent valuation and choice experiments and social ranking and rating approaches. Heritage and spiritual benefits and bequest values have been derived only in studies that directly approached stakeholders. In contrast, therapeutic, amenity, existence and option values as well as economic opportunities were also assessed in studies that did not address them directly. For instance, Chen, Li, and Wang (2009) estimated amenity values by conducting a combination of GIS-based accessibility and viewshed (visibility) analysis, forgoing public participation. Similarly, Morri, Pruscini, Scolozzi, and Santolini (2014) estimated therapeutic values of drinking water supply by forests of a river basin by multiplying the forests' water retention capacity and market prices.

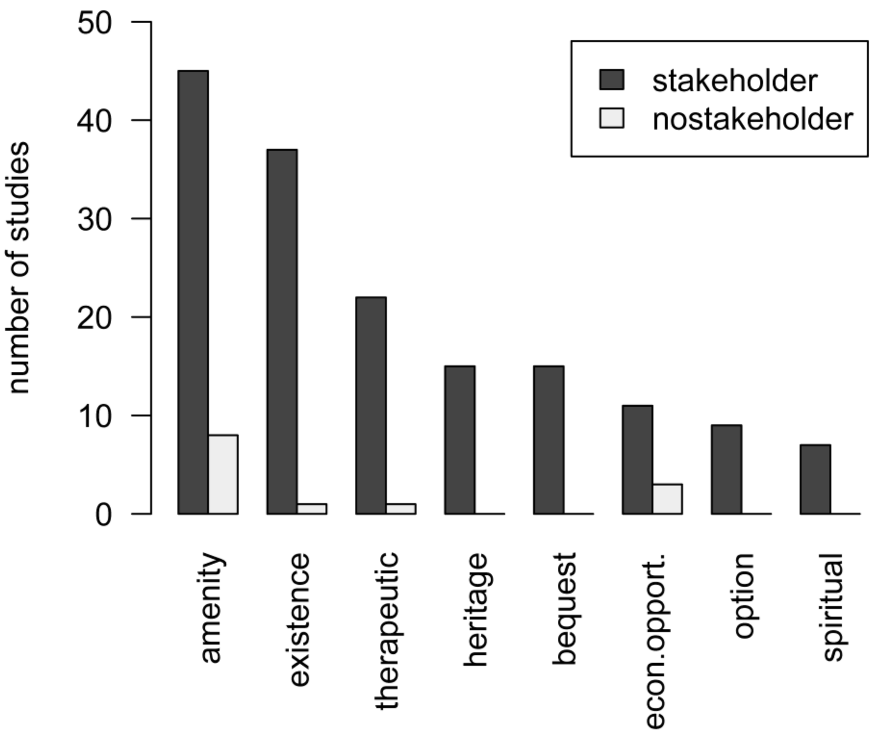

Figure 3.3. Number of studies that assess social benefits based on stakeholder participation

Further analysis showed that studies that address stakeholder values directly are significantly more likely to assess therapeutic, amenity and existence values (Table 3.6). Particularly existence values were more likely to be derived when the public or stakeholders were integrated in the study, e.g. by estimating WTP towards the preservation of a threatened area (Mmopelwa & Blignaut, 2006; Wang et al., 2013), by deriving the perceived importance of preserving an ecosystem with social rating (Larson et al., 2013; Wakita et al., 2014) or choice experiments (Cerda, Ponce, & Zappi, 2013; Zander, Parkes, Straton, & Garnett, 2013). Amenity values were assessed for instance through a mix of ranking and rating of different stakeholder groups (Hicks, Graham, & Cinner, 2013) or the wider public (Liu et al., 2013) and the WTP of tourists for the provision of recreational opportunities (Chen et al., 2013). Therapeutic values were mostly assessed using contingent valuation (García-Llorente, Martín-López, Díaz, & Montes, 2011; Kaplowitz, Lupi, & Arreola, 2012), social rating (Hicks et al., 2013; Wakita et al., 2014) or choice experiments (e.g. Colombo et al., 2013; Drake, Smart, Termansen, & Hubacek, 2013).

Table 3.6. Odds ratios of the logisitic regression models of social benefits and stakeholder/public participation. Each line represents a model for the social benefit type with stakeholder/public participation as only predictor. Coefficients in bold font were significant with $p < 0.05$.

	Stakeholder/public participation	Intercept	AIC
Therapeutic	**4.9**	**0.07**	99.68
Heritage	9.22E+07	3.17E-03	74.75
Amenity	**3.7**	**0.22**	141.7
Spiritual	1.18E+08	1.17E-03	52.75
Existence	**45.2**	**0.02**	105.2
Economic opportunities	4.7	**0.04**	80.19
Option	7.6	**0.02**	66.34
Bequest	9.22E+07	3.17E-03	74.75

$\mathrm{logit}(social\ benefit\ type) = \beta_1 participation + \beta_0$

Taken together, these results indicate a correlation between the assessment of social benefits and the public/stakeholder participation in the reviewed valuation studies. Our results suggest that within the reviewed body of literature, particular social benefit types, e.g. heritage, spiritual, bequest benefits, have not been assessed without the engagement of stakeholders. Also existence, therapeutic and amenity benefits have been assessed more frequently when the valuation methods were used which directly elicit the stakeholders' views.

3.5 Discussion

3.5.1 The current role of social benefits in ecosystem service assessments

Our review underlines that social benefits are frequently subject to the valuation of ecosystem services. While we confirmed that certain social benefits co-occur with a row of cultural ecosystem services (Hypothesis 2), we also showed that they are abundant across studies that assess either of the four ecosystem service types (Hypothesis 1). Furthermore, simulated market valuation techniques such as contingent valuation approaches and choice experiments were found to explicitly mention social benefits next to deriving monetary values (Hypothesis 3). Lastly, we found that studies that directly address stakeholders, had an increased likelihood of the assessment of social benefits (Hypothesis 4).

This study does not support the assumption that social benefits strictly correlate to the assessment of cultural ecosystem services (Hypothesis 1). In contrast to other recent literature reviews on ecosystem services (Hernandez-Morcillo, Plieninger, & Bieling, 2013; Milcu, Hanspach, Abson, & Fischer, 2013), we include studies that assess provisioning, regulating and supporting services next to cultural ecosystem services in our analysis. We found that social benefits are assessed across all ecosystem service types and significantly overlap with cultural, provisioning and supporting services. Our analysis further suggests a strong link between both provisioning and supporting services and social benefits, indicating the awareness of social implications regarding both provisioning and supporting services. Studies explore existence benefits of the nutrient cycling and habitat function of marine ecosystems (Jobstvogt, Hanley, Hynes, Kenter, & Witte, 2014; Wakita et al., 2014) as well as the awareness of personal benefits of photosynthesis, soil formation and nutrient cycling (Shoyama et al., 2013). As the awareness for personal benefits for supporting services in the latter study was rather high, results indicate a general understanding of ecological processes and their relevance for society. In contrast, studies that assessed regulating services frequently focused on ecosystem functions and processes and did not explicitly link their analysis to social benefits and human-wellbeing (Colloff, Lindsay, & Cook, 2013; Stanley, Gunning, & Stout, 2013; Watanabe & Ortega, 2014).

Though our results suggest numerous relations of social benefits and cultural ecosystem services in the reviewed studies (Hypothesis 2), the aforementioned examples show that this link is not always of direct nature but instead may be caused by the plurality of cultural ecosystem services assessed. Social benefits were found to co-occur in studies that assessed cultural ecosystem services, namely therapeutic benefits and science/education and inspiration, amenity benefits and recreation/tourism and aesthetic appreciation, spiritual benefits and inspiration and cultural heritage, existence benefits and recreation/tourism, option benefits and cultural heritage as well as bequest benefits and cultural heritage. Whereas amenity benefits have been derived directly from recreation/tourism and/or aesthetic appreciation in several studies (Aretano, Petrosillo, Zaccarelli, Semeraro, & Zurlini, 2013; Karjalainen, Marttunen, Sarkki, & Rytkonen, 2013; Liu et al., 2013; Ruiz-Frau, Hinz, Edwards-Jones, & Kaiser, 2013; Sherrouse et al., 2011), therapeutic benefits in contrast were found to be assessed in the same studies that valued science/education or inspiration services without direct causal link (Calvet-Mir et al., 2012; Larson et al., 2013). This finding suggests an inaccuracy resulting from the use of data sets that include multiple services and benefits (see section 3.5.3), while also pointing to a correlation between said cultural ecosystem services and cultural benefits as they have been the simultaneous objects of interest in a number of studies. On the other hand, several expected correlations could not be substantiated by our analysis, for instance between spiritual benefits and the assessment of spiritual experience as a cultural service or heritage benefits and cultural heritage. Other benefit-service pairs were noted but not further examined as they were not immediate subject to our study, e.g. therapeutic values and regulating services by Kaplowitz et al. (2012) or existence values and supporting services by Yao et al. (2014). Further research is required to establish which social benefit types relate to which provisioning, regulating, supporting or cultural ecosystem services.

Similar to what Milcu et al. (2013) find in their review of valuation studies of cultural ecosystem services, our analysis across all ecosystem service types found that monetary methods prevail over non-monetary methods in the assessment of social benefits. A large part of the reviewed studies particularly used simulated market approaches in which values are derived by stated preference techniques such as contingent valuation or choice experiments to value social benefits of ecosystem services. Market-based and surrogate market valuation approaches on the other hand, could surprisingly not be associated with the valuation of specific social benefits. This can partially be explained by the low number of studies that use market-based or surrogate market methods. Whereas simulated market approaches were found suitable to derive monetary values while explicitly assessing social benefits, studies that employed non-monetary techniques such as social ranking, deliberative approaches and social rating indicated a large overlap with the assessment social benefits by a small numbers of studies. Similar to what Wilson and Howarth (2002) found over a decade ago regarding discourse-based methods, we found that non-monetary social valuation methods have yet to be thoroughly applied in the practice of ecosystem service valuation. One of the few examples that use non-monetary techniques is by Agbenyega, Burgess, Cook and Morris, (2009), who conduct a survey with residents that includes a non-monetary rating of various ecosystem services provided by community woodlands, acknowledging therapeutic, amenity and heritage values. As demonstrated by our study, social benefits can generally appear as value constructs that underlie monetary values, i.e. in simulated market approaches, or they can well be valued directly in social valuation exercises, such as rating, ranking or deliberative methods. We suggest concentrating further research on the employment of non-monetary valuation techniques to enhance knowledge on the social benefits provided by ecosystem services.

Moreover, directly addressing stakeholders appears to have a positive effect on the consideration of a number of social benefit types, as they were derived then significantly more frequently. This finding is closely related to the choice of valuation methodology of course. Directly eliciting stakeholders' views and the necessary interaction with individuals or stakeholder groups, however, often also has implications for the research processes and setting. It can trigger learning processes (Reed et al., 2010) and can support the inclusion of relevant stakeholders in decision-making (Reed, 2008), with deliberative methods such as participatory mapping (e.g. Klain & Chan, 2012) being predestinated for highly discursive stakeholder engagement. Both have proven effective in enhancing the acceptance and compliance of results for decision-making (Menzel & Teng, 2010). Few of the reviewed studies assess social benefits without addressing stakeholders directly. Related techniques are mostly found in modelling-based studies, which allow for first estimates. One example is the InVEST Recreation Model that assesses amenity benefits by modelling visitation rates using geotagged photographs posted to the website flickr (Sharp et al., 2014). We see a need to further investigate the validity of such models.

3.5.2 Multidisciplinary approaches

As the exclusive use of monetary valuation methods remains contested, a couple of authors suggest the notion of multi-dimensional value domains, e.g. multi-criteria evaluation to overcome issues of incommensurability and incompatibility across value types (; Gomez-Baggethun & Groot, 2010) and methodological pluralism (Kumar & Kumar, 2008; Quintas-Soriano et al., 2016). De Groot et al. (2002) have discussed the multi-dimensional facets of total value (ecological, socio-cultural, and economic) of ecosystem goods and services at an early stage of the implementation of the ecosystem services concept. This notion was later adapted by the TEEB conceptual framework (de Groot et al., 2010, Chapter 1), yet has not been incorporated by the better part of studies conducting ecosystem service assessments. Chan, Satterfield et al. (2012) advocate a multi-method and multi-metric approach to ultimately improve the validity and legitimacy of ecosystem service research. In practice, as demonstrated by our analysis, very few of the studies reviewed in this analysis use a mix of monetary and non-monetary approaches when valuing social benefits. Further research is required to test multi-method and multi-metric approaches to examine the multi-dimensional link between ecosystem services and human well-being and ultimately strengthen the ecosystem services concept.

3.5.3 Implications of the methodology

The case survey method allowed for a systematic analysis of ecosystem service valuation studies by combining qualitative and quantitative techniques. One shortcoming of the current study is the limited selection of reviewed studies. This could have been enhanced by including broader search terms from outside the ecosystem service research community, such as landscape service, environmental goods, etc. Another limitation is the partial inaccuracy of the collected data. Whereas we elicited social benefits and the service types/methods used per reviewed paper, we did not explicitly assign every social benefit to the ecosystem service analysed/method employed. Whereas our analysis suggests numerous dependencies of social benefits from cultural ecosystem services in the reviewed studies, a closer look at the case studies reveals that the link is not always of direct nature (see Hypothesis 2 and discussion above). A number of studies include multiple service types or techniques to derive values (Joshi & Negi, 2011; Martín-López, García-Llorente, Palomo, & Montes, 2011). In these instances, our results may suggest a tendency of variables appearing in the same studies but must be interpreted with caution. Likewise, our results do not allow us to conclude on the suitability of valuation techniques or stakeholder involvement to derive values for social benefits. However, the case survey method and its way of qualitatively reviewing existing case-study literature allowed for a critical interpretation of the ecosystem service types and particulary cultural services assessed, methods used and direct incorporation of stake holderś views and thus proved a suitable method for our research objectives.

3.6 Conclusions

The practice of ecosystem service assessments displays different approaches of taking into account the effect of ecosystem services on human well-being. Our analysis revealed that (1) a variety of social benefits are valued in studies that assess either of the four ecosystem service types, (2) certain social benefits are likely to co-occur in combination with certain cultural ecosystem services, (3) of the studies that employed monetary valuation techniques, simulated market approaches overlapped most frequently with the assessment of social benefits and (4) studies directly addressing stakeholders were more likely to also assess social benefits. Though there appears to be a general understanding of social benefits provided by ecosystem services in the reviewed ecosystem service assessments, there is no common understanding on which ecosystem services potentially provide which particular social benefits. Moreover, the definition of benefits and values (held/assigned) varies significantly in the reviewed case studies as well as classifications and conceptual contributions. To acknowledge the effect of environmental management on human-wellbeing, we advocate a consistent integration of social benefits in ecosystem service assessments. This requires a common classification of social benefits of ecosystem services.

Particularly with the explicit attention to social benefits and values also in practical policy implementation such as the European Landscape Convention (Jones & Stenseke, 2011), the field of social benefits and values of ecosystem services bears great potential. We suggest further research on the employment of non-monetary and monetary valuation techniques, and the implications of valuation methods and forms of addressing and involving stakeholder for social benefits in ecosystem service assessments. Further experimental investigations are needed to explore the potential of multi-dimensional value assessments of ecosystem services to equally accommodate economic, ecological and social values in environmental management and decision-making.

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← Entrance
Flotterstone Information Centre
Pentland Hills
Regional
Park
Welcome to the Pentland Hills Regional Park
Flotterstone
isabled Person
Please leave
parking space
POLICE WARNING
Motorists!
Don't leave
valuables
in your
car
KU06 KWH

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

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.

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4.1 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 characterisation 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, Martín-López 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 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.

4.2 Methods

4.2.1 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 (Figure 4.1). 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).

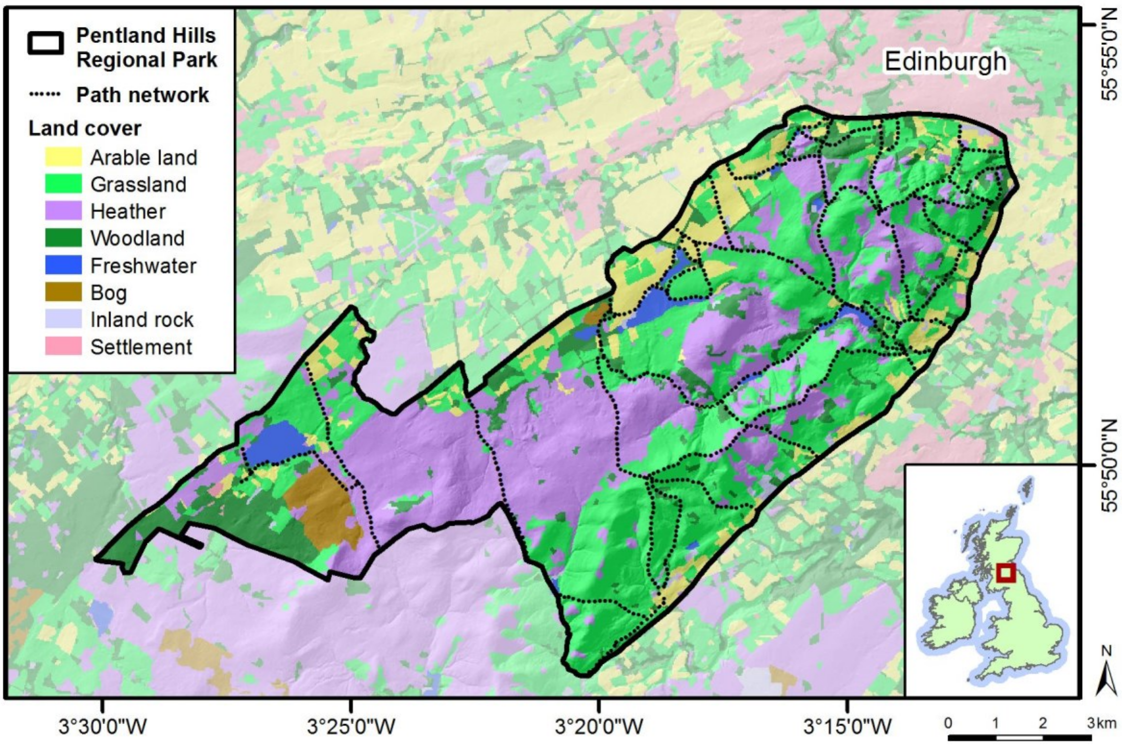

Figure 4.1. Location, land cover and paths of the Pentland Hills Regional Park. The shaded areas indicate elevations.

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 livery. 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.

4.2.2 Data collection

4.2.2.1 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).

4.2.2.2 Questionnaire and selection of ecosystem services

The final questionnaire (see Appendix 2) 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 4.1) 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.

Table 4.1. 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

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 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 Figure 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 3. 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.

4.2.3 Data analysis

We applied a mixed analytical approach that includes different steps (Figure 4.2). 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 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.

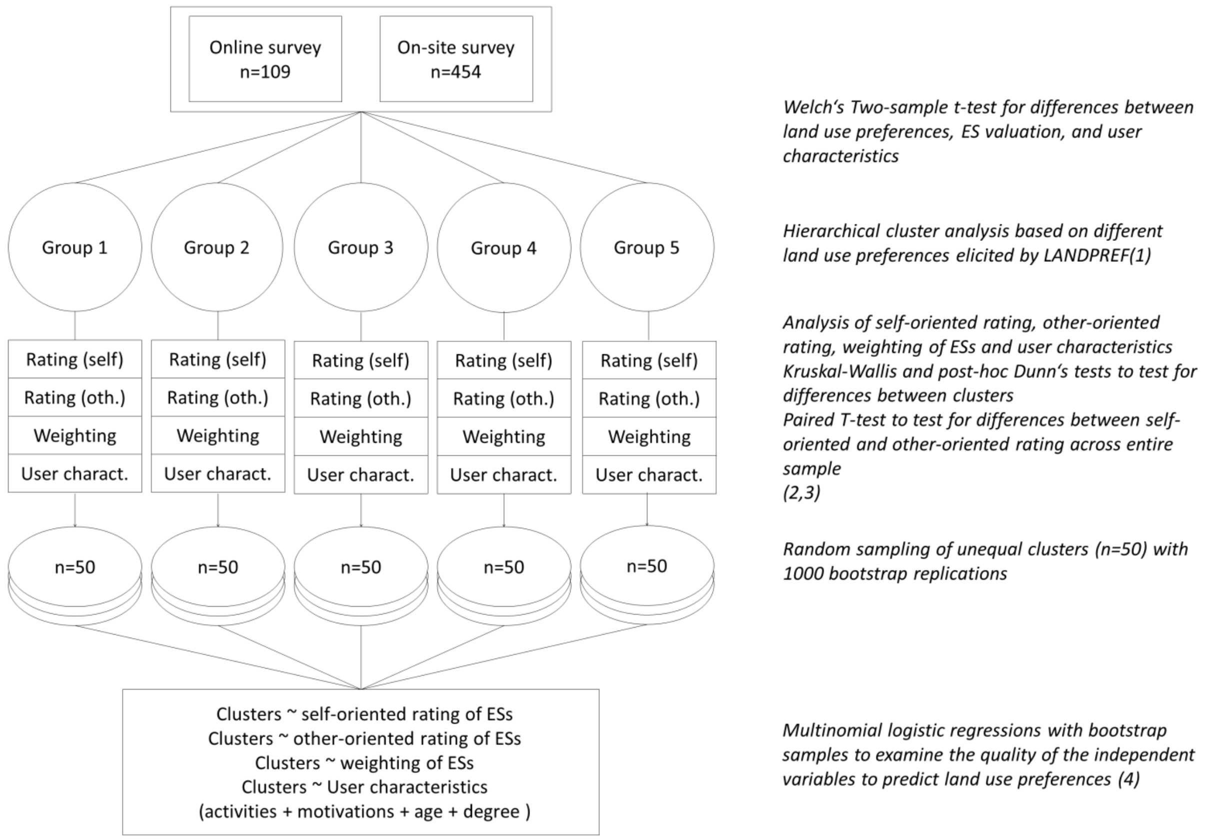

Figure 4.2. Graphical flow chart of the data analysis in this study. Numbers in parentheses refer to the specific objectives of this research (see section 4.1).

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).

4.3 Results

4.3.1 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 Figure 4.3A based on the median values of land use preferences of each cluster as shown in Figure 4.3B. 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 ("Multi-functionalists"). 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.

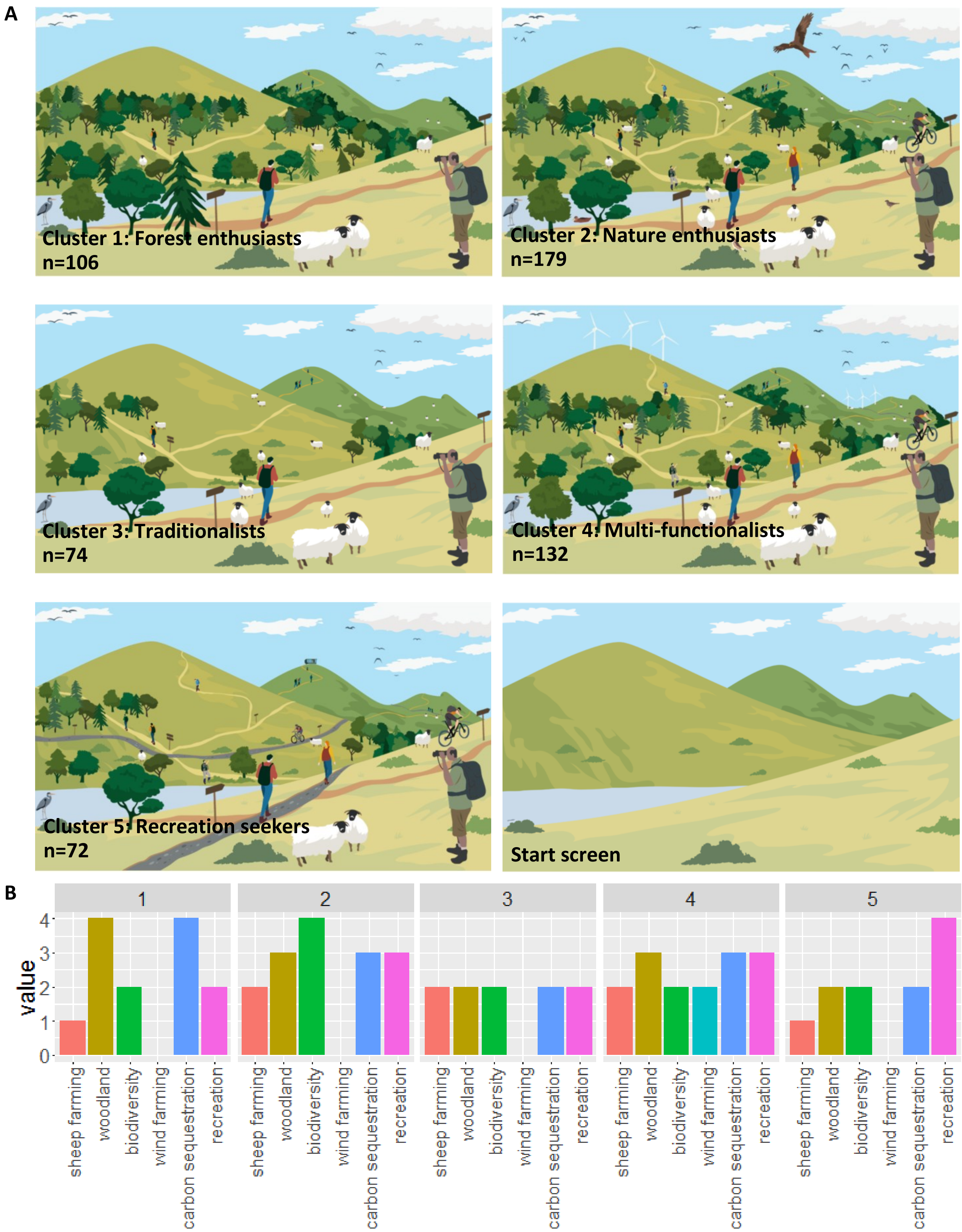

Figure 4.3. Preference clusters for future land use management within the Pentland Hills Regional Park. (A) Composition of the future landscape settings visualised for each of the five clusters with attributed cluster name and size and the start screen of LANDPREF, (B) Median rating of each of the land use options for the five clusters.

4.3.2 Socio-cultural values of ESs

Results of the socio-cultural valuation revealed various values of ESs depending on the respective socio-cultural valuation method (Figure 4.4). The self-oriented rating of ESs unveiled particularly 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.

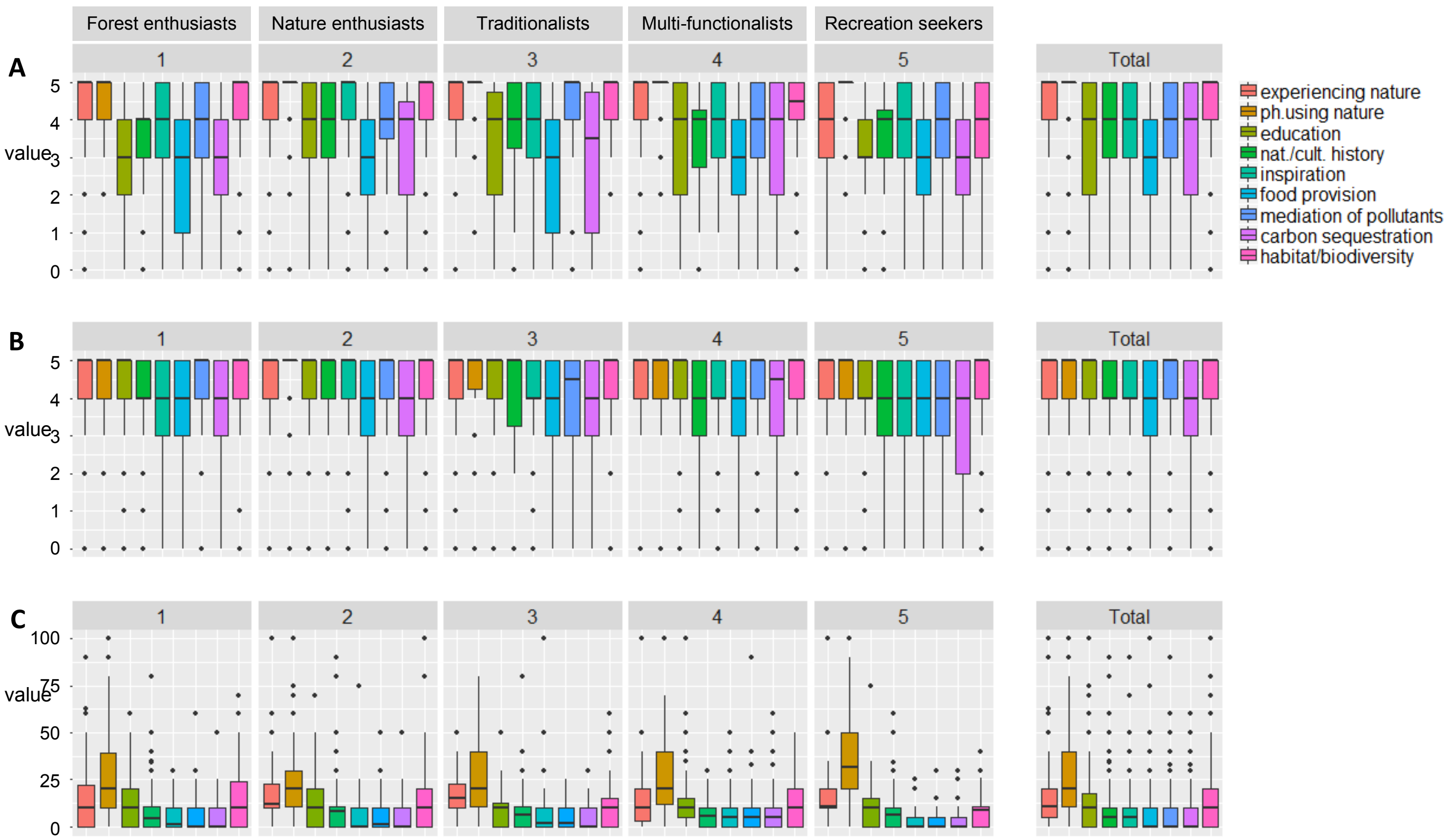

Figure 4.4. Median, 25th, and 75th percentiles of the (A) self-oriented rating of ecosystem services (ESs) on a Likert-scale, (B) other-oriented rating of ESs on a Likert-scale, and (C) weighting by allocating 100 points across all ESs. The last group of boxes in each row labelled "Total" indicates the median, 25th, and 75th percentiles for the entire sample for each valuation exercise.

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 4.2, see Appendix 4 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 4.2, Appendix 4). 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 4.2, Appendix 4), 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.

Table 4.2. 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	Chi²	p-value	Chi²	p-value	Chi²
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

4.3.3 Socio-demographic and visitor characteristics of users

We found little socio-demographic differences between the clusters (Table 4.3). In fact, only age differed significantly between clusters. Cluster 4 (Multi-functionalists) 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 4. 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 4.3). 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 4.3).

Table 4.3. Socio-demographic and visitor characteristics of respondents (proportion within clusters). The last column indicates proportions of total sample.

	Chi²	p-value	Cluster 1 Forest enthusiasts	Cluster 2 Nature enthusiasts	Cluster 3 Traditionalists	Cluster 4 Multi-functionalists	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

4.3.4 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 Figure 4.4. 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 5). 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.

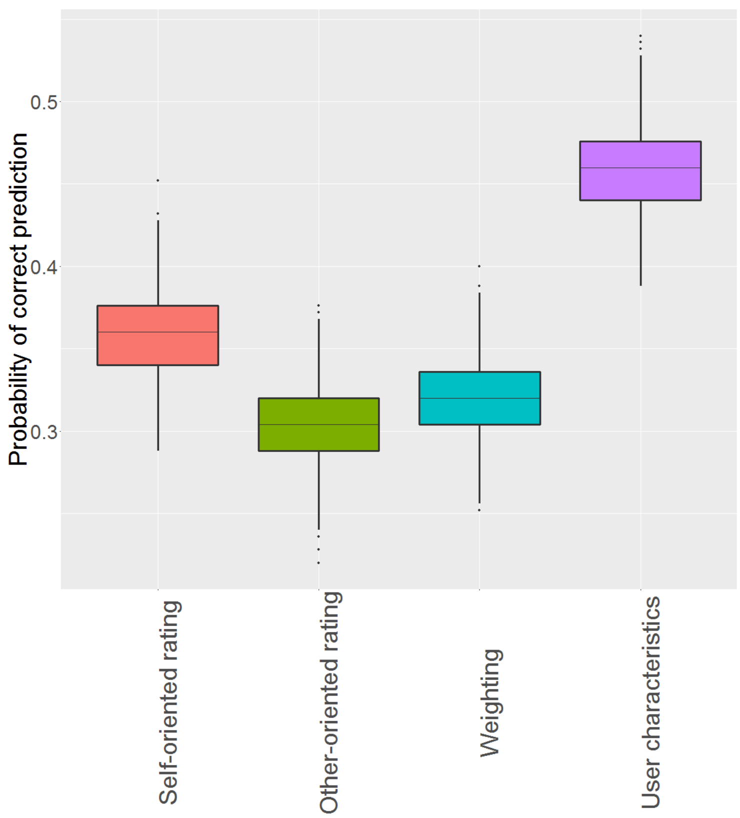

Figure 4.4. Results of the multinomial logistic regressions, indicating the probability of each predictor model to correctly predict cluster membership. Computations are based on 1000 bootstrap data sets.

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 6). 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

−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 6).

4.4 Discussion

4.4.1 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 prioritise 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.

4.4.2 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 multi-functional, 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).

4.4.3 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.

4.5 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 multi-functional 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 multi-functional landscapes that allow people to recognise the value of multiple ESs regardless of the specific land use configuration.

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5. Key landscape features in the provision of ecosystem services: Insights for management

Abstract: Whereas ecosystem service research is increasingly being promoted in science and policy, the utilisation of ecosystem services knowledge remains largely underexplored for regional ecosystem management. To overcome the mere generation of knowledge and contribute to decision-making, scientists are facing the challenge of articulating specific implications of the ecosystem service approach for practical land use management. In this contribution, we compare the results of participatory mapping of ecosystem services with the existing management plan for the Pentland Hills Regional Park (Scotland, UK) to inform its future management plan. By conducting participatory mapping in a workshop with key stakeholders (n=20), we identify hotspots of ecosystem services and the landscape features underpinning such hotspots. We then analyse to what extent these landscape features are the focus of the current management plan. We found a clear mismatch between the key landscape features underpinning the provision of ecosystem services and the management strategy suggested. Our findings allow for a better understanding of the required focus of future land use management to account for ecosystem services.

Based on:

Schmidt, K., Martín-López, B., Phillips, P., Julius, E., Makan, N., Walz, A., under review. Key landscape features in the provision of ecosystem services: Insights for management. Re-submitted to Land Use Policy.

5.1 Introduction

The concept of ecosystem services is thought to protect nature by contributing to more informed decision-making in land use management. Although the utilisation of ecosystem services knowledge in decision-making is increasingly being promoted by academics and policy makers, its actual uptake in land use management remains largely undetermined (Cowell and Lennon, 2014; Jordan and Russel, 2014; Martinez-Harms et al., 2015). Though there are a few studies that establish a clear link between ecosystem services knowledge and its implications for management (e.g. Bryan et al., 2010), a large body of ecosystem services literature provides valuable insights on methods, conceptual issues, and reviews but fails to incorporate concise implications for land use management. Consequently, the utilisation of knowledge on ecosystem services in decision-making is found to be "massively under-researched" (Russel et al., 2016).

Recent review papers suggest actions to overcome the mere generation of knowledge of ecosystem services and to effectively contribute to better environmental management. For instance, several "blind spots" are reported that are currently not sufficiently addressed in ecosystem services research, one of which referred to the relevance and usability of the case study results for the operationalisation of the ecosystem services concept (Lautenbach et al., 2015). Another review on the use of monetary valuation in ecosystem service assessments concluded that researchers often seek to raise awareness rather than effectively contribute to decision-making (Laurans et al., 2013). Similarly Martínez-Harms et al. (2015) identified the need to clarify how knowledge of ecosystem services can be used to support practical management decisions, by means of the clear articulation of objectives, consideration of alternative actions, and inclusion of stakeholder values and preferences by means of deliberative and participatory methods. In one of the few studies about the utilisation of ecosystem services knowledge that adopts an empirical approach, Posner et al. (2016) explore the factors that affect the impact of ecosystem services knowledge on decision-making based on 15 case studies. They found that the legitimacy of knowledge is the most important factor and advise that researchers engage meaningfully with decision-makers and stakeholders to incorporate the diversity of views transparently.

Participatory mapping has become a popular approach in ecosystem services research to identify spatial areas of supply and demand of ecosystem services which can be prioritised by land managers for their conservation and restoration (Brown et al., 2012; Wolff et al., 2015). Participatory mapping studies describe processes where individuals take part in the creation of a map (Brown and Fagerholm, 2015). They include public participation geographic information system (PPGIS) studies that use GIS technologies and aim to collect local knowledge and to include and empower marginalised populations (Brown et al., 2012; García-Nieto et al., 2015; Brown and Fagerholm, 2015). Because ecosystem services mapping explicitly relates landscape features (spatial indicators) and ecosystem services supply (de Groot et al., 2010), participatory mapping is found a useful method to support decision making in land use management aiming to ensure their future supply by producing spatially explicit results that can be integrated into explicit land use decision criteria (Brown and Fagerholm, 2015). However, little evidence is found that mapped ecosystem services data is being utilised for land use management and few studies contain precise recommendations to integrate the mapped results into decision making (Brown and Fagerholm, 2015).

In ecosystem services research, recent studies analyze the interlinkages between landscape features and the supply of ecosystem services (e.g. Burkhard et al., 2009; Martínez Pastur et al., 2016; van Zanten et al., 2016; Oteros-Rozas et al., 2017; Tenerelli et al., 2016). Landscape features can be directly linked to the supply of ecosystem services, for instance by a specific land cover, e.g. forest being directly linked to the provision of timber (e.g. Burkhard et al., 2012). Landscape features can be also related with ecosystem services supply through the use of additional proxies, e.g. recreational services of a landscape are defined by its land cover (e.g. natural area), and also depend on accessibility proxies (e.g. distance to roads; de Groot et al., 2010). Therefore, it is an important challenge for future research to associate these results with current land use management practice in order to utilise ecosystem knowledge and make it applicable for decision-making.

Practices and priorities in land use management are commonly laid out in plans or strategic visions that aim to conserve biodiversity and other natural values (Pressey et al., 2007). As such, conservation plans delineate strategic priorities for land management (Game et al., 2013). These management plans can be strongly targeted to particular features. To streamline the management of ecosystems towards an ecosystem service perspective, it this therefore crucial to associate these landscape features with the supply of ecosystem services. A common method to extract strategic priorities from policy documents is content analysis (Krippendorff, 2012; Neuendorf, 2016). Having its origins in social sciences and humanities, content analysis has recently also been employed in the examination of conservation policy documents (e.g. Leone and Zoppi, 2016; Li et al., 2016; Mascarenhas et al., 2015).

The main aim of this study is to develop an approach that combines approved methods from ecosystem service research to apply the ecosystem services concept in practical land use management, and discuss implications for the prioritisation in management planning for a case study in the Pentland Hills Regional Park (Scotland, UK). In doing so, we (1) identify hotspots of cultural, provisioning and regulating ecosystem services through participatory mapping, (2) explore landscape features able to provide such ecosystem services hotspots, (3) investigate current land use management priorities, and (4) uncover mismatches to allow for a better understanding of the intended focus of future land use management measures to account for ecosystem services (Figure 1). We combine three approaches, i.e. participatory mapping, spatial analysis of landscape features and ecosystem service supply, and document analysis, to inform land use management in the Pentland Hills Regional Park (Scotland, UK).

5.2 Study area

The Pentland Hills Regional Park (PHRP) is located to the south-west of Edinburgh (Figure 3 A) and fulfills various functions. Designated under the Countryside (Scotland) Act 1967 and the Regional Parks (Scotland) Regulations 1981, the main objective of the protected area is to promote the integrated management of land for economic (e.g. agriculture, forestry), nature conservation, and recreational objectives (Scott Wilson, 2007a).

Covering an area of approximately 9.200 hectares, it comprises a range of different land covers and semi-natural habitats and is predominantly upland in character. The highest point in the Park is Scald Law at 579m. The upland areas of the park are dominated by grassland (41 % of the park area) and dwarf shrub heath (32.5 %). Better quality arable land (9 %) is present at the peripheral areas at the park boundary. Particularly in the south-west of the park, coniferous woodland is the other major land cover (11.5 %). Broadleaved and mixed woodland is found in smaller patches across the park, mostly on lower lying slopes and in the glens that divides the park. Parts of Edinburgh's water supply are provided by two reservoirs, two other reservoirs provide drought option sources, and there are also a number of private water supplies in the park. The PHRP has been subject to a study on socio-cultural values of its visitors in 2014 (Schmidt et al., 2016a; Schmidt et al., 2017) and a subsequent study on the application of the ecosystem approach to collaborative land use and management (Phillips et al., 2016) funded by Scottish Natural Heritage, the lead public body responsible for advising local and national authorities on all matters relating to the natural heritage.

Decisions concerning the practical use and management of land in the regional park are subject to a range of public and private interests. The role of the park management is to offer support and build consensus on shared objectives for the use and management of the park, recognising that decisions concerning most land in the park are ultimately within the hands of the landowner/tenant. The City of Edinburgh Council is currently the managing and lead authority of the park and therefore responsible to revise the current management plan which will give a new strategic vision of the park. The management plan's purpose is to provide the contemporary strategic framework guiding the PHRP management in the formulation of related management action plans (Scott Wilson, 2007a). The current management plan (81 pages) consists purely of text and tables that outline management actions, spatially explicit considerations for individual areas are not made. Input to issues regarding land use and management planning is provided by the Consultative Forum, a stakeholder group containing a range of interests within the regional park. Ecosystem services are currently not accounted for in the management plan.

5.3 Methods

We used a mixed methods approach to explore the various objectives (Figure 1). Mixed methods research is praised for its pragmatism because it legitimizes researchers to combine methods that are most suitable for answering their research questions (Johnson and Onwuegbuzie, 2004). The methodological approach involves four steps. Within the first step (section 3.1), we facilitated a participatory mapping exercise of ecosystem services to identify their spatial location within the park. We employed intensity analysis in GIS to combine the mapped ecosystem services to ecosystem services hotspots. In a second step (section 3.2), we explored biophysical landscape features that underpin the occurrence of ecosystem services. We conducted redundancy analysis to examine the spatial relationship between landscape features and ecosystem services hotspots. In the third step (section 3.3), we analysed the content of the management plan of the PHRP to detect current management priorities related to landscape features. Finally, we compared the results of the redundancy analysis of landscape features that underpin the supply of ecosystem services and the results of the content analysis that reveal current priorities in the management of landscape features. The mismatch we uncovered was used to suggest a possible focus for future management.

5.3.1 Participatory mapping and post-processing of ecosystem services hotspots

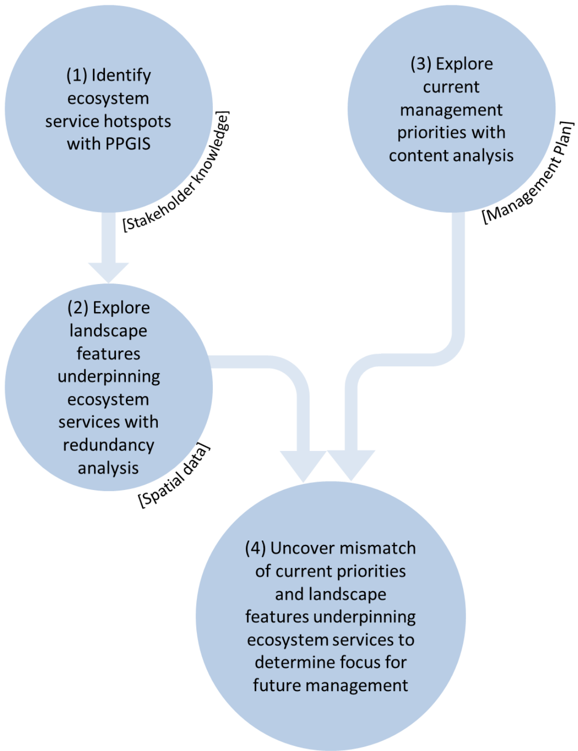

Figure 1. Flow chart of the objectives and methods (circles) and used data (rectangular brackets) in this study.

We applied PPGIS to identify hotspots of ecosystem services supply during a stakeholder workshop. Participatory mapping of ecosystem services draws on the expertise and local knowledge of stakeholders to explore spatial relationships between landscape characteristics and ecosystem services supply (Brown and Fagerholm, 2015). The workshop was attended by 20 self-selecting members of the Consultative Forum of the PHRP (section 2). Participants included representatives of local authorities (5 participants), local communities (2), farmers and land owners (5), organised recreational groups (4), a non-governmental organisation (1), and statutory agencies (3).

During the mapping exercise, we used large (A0) paper maps of the Pentlands on a 1:18,000 scale to allow participants to identify the location of different ecosystem services provided by the regional park. Ecosystem services were selected for consideration in the workshop by the project facilitation team, which consisted of an environmental consultancy, Scottish Natural Heritage, and three researchers who have been engaged in ecosystem services research in the Pentland Hills since 2013. The list of ecosystem services was informed by results from the previous study on visitors' socio-cultural values of ecosystem services (in agreement with the regional park management, see Schmidt et al., 2016a; Schmidt et al., 2017). Participants used sticky dots and drawing directly on the maps to indicate the places where ecosystem services are supplied and draw directly on the maps (Figure 2). The maps included some existing information about the physical characteristics of the park as prompts for this exercise:

- cultural ecosystem service map: formal paths, listed buildings, areas that might be considered ‘wild’, gardens and designed landscapes, scheduled monuments, conservation areas, country parks;
- provisioning ecosystem service map: burns, arable land, pasture, new woodland plantings (2007-2013), windfarm application;
- regulating ecosystem service map: burns, riparian woodland, woodland on steep slopes, carbon rich soil/deep peat.

At the beginning of the workshop, participants were introduced to the concept of ecosystem services which were referred to as “natural environment benefits”.

Figure 2. Participatory mapping in the Pentland Hills Regional Park. (A) One of three stakeholder groups deliberating the spatial dispersal of cultural ecosystem services. (B) Close-up view of mapped regulating ecosystem services. (C) Map with sticky dots and notes of regulating ecosystem services. (D) Facilitator giving introductory presentation to workshop participants. Photographs by V. Burton.

Participants were divided into three groups of 6 or 7 stakeholders, each with representatives of (almost) every stakeholder group. Each group was asked to map ecosystem services out of an assigned ecosystem service category (Table 1). In the regulating service category, we had initially also asked participants to map the service "erosion control". As suspected during the discussion in regulating services group and confirmed by the spatial location of the data points, participants conflated "erosion control" with the occurrence of erosion. Therefore, we did not include "erosion control" in the analysis as it actually represents the "erosion" pressure.

Table 1. Ecosystem services mapped at the stakeholder workshop

Category	Definition	Benefits discussed at the workshop
Cultural	The non-material benefits obtained from ecosystems	Experiencing nature Physically using nature Spiritual and religious benefits Educational benefits Aesthetic benefits and inspiration
Provisioning	The products obtained from ecosystems	Freshwater Food – farmed Food – game and wild collected food Timber and other wood products Energy – biomass Energy – wind
Regulating	The benefits obtained from the regulation of ecosystem processes	Climate regulation Flood regulation Water purification

Data points that were collected at the workshop were digitised in a GIS. To describe the spatial intensity of the mapped ecosystem service categories, we used a quadratic Kernel function that calculated the density of point features around each output raster cell in a raster grid (Silverman, 1986), which is a commonly used method for identifying the spatial arrangement of ecosystem services in research (Brown and Fagerholm, 2015). The Kernel function fits a smoothly curved circular surface over each point by adding the values of all the kernel surfaces where they overlay the center of the raster cell. The Kernel density search radius was set to 200m to reflect the local scale of the landscape and to compensate potential inaccuracy of the mapped out ecosystem services. The outputs of the Kernel analysis are referred to as 'ecosystem services hotspots'. Building on Brown and Fagerholm (2015), we define hotspots as those areas in the regional park where the workshop participants identified multiple ecosystem services and that therefore have a relative higher concentration of services. We differentiate between hotspots for cultural, provisioning and regulating ecosystem services.

5.3.2 Redundancy analysis to identify landscape features underpinning ecosystem services hotspots

We performed redundancy analysis (RDA) to examine the relationships between ecosystem services hotspots (dependent variables) and landscape features (explanatory variables) in the PHRP. RDA has been suggested as an adequate quantitative method to examine whether the overall ecosystem service supply can be explained by a set of environmental factors (Mouchet et al., 2014). RDA visualises ordinations of response variables constrained by explanatory (e.g. environmental) variables (Legendre et al., 2011). First, it performs multivariate regressions of a response matrix on an explanatory matrix and so produces a matrix of fitted values. Second, it performs a principal component analysis of this matrix with fitted values. This principal components analysis produces the canonical eigenvalues and eigenvectors, and canonical axes which are used for the ordination diagrams.

To explain hotspots of ecosystem service supply (i.e. response variables), landscape features were derived from spatial data (i.e. explanatory variables). We prepared a regular vector grid with 9180 cells and a cell size of 100 x 100m to cover the regional park. All landscape features were extracted for each cell of the vector grid using various analytical GIS indicators (see Table 2 for an overview of dependent and explanatory variables). The landscape features and additional proxies were grouped into landscape feature classes (Table 3) which relate directly to the management priorities in the current management plan (see section 3.3).

Landscape features and proxies were based on land use and land cover data as well as further geoprocessing work (e.g. distance calculations; Table 2). For instance, we mapped accessibility and recreational assets by measuring the distance between car parks, park paths, bus stops, woodland, water, and hilltops and each grid cell with the GIS proximity tool. This way, we recognise particular logistical or landscape features outside of the grid cells that may still have an impact on recreational use. Additionally we identified if the cells lay within one of the two Country Parks, which are areas with landscape, recreational, and wildlife attributes that are representative of the Pentland Hills but managed exclusively by the local authorities and therefore without commercial pressures, for instance, of farmers. We also performed a visibility analysis using viewshed to identify the visual range of each cell. Here we assumed that visibility of the landscape has a large impact on recreational services (see e.g., Chen et al., 2009). To represent biodiversity, we used Scottish Natural Heritage's map of Wild Land Areas to assess the relative wildness of each cell. The data set used four physical attributes to describe wilderness: perceived naturalness, rugged or challenging terrain, remoteness from public mechanised access, and visible lack of built development and other modern artefacts. Though the Pentlands are not part of a recognised Wild Land Area, the wilderness index is used as a relative measure of wildness in between cells. Additionally, we used a focal neighborhood analysis to assess the number of land cover classes in the surrounding cells as measure of habitat heterogeneity. All editing and analysis of spatial data was conducted using Esri's ArcMap 10, except for the viewshed analysis where QuantumGIS 2.14 was used.

We used Moran's Index (Moran, 1950) to measure spatial autocorrelation of ecosystem services hotspots (specification of hotspots as described in section 3.1). Because we found positive correlations among all three sets of hotspots (cultural: Moran's I: 0.22, z-score: 13.7, regulating: Moran's I: 0.16, z-score: 10.25 provisioning: Moran's I: 0.20, z-score: 13.1), we continued our analysis with a random selection of 10 % of the data points (García-Nieto et al., 2015; Palomo et al., 2014). We selected a balanced subset of the sample in which half of the data points lay within ecosystem services hotspots and the other half outside. Data points within hotspots were selected proportionally to the amount of points (sticky dots) that were originally mapped per ecosystem service category (cultural: 35%, regulating: 42%, provisioning: 23%). We randomly selected 161 cells with the highest density of cultural services, 105 cells with the highest density of provisioning services, and 193 cells with the highest density of regulating services. 469 cells were additionally selected outside of ecosystem services hotspots acting as reference points. There is a slight overlap between the highest density cells of the three ecosystem service categories so that the cultural and regulating ecosystem services hotspots share 15 cells, cultural and provisioning share 10, and provisioning and regulating ecosystem services hotspots share 7 cells. Kernel intensity of each data point was based on the density values (Kernel Analysis output) for each of the cultural, regulating and provisioning ecosystem services hotspots.

To test for linear dependencies among the explanatory variables, we calculated the variance inflation factors (VIF) for each constraint (Belsley, 1991). Whereas a VIF of 1 indicates non-collinearity, a VIF over 10 indicates redundant constraints. In the redundancy analysis, we omit all explanatory variables that have a VIF > 5. We used Monte Carlo permutation tests to assess the significance of the explanatory variables (ter Braak, 1992). Then we calculated the proportion of variance that was explained by the axes to assess how well the ordination was representing each hotspot (goodness of fit). To find the best model of explanatory variables, we used automatic stepwise model building based on permutation tests (Blanchet et al., 2008). We generated a biplot of the variables of the best model RDA to graphically display the patterns of landscape features and how they relate to the ecosystem services hotspots. To avoid heteroscedasticity, we log-transformed both dependent and explanatory variables before carrying out the RDA. All calculations were performed with the statistical software R version 3.3.3 (2017-03-06; R Core Team, 2017). The RDA was performed with the 'rda' function in package 'vegan' (version 2.4-2).

Table 2. Variables used in redundancy analysis. Explanatory variables marked with * were excluded from the final analysis due to a VIF > 5.

	GIS indicators	Data reference
Ecosystem services hotspots		
Cultural	Kernel Density analysis	Digitised from stakeholder workshop
Regulating	Kernel Density analysis	Digitised from stakeholder workshop
Provisioning	Kernel Density analysis	Digitised from stakeholder workshop
Landcover		
Arable land	Area in % within cell	CEH (2011)
Bog	Area in % within cell	CEH (2011)
Grassland	Area in % within cell	CEH (2011)
Heather	Area in % within cell	CEH (2011)
Surface water	Area in % within cell	CEH (2011)
Wood	Area in % within cell	CEH (2011)
Biodiversity		
Land cover diversity	Number of LC Classes in neighbour cells (300x300m)	CEH (2011)
Wildness	Wildness index	SNH (2014)
Hills		
Altitude	Altitude in meter	10m DTM (EC, 2013)
Slope	Slope	10m DTM/Slope (EC, 2013)
Cultural heritage		
Historical buildings	Number of historical buildings in cell	Historic Environment Scotland (HES, 2011a)
Scheduled monuments (histMonA)	Area in % within cell	Historic Environment Scotland (HES, 2011b)
Building	Building in Cell (yes/no)	Ordnance survey (2017)
Geology		
Geological Sites (histGCRa)	Area in % within cell	SNH (2016)
Recreational assets		
Distance to water*	Distance to next surface water in meter	CEH (2011) Vector
Distance to Woodland*	Distance to next woodland in meter	CEH 2007 LULC Vector
Country Park	Middle Point in Country park (yes/No)	SNH (2011)
Distance to paths (DistPaPH)	Distance to Pentland Paths (advertised by PHRP)	Pentland Paths digitised from PH brochure
Distance to hill top (DistHiTo)	Distance to next Hilltop	All Hilltops over 400m digitised from 10m DTM (EC, 2013)
Viewshed	Viewshed analysis	DTM 25m (EC, 2013)
Accessibility		
Distance to car park	Distance to next car park	Car parks digitised from PH brochure
Distance to bus stop	Distance to next bus stop	Bus stops digitised from PH brochure

5.3.3 Content analysis to identify current management priorities

To review current management priorities, we performed quantitative content analysis on the current Management Plan (Scott Wilson, 2007a). Content analysis is a widespread, originally qualitative research methodology that emerged from the social sciences but has been repeatedly employed in other fields of study including ecosystem services research (e.g. Garrido et al., 2017; Richards and Friess, 2015). Content analysis is found a suitable approach to summarise and quantitatively analyse so-called ‘messages’ which follows the standards of other scientific criteria (Neuendorf, 2016). After determining the type of content to be examined, the investigators need to typically define variables that are used in their study as well as measures or units of data collection. On this basis, the investigator can develop appropriate coding schemes to finally conduct the content analysis (Neuendorf, 2016).

In this study, we derived a broad list of key categories (‘codes’) for possible management priorities by examining the landscape feature classes able to provide ecosystem services hotspots (Table 3). We disregarded possible management aims that were unrelated to any of the landscape feature classes underpinning ecosystem services hotspots, e.g. renewable energy. The management plan was then scrutinised for phrases (‘codings’) that related to these codes, e.g. “recreational pressure” as a coding for “recreation” (code), “landscape and the habitat” as a coding for “biodiversity” (code). Subsequently, we added together the amount of codings for each of the codes. This approach was based on the assumption that priorities in land use management would be more frequently addressed than subordinate management objectives. We used MAXQDA Analytics Pro software (MAXQDA, 2017) to facilitate the content analysis.

Table 3. Relationship between landscape features derived by GIS analysis and codes used in content analysis. Those landscape features marked with * were excluded from the final analysis due to a VIF > 5.

Codes Management Plan	**Landscape feature classes**	**Landscape features**
Arable land / Farmland	Arable land	Arable land
Moorland / Bog	Moorland	Bog
Grassland	Grassland	Grassland
Heather	Heather	Heather
Water	Water	Water surfaces
Woodland / Forestry	Woodland	Woodland
Biodiversity / Species	Biodiversity	Wildness index Land cover in neighboring cells
Cultural heritage	Cultural heritage	Historical buildings Scheduled monuments Buildings
Geology	Geology	Geological Conservation Review Sites Scotland
Recreation	Recreational assets	Country Park Viewshed analysis Distance to park path Distance to water* Distance to woodland* Distance to hill top
Accessibility	Accessibility	Distance to bus stop Distance to car park
Hills Landscape character	Hills	Altitude Slope

5.3.4 Comparison of ecosystem service providing landscape features and current management priorities

We compare RDA scores and content analysis counts by ranking them. By comparing the ranks of landscape feature classes, we uncovered mismatches between the landscape features providing ecosystem services and the landscape features included in the current management plan. Because RDA scores for landscape features were multidimensional, i.e.

available on three axes, we ranked them according to their weighted means based on the proportion of each axis' contribution to the explained variance (section 4.2). Management plan codes were ranked based on the counts of their respective codings (section 4.3). The results of the ranking exercise allow for a better understanding of the required focus of future land use management measures to also account for ecosystem services.

5.4 Results

5.4.1 Ecosystem services hotspots

The spatial distribution of ecosystem services hotspots as indicated in the participatory mapping differs between ecosystem service categories (Figure 3. B-D). Cultural services such as experiencing nature, physically using nature and educational services are mostly located near water reservoirs in the northwest of the park. The upland areas located in the north of the park and the ridge ranging from the south-east center further south east are important areas for the recreational use of nature but also aesthetic, inspiration and spiritual benefits. Regulating service hotspots were mostly identified in bog areas (i.e. climate regulation, flood regulation) and in and around reservoirs (i.e. flood regulation, water purification) and waterbodies (i.e. water purification). Provisioning services were identified in a cluster around the north-west center, i.e. in the reservoirs (providing game fish and freshwater), in the grassland areas used as grazing and arable land (providing game and wild collected food, biomass for energy production, timber and other wood products), and scattered across the rest of park, i.e. within woodland patches (providing timber and other wood products), individual wind turbines (providing wind energy), along the arable and grazing land of the south-east border of the park (providing farmed food).

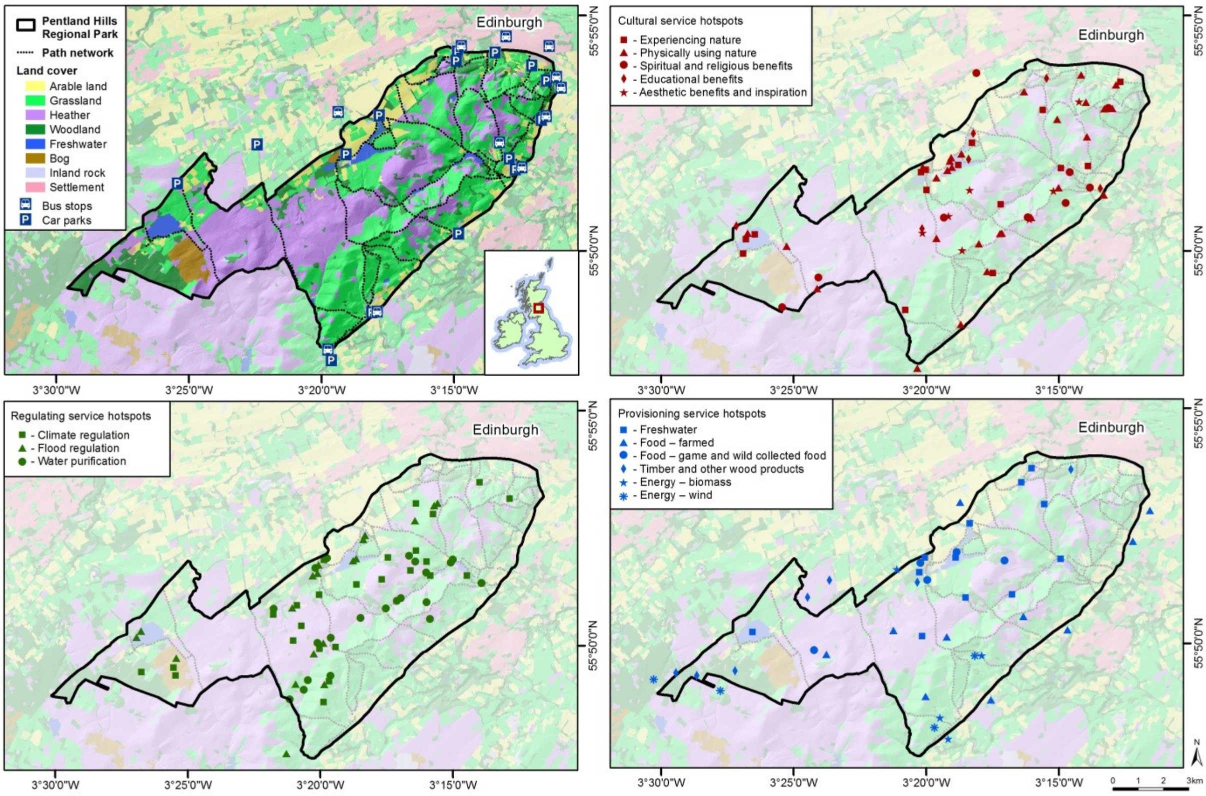

Figure 3. The Pentland Hills Regional Park. (A) Land cover and selected landscape features. The shaded areas indicate elevations. (B) Cultural ecosystem services hotspots, (C) Regulating ecosystem services hotspots. (D) Provisioning ecosystem services hotspots.

5.4.2 Landscape features able to provide ecosystem services

The permutation test indicated a statistically significant association between landscape features and ecosystem service hotspots (p-values: RDA1 0.001, RDA2 0.001, RDA3 0.01 from 999 permutations). VIF diagnostics revealed linear dependencies between distance to water (VIF 11.05) and water as well as distance to woodland (VIF 7.69) and woodland. We therefore omitted distance to water and distance to woodland from the further analysis (see Table 2).

The first two axes explained 95% of the total explained variance (Table 4). Goodness of fit diagnostics suggested that cultural ecosystem services hotspots were best explained by the analysed landscape features, followed by regulating ecosystem services hotspots. The first axis (72% of variance) showed that the presence of water has the strongest implications for all three service categories, followed by the presence of bogs, diversity of land cover, absence of grassland, proximity of park paths, altitude, wildness, absence of arable land and viewshed (Table 4, Figure 4). The second axis (23% of variance) indicated a trade-off between cultural and regulating ecosystem services hotspots. Whereas cultural services hotspots are mostly determined by recreational (historical buildings and viewshed) and accessibility indicators such as the proximity (as opposed to “distance to”) to park paths, car parks, and of bus stops, regulating ecosystem services hotspots are characterised by the absence of these recreational assets, i.e. long distances to park paths, car parks, and bus stops, as well as little viewshed. Regulating services hotspots coincide with bog areas and places that are considered wild, whereas recreational ecosystem services hotspots mostly coincide with the presence of arable land and the absence of wildness and bogs (Table 4, Figure 4).

The third axis (5% of variance) indicated a link between provisioning services hotspots and long distances to the next hilltop, the presence of fresh water and arable land and the absence of bogs. Interestingly, the proximity to car parks and bus stops and the presence of historical buildings coincide with provisioning ecosystem services hotspots as well (Table 4).

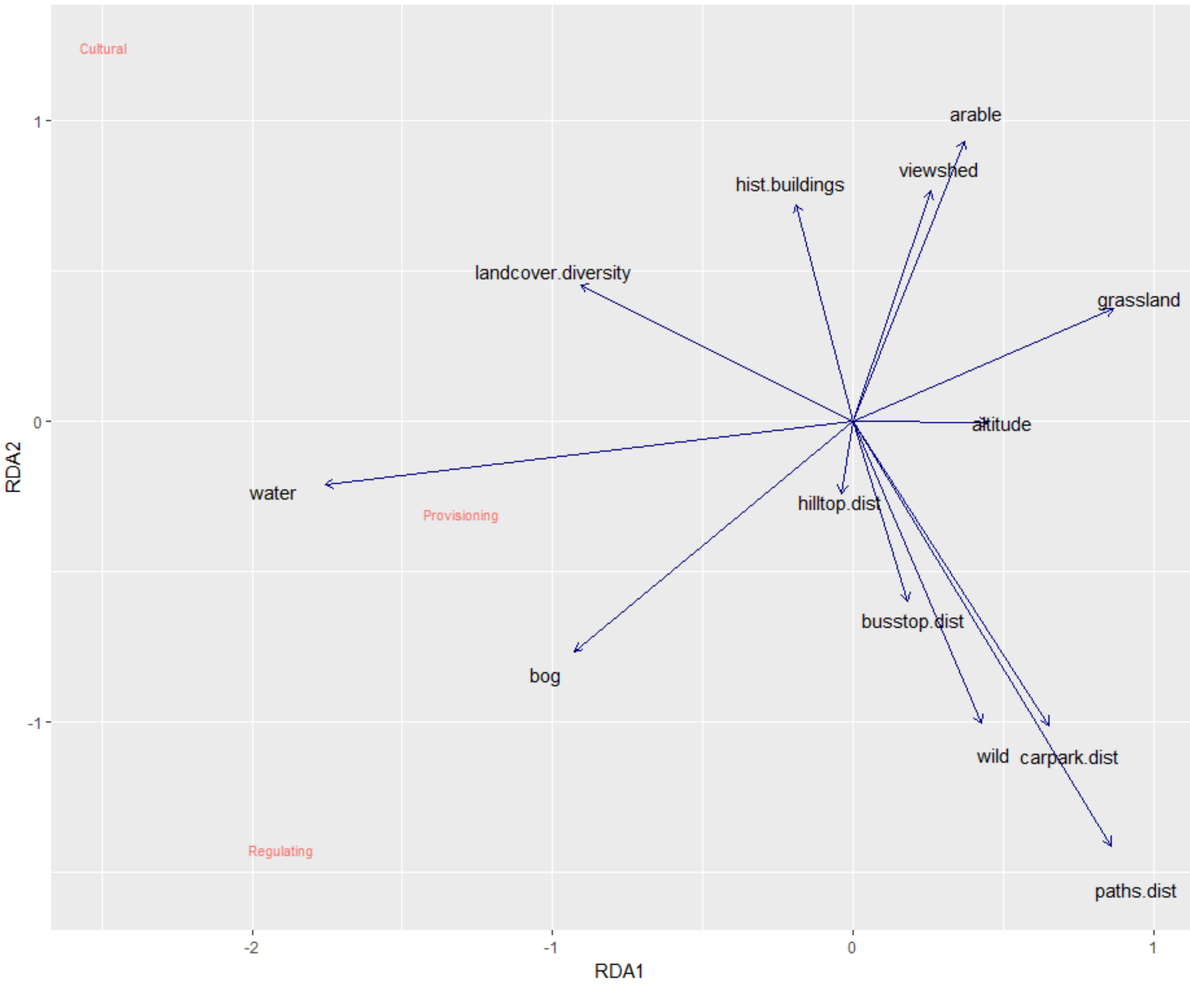

Figure 4. Redundancy analysis (RDA) biplot. The biplot shows the relationship between landscape features with a p-value < 0.05 after stepwise model building and ecosystem services hotspots, representing the first two axes of the RDA. Arrows point in the direction of increasing values for that variable. Variables are abbreviated as follows: busstop.dist = distance to bus stop, carpark.dist = distance to car park, hilltop.dist = distance to hilltop, hist.buildings = historical buildings, wild=wildness.

Table 4. Biplot scores for the redundancy analysis variables, related landscape feature classes, and importance of RDA components. Dependent variables show goodness of fit scores in parentheses. Explanatory variables with a p-value <0.05 after stepwise model building are in bold.

	Axis 1	Axis 2	Axis 3
Species scores (dependent variables)			
Cultural services hotspots	-2.55 (0.28)	1.25 (0.34)	0.17 (0.34)
Provisioning services hotspots	-1.29 (0.11)	-0.31 (0.11)	-0.81 (0.16)
Regulating ecosystem hotspots	-1.92 (0.15)	-1.45 (0.23)	0.32 (0.24)
Biplot scores (explanatory variables)			
Land cover			
Arable	0.16	0.40	-0.18
Bog	-0.39	-0.33	0.17
Grassland	0.37	0.16	0.00
Heather	0.17	-0.14	0.38
Water	-0.74	-0.10	-0.33
Woodland	-0.09	0.14	-0.12
Biodiversity			
Wildness	0.18	-0.43	0.55
Land cover diversity	-0.39	0.19	0.11
Hills			
Altitude	0.19	0.00	0.31
Slope	0.49	0.12	0.21
Cultural heritage			
Historical buildings	-0.08	0.31	0.18
Scheduled monuments	-0.16	0.19	0.34
Building	-0.08	0.31	-0.22
Geology			
Geological sites	-0.02	-0.06	0.24
Recreational assets			
Country park	-0.20	-0.10	-0.27
Distance to park paths	0.37	-0.60	0.04
Distance to hilltop	-0.02	-0.10	-0.46
Viewshed	0.11	0.33	0.11
Accessibility			
Distance to car park	0.28	-0.43	0.18
Distance to bus stop	0.08	-0.25	0.12
Importance of components			
Eigenvalue	0.82	0.26	0.05
% variance explained	72.22	22.92	4.86
Cumulative % of variance explained	72.22	95.14	100.00

5.4.3 Content analysis of current management priorities

The content analysis of the current management plan indicated a strong strategic focus on recreational and cultural use of the park, accessibility and biodiversity management (Figure 5). Most types of land cover (i.e. moorland, water, heather) were mentioned only a few times or have not been referred to once in the management plan (i.e. grassland).

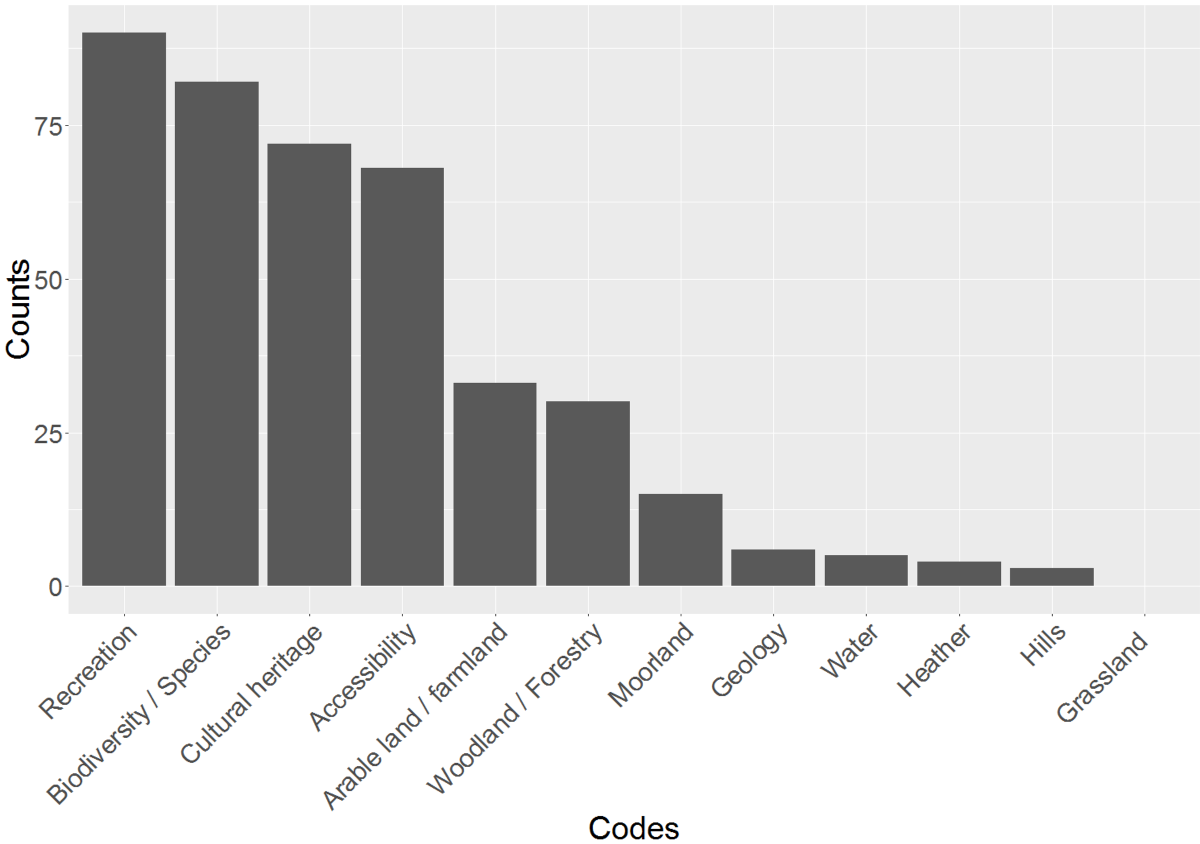

Figure 5. Number of counts for each code within the current Pentland Hills management plan (2007-2017).

Codings for recreation included several mentions of recreational pressures as well as recreational activities (Table 5). Biodiversity was referred to as “landscape”, “habitat”, and “environment”, and was accounted for by a few examples of habitat and species. Cultural heritage codings included direct mentions as well as accounts of landscape character. Codings for accessibility ranged from “responsible access for all” to public and private transportation modes. Woodland was frequently mentioned within the scope of forestry. Arable land / farmland was referred to as the predominant business activity in the Pentlands and described as a significant land use within the park which shapes the landscape. Geology codings included direct mentions as well as a few indirect ones through the account of Regionally Important Geological and Geomorphological Sites (RIGS) groups. Codings for moorland conservation were sometimes conflated with heather management. On a few occasions, they were counted towards “moorland”, despite containing references to “heather” (e.g.,”implementation of Moorland Management Plans for core areas of heather cover to ensure that the resource is maintained and enhanced”). Codings for water include water based recreation, integrated water management, and the management of reservoirs. Hills were acknowledged by their “essential character”.

Table 5. Examplary codings from the Pentland Hills regional park management plan

Codes	Exemplary codings
Recreation	“recreational pressure” “land use pressures of those visiting” “responsible public enjoyment” “recreational activities”
Biodiversity	“landscape and the habitat” “changing environment” “grouse moor” “ adder” “otter” “water vole”
Cultural heritage	“conservation of the Pentland Hills Regional Park’s natural and built heritage assets” “the Park’s landscape, cultural and natural heritage feature” “drystane dykes contribute to the landscape character and their repair encourages the retention of traditional skills”
Accessibility	“responsible access for all” “promotion and management of responsible access” “monitoring path conditions” “public access network of paths” “transport links” “private to public transport” “vehicle parking” “public utilities”
Woodland	“new forestry design to complement the hill environment” “cognisance of changes in policy and practice in relation to forestry”
Arable land / farmland	“traditional land use” “agriculture is the predominant business activity and a significant land use within the Pentland Hills Regional Park which has an influence on the landscape”
Geology	“understanding of the underlying geology of the Pentland Hills” “support and encourage participation in local RIGS [Regionally Important Geological and Geomorphological Sites] groups and include information about RIGS in interpretive material” and “discuss with local RIGS groups the potential to assess all geological expanses in the PHRP”
Water	“water based recreation” “integrated land and water management” “transfer of some of the PHRP reservoirs from Scottish Water to the City of Edinburgh Council (CEC)”
Moorland	“Blanket bog”

	"Halting the loss of moorland habitat " "Support the production and implementation of Moorland Management Plans for core areas of heather cover to ensure that the resource is maintained and enhanced"
Heather	"Secure funding to re-survey heather cover in the PHRP to allow comparison to be made with 1993 Heather Moorland Survey and 1976 Vegetation Survey" "Changes in the levels of heather moorland cover"
Hills	"the essential character of the hills"

5.4.4 Comparison of current management priorities and landscape features able to provide ecosystem services

The comparison of results of the RDA with the content analysis of the management plan revealed multiple mismatches (Figure 6). When ranking landscape features according to their weighted means based on the proportion of all three axes' contributions to the explained variance, we found surface water was the most important landscape feature for the provision of ecosystem services, followed by distance to park paths (as proxy for recreational assets), bog, land cover diversity (as proxy for biodiversity), distance to car parks (as proxy for accessibility), and grassland. Surface water and bog/moorland play a minor role in the current management plan although they are important landscape features for the provision of regulating, provisioning, and regulating ecosystem services. By contrast recreational assets ranked first in the content analysis, although they are mostly important for the provision of cultural ecosystem services. Biodiversity features, which play an important role mostly for cultural and regulating ecosystem services, are also frequently discussed in the current management plan, though there is no explicit mentioning of 'wildness'. Cultural heritage features are associated with cultural ecosystem services in the RDA and are frequently mentioned in the management plan.

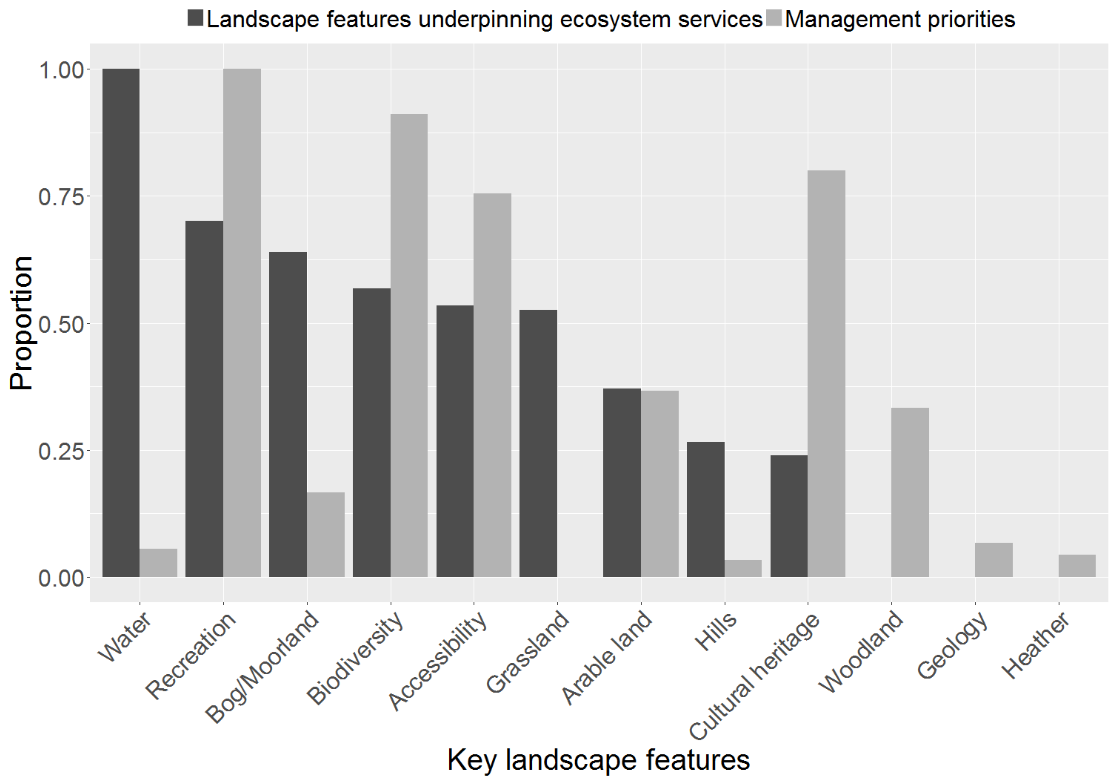

Figure 6. Proportional value of key landscape features based on landscape features underpinning ecosystem services (redundancy analysis results-dark grey) and management priorities (content analysis results-light grey). Values for landscape features underpinning ecosystem services were based on ranks according to weighted means based on the proportion of each axis' contribution to the explained variance and normalised. Values for management priorities were based on counts of the codings for each key landscape feature and normalised.

5.5 Discussion

5.5.1 Methodological approach

This study adopts an innovative approach towards the operationalisation of the ecosystem services approach in land use management. By integrating complementary and diverse methods and disciplines as well as including multiple actors, we address a few of the current challenges towards real-life application of ecosystem services valuation (Jacobs et al., 2016; Jacobs et al., 2017). Our study illustrates an effective empirical approach to utilise ecosystem services knowledge by comparing the landscape features underpinning the provision of ecosystem services with the current land use management strategy. For practical use in land use management, it can be easily reduced to a PPGIS mapping exercise which highlights spatially explicit hotspots of ecosystem service supply and potential conflicts between ecosystem services, including areas that need special attention. However, we need to mention several limitations of our mixed methods approach as well as aspects that could be developed further through future research.

First, interactions among sets of ecosystem services, so-called ecosystem service bundles, and understanding the mechanisms behind their grouping can be used to adapt management requirements in a way that they avoid trade-offs and create synergies instead of simply responding to existing synergies and trade-offs (Bennett et al., 2009). In our study, we chose a simple PPGIS approach to assess and map ecosystem services without accounting for their interactions among each other. We reviewed the correlation of ecosystem services by accounting for spatial autocorrelation and selecting a balanced sample for our further analysis. However, future research should elaborate on the landscape mechanisms behind the grouping of ecosystem services in bundles.

Second, our PPGIS approach to mapping ecosystem services is based on stakeholder perspectives and understanding of the Pentland Hills landscape and the mechanisms by which landscape features can contribute to ecosystem services supply. This is a recognised approach for mapping ecosystem services supply (Brown and Fagerholm, 2015), and essentially relies on the socio-cultural values of diverse, stakeholders. It thus highlights areas of great importance to people in the park. Stakeholders in this study had a high degree of local knowledge based human-environment interactions and personal experience in the park (see Raymond et al., 2010) as they included people from the park management, local farmers and land owners, and diverse user groups (e.g., recreational, conservation volunteers). Participants to the workshop also included people from the councils and community councils with local knowledge on plans and development planning as well as people from individual sectors with very specific local knowledge, e.g. Scottish water companies. However, our PPGIS approach is premised on stakeholder perceptions only. To present a multidimensional view of ecosystem services, future contributions should seek to combine our approach with biophysical and monetary methods based on empirical assessments of physical flows of ecosystem services, using environmental and monetary data (e.g. soil carbon stocks, recreational visitor surveys, agricultural yields).

Third, when we explore the landscape features that underpin ecosystem services, it is difficult to link ecosystem services to specific causal factors because there is still a lack of clarity of which variables contribute to the supply of ecosystem services (Andersson et al., 2015; Bennett et al., 2009; Mitchell et al., 2015). In our study, we chose a list of variables for which spatial data was available; however, to explore the effect of further variables on ecosystem services hotspots, such as species diversity, vegetation composition, and erosion risk can provide more specific information for the park management.

Fourth, the selection of sample cells has an impact on the analysis of landscape features and selection criteria need to be representative and transparent (Brown and Fagerholm, 2015). Instead of selecting all of the mapped ecosystem services by participants of the workshops, we deliberately used the Kernel function to account for the spatial variability of the landscape and not over-interpret the positional accuracy of mapped ecosystem services (Brown and Fagerholm, 2015). To account for spatial autocorrelation, we used only 10 % of the possible data points, while maintaining the balance of mapped ecosystem services per ecosystem services category in line with recent research studies (García-Nieto et al., 2015;

Palomo et al., 2014). Additionally, half of our sample cells were positioned outside of ecosystem services hotspots and served as reference points.

Fifth, the quality of content analysis is strongly dependent on the validity, reliability, accuracy and precision of measurements and can be strongly affected by human coding practice (Neuendorf, 2016). As such, coding in this study is at risk of rater bias as coding was only performed by the first author. As a general tendency, it is apparent that recreational features are repeatedly included in the current management plan while land cover and more ecologically focused landscape characteristics (e.g. water, grassland, woodland) are less frequently discussed. But slight variations in measurements have little effect in our mixed methods approach that compares general findings of the output of two strongly heterogeneous methods, such as quantitative redundancy analysis and qualitative content analysis. If, however, general terminological discrepancies arise, e.g. the conflation of farmland and grassland (section 5.2), researchers would be well advised to discuss these with the authors of the document, in our case the PHRP management, and ultimately avoid them. As a related point, it is entirely feasible that management objectives for landscape features other than recreational assets (e.g. land cover, ecologically focused aspects) are held in plans and practices that were not considered in the content analysis (e.g. whole farm plans, commonly accepted practices of farmers and other land managers, relevant regulatory regimes). Future research should aim to take a more comprehensive view of the plans, policies and practices impacting land use management in the Park by including additional material in the content analysis (including interviews with farmers and other land managers).

Finally, there are several caveats of PPGIS that apply to our case study as well, such as the effect of scale on the mapping results (Grêt-Regamey et al., 2015) and the number and selection of participants at the workshop (Palomo et al., 2014). Despite these aspects, our study demonstrates how ecosystem services knowledge can be used to guide future land use management towards a better understanding of landscape features that influence the provision of ecosystem services in the PHRP. The collaborative character of PPGIS between facilitators and participants, for instance, enables a better interpretation of the results. In this study it enabled us to exclude erosion control from the analysis due to false interpretation of this service on behalf of the participants.

5.5.2 Implications for land use management

In their review of empirical studies that map ecosystem services using PPGIS, Brown and Fagerholm (2015) report that none of the reviewed articles describe how their mapped ecosystem data could practically be used for land use management. By analysing landscape features that are capable to provide ecosystem services and comparing them to current management priorities, we addressed this research gap and provide recommendations for the revised management plan as outlined below.

In line with previous studies (Burkhard et al., 2009; Martínez Pastur et al., 2016; van Zanten et al., 2016), our findings suggest that certain types of land cover are important for the supply of ecosystem services. For instance, cultural ecosystem services have been linked to accessibility indicators (Martínez Pastur et al., 2016) and arable land (van Berkel and Verburg, 2014; van Zanten et al., 2016) in previous studies. Grassland is also a significant contributor to cultural services as it has the capacity to provide local identity and recreation (Martínez Pastur et al., 2016) as well as aesthetic value (Lamarque et al., 2011). Our results further underline Brown's (2013) findings that water has the greatest social value for ecosystem services and that land cover diversity is an important contributor to ecosystem services value (van Zanten et al., 2016). However, our results could not confirm the importance of woodland for the provision of ecosystem services (Burkhard et al., 2009; Brown, 2013; Martínez Pastur et al., 2016). This could be due to the small size and dispersal of patches in the PHRP that are covered with woodland (section 5.2.). The largest connected area covered with woodland, a non-native commercial conifer plantation, is at the very southwest border which is among the least visited of the park (Schmidt et al., 2016b). Consequently, stakeholders did not associate any of the cultural ecosystem services with that particular area. The comparison analysis between the identification of landscape features essential to provide ecosystem services and those landscape features included in the current management plan shows that there are numerous associations between current management practices and cultural ecosystem services. However, there is a need for land use management to focus on landscape features that are capable of supplying regulating and provisioning ecosystem services in future management planning.

Our analysis has the potential to increase the consideration of ecosystem services in future PHRP management by highlighting the mismatch between current priorities of landscape feature management and those landscape features that underpin ecosystem services supply. Several landscape features could be associated with ecosystem services in the spatial analysis but are currently not prioritised in the management plan. Based on our analysis, all ecosystem service categories would benefit if future management would highlight the importance of surface water bodies such as the reservoirs and emphasise an integrated management of the water bodies, e.g. by habitat management in riparian areas, access provision, water quality management. In the Pentland Hills, water bodies are partially owned and managed by Scottish Water, a publicly owned company that provides drinking water and disposes of sewage water in Scotland. Given that not all reservoirs lie within the management authority of the regional park, the effect of emphasising the benefit of water bodies in the next management plan may be restricted.

For the supply of cultural ecosystem services, we found recreational, accessibility, and cultural heritage features to be most important followed by biodiversity, arable land and grassland. Several of these landscape features are already among the priorities of current management planning (i.e. recreational assets, biodiversity, accessibility, and cultural heritage). In our spatial analysis, the important role of arable land for the provision of cultural ecosystem services could be conflated because of the proximity of arable land and the water reservoirs, which provide various opportunities for experiential and physical interactions with nature. We therefore suggest to further investigate the need to include arable land as a management priority (including possible risks to productive farm land that may arise from increased recreational pressure). Surprisingly, grassland received no mentions in the management plan at all, implying it has no priority despite its relevance for sheep farming activities and giving the Pentland Hills much of its landscape character. This can likely be explained by our selection of codings: We included “farmland” in the same category as “arable land” in our analysis of the management plan, not considering the possibility that farmland may refer to areas where sheep farming takes place, i.e. grassland. Whether an area is used for crop production or for sheep farming can have strong implications for the provision of ecosystem services, e.g. by limiting access to the area, compromising wildlife habitat. Grassland, which is also used for sheep farming in the PHRP, likely fell into the category of “farmland” in the terminology of the management plan, which in our analysis counted towards “arable land”. However, next to cultural, recreational, and accessibility features, cultural ecosystem services hotspots are frequently associated with grassland which should therefore be highlighted in the future management plan.

For the supply of regulating ecosystem services, we found bogs and biodiversity to be most important. Because heather was occasionally mentioned within moorland conservation measures in the management plan, the differentiation of bog and moorland in the document analysis was conflated in a few cases. If there was a clear reference to moorland conservation, we counted the coding toward “moorland”. While heather and moorland measures were sometimes conflated in the management plan, the spatial analysis suggested that bogs are a significant contributor to regulating ecosystem services while heather was found to be generally insignificant for the supply of ecosystem services. Because of this difference for ecosystem service supply, we suggest for the future management strategy to distinguish more clearly between measures for heather and bogs/moorland. Further, we emphasise the importance of moorland for regulating ecosystem services and suggest to make it a priority in the future management plan, e.g. by restricting bog areas to extensive grazing, moorland vegetation management, managing an effective muirburn regime.

Biodiversity and species conservation are currently the second highest priority in the management plan, and landscape features associated with biodiversity (i.e. wildness, land cover diversity) have also been confirmed highly relevant for ecosystem services supply. These results indicate good synergies between extant conservation measures and ecosystem service supply in the PHRP. The emphasis on biodiversity is considerably higher in the current management plan than its importance for ecosystem service supply (Figure 6). Even so, conflicts with biodiversity conservation measures would be very limited in this case study due to the generally low-impact use of the regional park, i.e. restricted development, extensive farming practices, sheep raising, principles for the management of events. Still, our results indicate that a shift towards an ecosystem service focused management can have implications on the conservation of habitats and biodiversity. Based on our results, we suggest to widen the scope of biodiversity measures and highlight the importance of wild land areas as well as the small-scale diversity of habitats because both make significant contributions to the provision of regulating and cultural ecosystem services. Both bogs and biodiversity are central for the supply of regulating ecosystem services. Including measures for both in the new management strategy could potentially maintain and enhance the supply of regulating ecosystem services.

We found the presence of water and arable land most important for the supply of provisioning ecosystem services. Within the management plan, arable land has been frequently associated with "traditional land use" as well as "the local economy of the hills". Because the management plan highlights the economic importance of agriculture for employment and it is one of the central land uses in the PHRP, we suggest to considering measures that enable a balanced use of farming, conservation, and recreational use to foster a sustainable and multifunctional land use management in the PHRP. Because both water and arable are currently given little priority in the strategic management and because of water's overall importance for the supply of ecosystem services, we emphasise that suitable measures, particularly for water management, should be identified and included in the revised management plan.

Finally, it is important to consider the drivers behind the production of the current management plan and the types of information and evidence used to inform this, as these factors influence the scope and content of the plan. Management plan development was informed by consultation with the PHRP Consultative Forum (see section 2), meetings with specific land managers and the PHRP ranger service, and an initial presentation of the draft plan to the PHRP Joint Committee, a steering group which comprises elected members from the three local authorities intersecting the park as well as several advising members and is responsible for all decisions within the park's remit. Further, a statutory strategic environmental assessment (SEA) of the draft plan was undertaken in accordance with the Environmental Assessment (Scotland) Act 2005. This provided a legal basis for wider public consultation on the draft plan along with *ex-ante* assessment of the plan's potential environmental effects on discrete environmental topics (e.g. species and habitats within the PHRP, water resources / assets, air quality) (Scott Wilson, 2007b). Although not considered explicitly in our study, these process aspects could undoubtedly influence the scope and final content of the management plan and therefore its efficacy in terms of landscape management for specific objectives, including protection of biodiversity and enhancement of ecosystem services. Future iterations of the management plan should consider how these process aspects can best be designed to ensure the provision of ecosystem services. For example, using SEA as a driver for more effective public participation and integration of wider public values with plan-making (Phillips and Jóao, 2017); considering how SEA could be used to assess the impacts of the plan *ex-ante* on ecosystems and ecosystem services (Geneletti, 2012; Baker et al., 2013); and further democratisation of land use management planning processes to capture wider public and stakeholder values (Bourgoin and Castella, 2011; Phillips and Jóao, 2017).

Though the results of this study have the potential to improve land use management decision-making for ecosystem services, the scope of the management plan in the PHRP is limited. Whereas the City of Edinburgh Council as the managing and lead authority is responsible to express the Park's strategic vision in the new management plan, the document provides an advisory function only for land owners. Despite this, deliberative processes such as stakeholder workshops that also act as a platform for communication in between actors may lead to greater acceptance of land use planning objectives (Hauck et al., 2013; Phillips and João, 2017). As indicated at the stakeholder workshop, participants appreciated the opportunity of being actively involved in land use planning issues. At a later meeting, workshop participants expressed interest of reconvening a regular land owner meeting as a forum for raising land owner specific issues. This could be an important mechanism for delivering practical on the ground action that is largely undertaken on the basis of landowner goodwill. Further, while it can be helpful to use ecosystem service information to guide land use management decision-making (i.e. where the objective is sustaining and enhancing the provision of priority services), empirical evidence from recent studies has shown weak links between ecosystem services provision and key aspects of biodiversity, especially birds (Chan et al., 2006; Morelli et al., 2017; Ziv et al., 2017). This highlights the importance of articulating clearly what the objectives are for the future management planning in the Park because a focus on ecosystem service provision will not necessarily result in benefits for biodiversity conservation. In this study, we suggest to incorporate ecosystem services information into the future management strategy to secure a broader set of desired outcomes. In this context, we recommend to use them alongside biodiversity and recreational conservation measures.

5.6 Conclusion

In the light of increasing calls for the operationalisation of ecosystem services, this study provides a practical approach for the utilisation of ecosystem service research and demonstrates the implications of adopting the ecosystem services concept in land use management. The methodology applied here, systematically reveals the variety of ecosystem services diverse stakeholders benefit from in the regional park, and effectively relates them to current management priorities. The comparison of landscape features underpinning ecosystem services and landscape features currently prioritised by land management indicated that the supply of ecosystem services could benefit from an explicit integration of specific landscape features that are crucial for the supply of ecosystem services, e.g. water bodies, bogs, and grassland into the management plan. Our results highlight the benefits of including stakeholders′ perspectives, local knowledge, and participatory mapping for practical land use management planning.

In addition, our study shows that such an ecosystem services centered approach to management planning can reveal the importance of features with high relevance for biodiversity, such as the emphasis on wild areas and habitat diversity in the PHRP. However, it might not be desirable to focus on the supply of ecosystem services under all circumstances, and potential conflicts with conservation or other management objectives need to be well evaluated, in particularly for protected areas. Therefore, to give a credible account of management recommendations, it is crucial to understand management objectives, potential synergies between biodiversity conservation and ecosystem services, and possible social conflicts derived from the management of different ecosystem services.

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6. Discussion

In this thesis, I have addressed several challenges to explore the ability of socio-cultural valuation methods for the operationalisation of ESs research in land use management. The main objectives of this research were (1) to assess the current role of socio-cultural valuation in ESs research, (2) to test socio-cultural valuation methods of ESs and their relevance for land use preferences by exploring methodological opportunities and limitations, and (3) to implement ESs research into land use management through socio-cultural valuation (Figure 1.1).

Here, I discuss the main findings of this dissertation. This chapter is structured as follows. First, I present the contributions of my work to socio-cultural valuation of ESs and its operationalisation in land use management. These contributions are structured by the three objectives of this dissertation and contain a summary of the answers of the research questions at the end of each subsection. Second, I present general methodological reflections. Third, I discuss my findings in the light of current policy developments. In the subsequent chapter, I present the general conclusions of this dissertation (chapter 7).

6.1 Contributions to socio-cultural valuation of ESs

6.1.1 Assessing the current role of social cultural valuation in ESs assessments

ESs assessments have traditionally focused on revealing monetary values, leaving non-monetary socio-cultural values largely underrepresented (Gómez-Baggethun et al., 2014; Nieto-Romero et al., 2014; Seppelt et al., 2011; Vihervaara et al., 2010). Having its background in ecology and economics (Gomez-Baggethun et al., 2010; Mace, 2014), ESs research for a long time has not put a theoretical or methodological focus on socio-cultural valuation (Iniesta-Arandia et al., under review; Scholte et al., 2015). As a result, socio-cultural values were referred to in a range of studies with widely differing context and meaning of the term, often times conflating them with cultural services (Chan et al., 2012b). In chapter 3, I contribute to the effort of developing the methodological background of socio-cultural values by reviewing their patterns of use in ESs assessments relating to ESs categories, cultural services in particular, specific valuation methods, and stakeholder participation. This chapter presents a novel typology of benefits to describe the socio-cultural value of ESs. Further, it highlights the role of socio-cultural values in contemporary ESs research and informs the ESs research community of methodological implications. It is the first study to review socio-cultural values for all ESs categories, as previous reviews have focused on the cultural service domain (e.g. Hernandez-Morcillo et al., 2013; Milcu et al., 2013).

My results provide evidence that socio-cultural values are an integral part of ESs research. While socio-cultural values were found across studies that investigate cultural, provisioning, and regulating services, I could show that they are linked to the assessment of cultural services to a greater degree than to the other ESs categories. My results showed a strong link between selected social benefits (i.e. heritage, therapeutic, and existence benefits) and provisioning and supporting services which indicates an awareness of social implications of provisioning and supporting services. Previous studies confirm high socio-cultural values for provisioning services (Oteros-Rozas et al., 2014) but indicate low values for supporting services (Raymond et al., 2009). Supporting services are different from the rest of the service types because they describe ecosystem functions and processes that are necessary for the production of the other ESs (MA, 2005). This indirect nature of their ability to contribute to human wellbeing might explain why people tend to undervalue supporting services (Carpenter et al., 2006). The practicality of supporting services has been widely debated in ESs research (Abson and Termansen, 2011; Wallace, 2007) which lead to their omission in the newer ESs classification (i.e. CICES; Haines-Young and Potschin, 2013a). In my own value assessment (chapter 4) and mapping of ESs (chapter 5), I used CICES which adopts a 'final service' approach that considers ecosystem outputs directly consumed or used by a beneficiary. Although previous studies have found correlations of the spatial occurrence between regulating and cultural services (Gomez-Baggethun and Barton, 2013; Maes et al., 2012), I could not demonstrate a significant relationship between regulating services and the assessment of socio-cultural values. This could partly be explained because regulating services are among the most challenging ESs to identify for stakeholders (Brown et al., 2012). My results suggest that studies that assessed regulating services frequently focused on ecosystem functions and processes and did not explicitly link their assessment to socio-cultural values or human well-being. In the light of those findings, it is of particular importance for future research to find ways to effectively address regulating services in socio-cultural valuation studies to underline their value for people.

While my results demonstrate that socio-cultural values are more frequently associated to cultural services than the other service categories, they also suggest that socio-cultural values are linked to certain cultural service types more than others. I showed the co-occurrence of amenity benefits and recreation/tourism and aesthetic appreciation, therapeutic benefits and science/education as well as inspiration, spiritual benefits and inspiration, and option and bequest values and cultural heritage. However, I could not substantiate some expected matches, as for instance between spiritual benefits and the assessment of spiritual experience and heritage benefits and the assessment of cultural heritage. Spiritual benefits are the least assessed of all social benefit types under review, which could explain why they did not show a significant association with the spiritual experience of nature. In the light of the frequent conflation of cultural services and socio-cultural values, which is arguably influenced by the study set-up, my results highlight the notion that they are indeed not interchangeable.

In line with other research that found a dominance of monetary methods in ESs research (Milcu et al., 2013; Seppelt et al., 2011), I found that monetary methods prevail over the use of non-monetary methods in the assessment of socio-cultural benefits. Similar to Iniesta-Arandia (under review), I found that quantitative non-monetary methods like rating were more frequently employed than qualitative deliberative methods. Chapter 3 demonstrates that studies using simulated market approaches such as contingent valuation or choice experiments also assess a wide range of socio-cultural values. Significant correlations were found between therapeutic, heritage, amenity, existence, economic, option, and bequest values. This underlines recent research on relationships between value types and valuation methods. Jacobs et al. (2017) showed the suitability of monetary methods to depict instrumental, i.e. contributions of nature to the achievement of human's life quality (such as therapeutic, heritage, amenity, and economic benefits) and non-anthropocentric values, i.e. values of nature independent of humans and inherent value of nature (such as existence, option, bequest values). Their study found monetary methods to be less suitable for relational values, which were not included in my review. Relational values refer to a fairly new class of values, which go beyond intrinsic and instrumental values by attributing values that are derivative of relationships between people and nature (Chan et al., 2016). Unlike simulated market approaches, market-based and surrogate market approaches did not or without significant frequency occur in studies that assess socio-cultural values. In contrast, all studies that used non-monetary valuation approaches also addressed socio-cultural values. These results highlight the limitations of certain monetary valuation methods (i.e. market-based, surrogate market) in regard to the assessment of socio-cultural values. On the other hand, I provide evidence that other monetary valuation methods (i.e. contingent valuation, choice experiments) have the potential to measure socio-cultural value by using a monetary metric.

There is a common understanding in ESs research that stakeholder participation facilitates the consideration of socio-cultural values (Chan et al., 2012b; Iniesta-Arandia et al., 2014; Scholte et al., 2015). My research empirically demonstrates that socio-cultural values were derived significantly more frequently in studies that included stakeholders (including the public) in their valuation exercise. My results in chapter 3 thus support the recent claims that future ESs valuation studies should include stakeholders in order to represent the diversity of values of nature (Diaz et al., 2015; Jacobs et al., 2016).

Research question 1: To what extent have socio-cultural values been addressed in ESs assessments?

Understanding to what extent socio-cultural values have been addressed in contemporary ESs research is central towards advancing and promoting them in future research. This dissertation provides evidence that socio-cultural values are an integral part in ESs research. Though they are linked to the assessment of cultural services to a greater degree, socio-cultural values should not be confined to the category of cultural services because they can be equally assessed for regulating and provisioning services. Socio-cultural values can be assessed by monetary and non-monetary methods and their assessment is effectively facilitated by stakeholder participation. The findings presented in this research support the development of systems knowledge of socio-cultural valuation which is relevant to facilitate its future application in ESs research.

6.1.2 Testing socio-cultural valuation methods of ESs and their relevance for land use preferences: exploring methodological opportunities and limitations

Central aim of this dissertation is to explore the opportunities and limitations of socio-cultural valuation methods for the operationalisation of ESs research in land use management. I address this aim in chapter 4 by comparing the results of different socio-cultural valuation methods of ESs. Though it has recently been demonstrated that the choice of valuation method bears the risk of affecting the valuation outcome (Martín-López et al., 2014), so far there are few methodological studies assessing this risk (Jacobs et al., 2017). In chapter 4, I compared two of the most understudied methods in ESs research, i.e. rating, weighting (Schmidt et al., 2016) and two value intentions, i.e. self-oriented, other-oriented (Kenter et al., 2015) to explore opportunities and limitations of socio-cultural valuation methods. I found that different methods of socio-cultural valuation revealed different values of ESs. For instance, I found significant differences between the rating (on a Likert-scale, which allows for an unlimited distribution of points) and weighting (allocation of 100 points across all 9 ESs, which prompts respondents to prioritise their benefits) of ESs (chapter 4.3.2). Whereas the rating exercise revealed information on the general importance of ESs, the weighting results indicated the relative importance of ESs and enabled me to draw conclusions on the respondents' priorities. Further, I found that different value intentions (i.e. self-oriented, other-oriented) can lead to very different results in ESs value. Whereas self-oriented values were distributed heterogeneously, attributing the lowest values to those ESs that respondents were least informed about, other-oriented values were collectively given high and very high values (chapter 4.4.1). This could be explained by the theory that ratings for nature are generally higher for a 'best friend' than for the participants themselves (Herzog et al., 2002). However, my finding underlines the need to consciously choose the value intention to be addressed and to articulate unambiguous questions according to this choice, or to explicitly include different value intentions in order to capture the richness of value motivations in ESs assessments (Jacobs et al., 2016; Kenter et al., 2015). Chapter 4 advances the understanding of the opportunities and limitations of socio-cultural valuation methods and can inform ESs researchers and practitioners how different methods of socio-cultural valuation may reveal different values of ESs.

I further addressed the recent rise of ESs applications in landscape research. As such, I developed a novel tool for the assessment and visualisation of land use preferences (LANDPREF). Based on preferences for future land use in the Pentland Hills identified with LANDPREF, I determined five groups of respondents with different land use preferences and explored their associations with socio-cultural values of ESs. By testing to what extent land use preferences could be explained by user characteristics or their socio-cultural values of ESs, I made a surprising discovery. ESs values were distributed fairly equally across the groups with diverging land use preferences. Although previous studies that explore preferences for land use management by using photorealistic landscape visualisations suggest that there is a strong link between ESs values and land use preferences (e.g., Garcia-

Llorente et al., 2012; Zoderer et al., 2016), in this study, ESs values could not explain land use preferences. This finding suggests that diverse land use scenarios have the capacity to provide similar ESs so that different landscape configurations may lead to the provision of similar ESs. For instance, a landscape that includes technical structures such as wind turbines (as indicated by Multi-functionalists) is found capable to provide 'experiential interactions with nature' to a similar extent as a landscape without technical structures (as indicated by Woodland enthusiasts; chapter 4.3.2).

Within LANDPREF, I address the challenge of the identification of synergies and trade-offs. LANDPREF allows respondents to interactively combine competing land uses at six intensity levels, providing instant visual feedback of their choice. However, land use options were restricted based on a rule-based algorithm that indicated the potential impact of every land use on each of the other land uses in order to account for trade-offs and synergies. Respondents were therefore restricted to make feasible choices in concurrent land uses. The development of LANDPREF and the understanding of the limited predictive power of socio-cultural ESs values for land use preferences contributed to ESs research in two ways. First, LANDPREF is an openly available tool for the assessment and visualisation of land use preferences that can either be directly used by practitioners and researchers or adapted to represent a different spatial context. Since its initialisation in the Pentland Hills, LANDPREF has been adapted for a study on woodland management and expansion strategies in the Scottish Highlands (Sing, 2016). Second, the low predictive power of socio-cultural values for land use preferences highlights the need to further explore the relationship between landscape configuration and ESs value, and that without further determination both should not be used interchangeably.

Research question 2: What are the implications of applying different socio-cultural valuation methods for ESs values?

Comparing different methods of socio-cultural valuation led to novel insights on ESs value. Whereas rating revealed a general value of ESs, weighting was found more suitable to identify relative values and priorities across the ESs. Value dimensions likewise differed in the distribution of values, generally implying a higher value for others than for respondents themselves. My research underlines the need to include different value dimensions to capture the richness of value motivations in ESs assessments and advances the understanding of the limitations and opportunities of different methods. It bridges the gap between systems knowledge, the understanding of socio-cultural values in ESs research, and normative knowledge, the assessment of ESs values and land use preferences.

Research question 3: To what extent are land use preferences explained by socio-cultural values of ESs?

Testing the extent to which land use preferences could be explained by socio-cultural values of ESs, contributed to a better understanding of the link between ESs values and landscape values. More specifically, I showed that ESs values were distributed very similarly across groups with differing land use preferences. Thus, I provided empirical evidence that ESs values and landscape values are two concepts that should not be used interchangeably. My research highlights the notion 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. It emphasises the need for a clear conceptual differentiation between ESs values and landscape values in both ESs and landscape research. By developing a novel tool for the assessment and visualisation of land use preferences, this research contributes to the effort of establishing new ways of value assessments and the development of normative knowledge.

6.1.3 Implementing ecosystem services research into land use management through socio-cultural valuation

The operationalisation of ESs research and with it the practical implementation of ESs knowledge into land use management has found to be gravely under-researched. While many studies (including chapters 3 and 4) focus on creating conceptual and methodological knowledge on ESs, calls have emerged to operationalise the ESs approach in everyday land use management. Chapter 5 provides a practical example of how socio-cultural ESs values can be implemented into land use management by illustrating which landscape features should be prioritised because of their role for the supply of ESs. Additionally, this study identifies those landscape features, which despite their importance for the provision of ESs, are not yet included in the management objectives.

In chapter 5, I used a mixed methods approach to explore a way to implement ESs knowledge and values into land use management. Socio-cultural values are found more suitable to effectively contribute to land use management than other value domains because of their ability to engage a range of disciplinary perspectives that can reflect multifaceted views better than valuation approaches that focus on a single direct use value (van Riper et al., 2017). It is advised to use complementary and diverse methods to adequately account for the diversity of ways by which people value nature (Jacobs et al., 2017). By combining disciplines and methods as well as including multiple social actors, my research addresses important challenges towards the real-life application of ESs valuation (Jacobs et al., 2016).

I address one of the current priorities in contemporary ESs research, namely to operationalise the approach for land use management (Daily et al., 2009; Dick et al., 2017), in several ways. First, I identified the integration of transdisciplinary research as one of the challenges to overcome towards the operationalisation of ESs research (chapter 1.2.3.). By adopting a mixed methods approach, I used methodological knowledge from multiple disciplines to explore a way to implement ESs knowledge and values into land use management. I used participatory mapping and stakeholder knowledge for data collection, which in itself is subject to two disciplines, i.e. geographic information systems (GIS) and public participation (PP)(Brown and Kyttä, 2014). For the analysis, I employed geospatial analysis as well as content analysis, the latter of which has its roots in the social sciences. This approach enabled me to integrate local knowledge with other sources of information, which was another challenge towards the operationalisation of the ESs approach (see Bennett et al., 2015). Second, is advised to use complementary and diverse methods to adequately account for the diversity of ways by which people value nature (Jacobs et al., 2017). By combining disciplines and methods as well as including multiple social actors, my research addresses important challenges towards the real-life application of ESs valuation (Jacobs et al., 2016). Third, chapter 5 contributes to an understanding of how spatial and participatory approaches can be linked to optimise the multifunctional use of ecosystems (de Groot et al., 2010). By addressing several challenges of the implementation of ESs knowledge into land use management (chapter 1.2.3.), chapter 5 adopts a pragmatic methodological approach and presents a practical example in a real world context. The study represents a vivid proof of concept for the implementation of ESs in land use management. My findings thus are likely to directly contribute to the elaboration of the next management plan of the Pentland Hills regional park, and the methodology can also be easily adapted by practitioners to be used within other spatial contexts.

Research question 4: Which landscape features with particular relevance to ESs supply are explicitly considered in land use management?

By using landscape features underpinning ESs supply and comparing these to landscape features considered in contemporary land use management, I combine quantitative and qualitative methods to a novel approach that links ESs knowledge and management priorities. This research provides on-the-ground knowledge to the land use management of the regional park on which landscape features that are important for ESs supply are not sufficiently accounted for in its current management strategy, i.e. water, bogs, land cover diversity, grassland, and areas considered wild. This knowledge is useful for the identification of priority sites for land use management and to account for a broader set of desired outcomes. However, I emphasise that this research can support but should not replace the clear articulation of management objectives in the light of recent findings that there are weak links between the supply of ESs and key aspects of biodiversity. This approach bridges the gap between normative and transformative knowledge because it adopts socio-cultural valuation (i.e. participatory mapping) to implement ESs research into land use management.

Research question 5: How can participatory approaches accounting for ESs be operationalised in land use management?

In this research, I provide a novel approach to explore how ESs knowledge can be operationalised in land use management. I demonstrate how stakeholder knowledge and values can be used for the identification of ESs hotspots and how these hotspots can be used for site prioritisation when they are linked to current management priorities. Integrating local knowledge is a crucial undertaking land use management, which is also called for by global and regional policies. It enables stakeholders (and the public) to express diverse needs and interests. This enables the consideration of the diverse values of nature and allows for constructive discussions towards a more sustainable management should these values not be aligned with the conservation objectives.

6.2 Overall methodological implications

The methodological approach adopted in this dissertation has some limitations but also creates opportunities that deserve attention. First, the quantitative measurement of a limited set of ESs (chapter 4) may not capture the broad range of value items relevant to the socio-cultural context at stake (Tadaki et al., 2017). I used this expert-based selection of ESs with the aim to facilitate a comparative analysis of the outcomes of different methods. Second, despite its suitability in certain management contexts, the sole assessment of assigned values may not shed light on the underlying motivations and held values (ibid.). These limitations can be addressed by using qualitative methods for eliciting socio-cultural values of ESs such as focus groups, deliberative methods, and narrative approaches. In this research, I provide novel methodological insights on how multiple valuation methods and quantitative and qualitative data can be combined in a non-monetary valuation approach towards the delineation of diverse values of nature and ESs. Furthermore, I advance the operationalisation of ESs knowledge by demonstrating a practical approach of how participatory mapping of ESs can be implemented into strategical land use management.

6.3 Policy relevance

Interest in including diverse values for ESs has increased in international policy making over the last years. The 'Ecosystem Approach' is the primary framework under the Convention on Biological Diversity (CBD) for the integrated management of land, water, and living resources that promotes conservation and sustainable land use in an equitable way (UNEP, 2000). Of its 12 principles, five more or less explicitly refer to the importance of people's values. For instance, Principle 1 of the Ecosystem Approach states that objectives of land, water, and living resources management are a matter of societal choices. Subsequently, Principle 2 calls for a decentralized management to the lowest appropriate level, to account for responsibility, participation, and the use of local knowledge. Principle 7 expresses the importance of undertaking the ecosystem approach at the appropriate scales, indicating that this appropriateness depends on the objectives which will be defined operationally by users, managers, and scientists. Further, Principle 11 articulates that within the Ecosystem Approach all forms of relevant information should be considered, including scientific, indigenous, and local knowledge, innovations and practices. Finally, Principle 12 calls for an involvement of all relevant sectors of society, and scientific disciplines to address the complexity of socio-ecological systems. The ESs approach is also central to the 'Aichi Biodiversity Targets' which are part of the Strategic Plan for Biodiversity 2011-2020 of the CBD (UNEP, 2010). Within Strategic goal A., the Aichi Targets address the underlying causes of biodiversity loss by mainstreaming biodiversity across government and society. By 2020, people should be aware of the values of biodiversity and the steps they can take to conserve it and use it sustainably (Target 1) and biodiversity values should be integrated into national and local development (Target 2). Further, traditional knowledge and practices of local communities should be integrated (Target 18) and biodiversity knowledge should be improved, widely shared and transferred, and applied (Target 19). Both strategic approaches of the CBD (i.e. the Ecosystem Approach and Aichi Targets) emphasise the importance of public knowledge and values in order to either set biodiversity goals as priorities or to raise awareness and co-develop solutions to overcome these barriers towards a sustainable land use management.

To meet the goals of the Ecosystem Approach and the Aichi Targets, these strategies have been adopted in European and national policies. On the European level, the European Biodiversity Strategy aims to halt the loss of biodiversity and ecosystem services in the EU by 2020 (European Commission, 2011). Although the European Biodiversity Strategy briefly recognises the importance to promote economic, territorial, and social cohesion and to safeguard the EU's cultural heritage, it does not emphasise the merit of public knowledge and values to contribute to biodiversity conservation or to raise awareness in any of its six targets. This is rectified by the European Parliament within its resolution on the mid-term review of the Biodiversity Strategy, which, as a headline target, "calls for a multi-stakeholder approach and stresses the vital role of national, regional and local actors, and of their full participation in this process; stresses that funding and greater public awareness and understanding of, and support for, biodiversity protection are also essential; considers that a good information policy and the early involvement of all actors concerned, including socio-economic actors, is therefore key to achieving these objectives" (European Parliament, 2016). The resolution on the mid-term review particularly recognises the eminent role of people to contribute to the preservation of biodiversity, for instance by sustainable and responsible land cultivation and livestock breeding (E.) and individual measures by members of local or regional action groups to promote biodiversity (K.), and highlights the increased public interest in biodiversity loss (J.). Considering that the mid-term report anticipates continuing loss of biodiversity and that the 2020 targets will not be achieved without additional efforts, the emphasis on an active public involvement to contribute to these goals is particularly meaningful.

To contribute to international biodiversity targets, the ESs approach is also adopted by various national policies. For instance, the delivery of the CBD and Aichi Targets in the UK is guided by the UK Post-2010 Biodiversity Framework, which is overseen by all four governments of the UK (Joint Nature Conservation Committee; JNCC and Defra, 2012). This framework explicitly aims to enhance implementation through participatory planning, knowledge management, and capacity building (Strategic goal E). In the case of Scotland, the framework underpinning the international biodiversity frameworks is the Scottish Biodiversity Strategy. It comprises the 25-year strategy for the conservation and enhancement of biodiversity in Scotland (Scottish Executive, 2004) and the response to the more recent Aichi Targets, EU Biodiversity Strategy, and advancement of the ESs approach, namely the '2020 Challenge for Scotland's Biodiversity' (Scottish Government, 2013). The Scottish Biodiversity Strategy accounts for human-nature relationships, for instance by highlighting the importance to promote public interest in and awareness of biodiversity, to facilitate enjoyment and appreciation of biodiversity particularly in the light of health benefits, and to include people in decision-making (especially those who benefit from ESs and those who manage them). In addition, the Scottish Land Use Strategy, which has been initialised by the Climate Change Scotland Act, implemented the ESs approach in 2011 in its framework towards sustainable land use (Scottish Government, 2016). The Land Use Strategy states that people should have opportunities to contribute to debates and decisions in land use management "which affect their lives and their future" (Principle h.).

These recent developments towards the integration of the ESs approach in national policies and the emphasis on peoples' knowledge and values in decision-making processes open the way for the operationalisation of the ESs approach including socio-cultural values in real-world land use management. For instance, Scottish Natural Heritage (SNH), the Scottish public body responsible for the country's natural heritage, started in 2015 to promote the 'ecosystem approach' as central to meeting the 2020 Challenge for Scotland's Biodiversity and to secure the ecosystems' services for future generations. As a result, SNH encouraged operational pilot projects on collaborative, ESs based approaches to land use management. After learning about the results of my previous study on socio-cultural values of ESs in the park, one of these pilot studies was developed and co-designed for the Pentland Hills regional park by park managers, researchers, and SNH. SNH finally initiated the stakeholder workshop described in chapter 5.3.1 as part of their project on collaborative land use management in the Pentland Hills regional park. This framing made it possible to assemble land owners, organized stakeholder groups, council representatives, and park managers together to discuss overarching values of the park and their potential implications for the park's future strategic management (as described in chapter 5). This example demonstrates how international and national policy developments that emphasise the adoption of the ESs approach as well as public participation in land use management, has the potential to trickle down to regional levels and eventually lead to practical examples of the operationalisation of the ESs approach. My involvement with the regional park and my research as described in chapter 4 sparked SNH's interest and stimulated their pilot study in the Pentland Hills.

By investigating users' preferences and values (chapter 4), methods to elicit them (chapter 4), as well as stakeholder knowledge (chapter 5), this dissertation contributes to the methodological and strategical advancements of the ESs approach. These advancements can be used to account for social-cultural values of ESs in line with the aforementioned international, European, and national policies. In particular, the methodological implications of socio-cultural valuation methods and their difference to land use preferences (chapter 4) support researchers and policy makers in finding a suitable valuation scheme for the assessment of public values. This understanding of public values is relevant to obtain support for decision-making processes (Kangas, 1994) or land use decisions (Brown, 2006), to promote constructive discourse (Webler and Tuler, 2001), and to set policy targets and measure progress in reaching those targets (Reyers et al., 2013). Although the understanding of methodological implications is crucial for the application of such socio-cultural valuation approaches, the valuation of nature should not be an end in itself. Therefore, this dissertation further provides a practical approach to include local stakeholder knowledge in land use management, which addresses a central research gap in the field of ESs science. The pragmatic approach I adopted in chapter 5 to implement ESs knowledge in land use management can be adapted by researchers and policy makers in other spatial contexts. This approach can be used for the consideration of stakeholder knowledge and values for site prioritisation. As recent research has demonstrated that ESs supply will not necessarily deliver benefits for biodiversity conservation (Morelli et al., 2017; Ziv et al., 2017), I recommend to clearly articulating what are the management objectives to carefully consider biodiversity along with other conservation measures. A better understanding of the spatial location of ecosystem services can support sustainable land use management in identifying important sites for conservation and in sustaining a broader set of desired outcomes.

7. Conclusions

This dissertation advances the understanding of the ability of socio-cultural valuation methods for the operationalisation of ESs research in land use management. My work contributes to ESs research by addressing one of the least studied value domains in the field of ESs science. Particularly in the light of recent calls for an integration of all value domains, the methodological understanding of methods and value intentions supports the future facilitation of socio-cultural valuation in ESs assessments. Further, empirical testing demonstrated the crucial delineation between socio-cultural values and land use preferences which highlights the importance of landscape configuration. The proposed approach for the integration of socio-cultural valuation of ESs into decision-making can assist bridging the gap between ESs research and its practical operationalisation and ultimately help guiding land use management in formulating sustainable conservation objectives.

In my thesis, I generated systems knowledge about the current practice of eliciting socio-cultural values for ecosystem services, normative knowledge about preferences for ESs of regional park visitors and their preferences for future land use management, as well as transformation knowledge that systematically indicates how socio-cultural valuation of ESs can be incorporated into land use management. I first demonstrated which and how socio-cultural values are currently investigated in ESs research and identified crucial gaps of their application in ESs assessments, in particular caused by the focus on cultural services, monetary valuation methods, and a small amount of stakeholder participation. Building on this improved system understanding, I elicited socio-cultural values in an exemplary case study which was strongly based on the dialogue and co-design with local decision-makers and stakeholders. In this case study, I gained normative knowledge by eliciting preferences for particular ESs that people benefited from. I further tested a number of established methods against each other and identified limitations of the assigned ESs values for preferences for future land use, independent of the techniques used. Finally, I generated transformative knowledge on how socio-cultural valuation of ESs can concretely support strategic land use management by applying PPGIS as a form of socio-cultural valuation to derive ESs hotspots. The comparison of landscape features underpinning those ESs hotspots with landscape features that are prioritised in the current management plan allowed for a better understanding of the required focus of future land management to account for ESs and provides an effective approach to operationalise ESs research.

In the light of recent policy developments towards the operationalisation of ESs in land use management and the integration of people's knowledge and views, my dissertation bears implications for the conservation and management of ecosystems. The inclusion of stakeholders and the understanding of people's preferences can support setting conservation goals as high priorities or raise awareness and co-develop solutions to overcome the mismatch of conservation targets and people's choices. However, recent research also highlights that ESs supply and biodiversity goals do not always overlap. Ultimately, it is the management's choice driven by people if and to what extent ESs are included in conservation management. This choice requires societal discourse. An advanced understanding of socio-cultural valuation methods contributes to the normative basis of this discourse, while the proposal for the implementation of ESs in land use management presents a practical approach of how to transfer this type of knowledge into practice. The proposed methods for socio-cultural valuation can support guiding land use management towards a balanced consideration of ESs and conservation goals.

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APPENDIX 1 List of reviewed Papers

1 Wakita K, Shen Z, Oishi T, Yagi N, Kurokura H, Furuya K, 2014, "Human utility of marine ecosystem services and behavioural intentions for marine conservation in Japan" Marine Policy 46 53-60

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16 Casado-Arzuaga I, Madariaga I, Onaindia M, 2013, "Perception, demand and user contribution to ecosystem services in the Bilbao Metropolitan Greenbelt" Journal of Environmental Management 129 33-43

17 Colloff M J, Lindsay E A, Cook D C, 2013, "Natural pest control in citrus as an ecosystem service:

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20 Larson S, Stoeckl N, Neil B, Welters R, 2013, "Using resident perceptions of values associated with the Australian Tropical Rivers to identify policy and management priorities" Ecological Economics 94 9-18

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APPENDIX 2 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 hrs) from home
On a day out (for more than 3 hrs) 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		
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
- e) Any comments?

APPENDIX 3 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

Impact of sheep farming on other land uses								
		Maximum possible level due to trade-off						
Land use	Impact	0	1	2	3	4	5	Reference(s)
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	5	4	3	2	1	1	Lal (2004) Liao et al. (2006)

	threatens tree generation, it also compromises carbon sequestration.							
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								
		Maximum possible level due to trade-off						
Land use	Impact	0	1	2	3	4	5	Reference(s)
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								
		Maximum possible level due to trade-off						
Land use	Impact	0	1	**2**	**3**	**4**	**5**	Reference(s)
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								
		Maximum possible level due to trade-off						

Land use	Impact	0	1	**2**	**3**	**4**	**5**	Reference(s)
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								
		Maximum possible level due to trade-off						
Land use	Impact	0	1	2	3	4	5	Reference(s)

Sheep farming	*No scientific evidence found of an impact of carbon sequestration on any other land use. As carbon sequestration, in this study, directly correlates with woodland expansion, the same trade-offs apply as for habitat for wild plants and trees.*	5	5	5	4	3	1	
Woodland development		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								
		Maximum possible level due to trade-off						
Land use	Impact	0	1	**2**	**3**	**4**	**5**	Reference(s)
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 Annual Report (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)
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*	

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APPENDIX 4 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

Self-oriented rating of ESs

	Chi²-Test		Groups according to Dunn's Test				
			Cluster 1 Forest enthusiasts	**Cluster 2** Nature enthusiasts	**Cluster 3** Traditionalists	**Cluster 4** Multi-functiona-lists	**Cluster 5** Recreation seekers
Ecosystem services	**P-value**	**Chi²**	**Groups**				
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

	Chi²-Test		Groups according to Dunn's Test				
			Cluster 1 Forest enthusiasts	**Cluster 2** Nature enthusiasts	**Cluster 3** Traditionalists	**Cluster 4** Multi-functiona-lists	**Cluster 5** Recreation seekers
Ecosystem services	**P-value**	**Chi²**	**Groups**				
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							
	Chi²-Test		Groups according to Dunn's Test				
			Cluster 1 Forest enthusiasts	**Cluster 2** Nature enthusiasts	**Cluster 3** Traditionalists	**Cluster 4** Multi-functiona-lists	**Cluster 5** Recreation seekers
Ecosystem services	**P-value**	**Chi²**	**Groups**				
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 5 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)

	Cluster 2 Nature enthusiasts									Cluster 3 Traditionalists								
	Self-oriented rating			Other-oriented rating			Weighting			Self-oriented rating			Other-oriented rating			Weighting		
Percentiles	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
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
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
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
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
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
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
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
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
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

	Cluster 4 Multi-functionalists									Cluster 5 Recreation seekers								
	Self-oriented rating			Other-oriented rating			Weighting			Self-oriented rating			Other-oriented rating			Weighting		
Percentiles	25th	Median	75th	25th	Median	75th	25th	Median	75th	25th	Median	75th	25th	Median	75th	25th	Median	75th
Intercept	-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	-0.28	-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	0.50	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	0.13	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	-0.25	-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	-0.11	-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	0.15	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	-0.15	-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	0.10	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	-0.49	-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 6 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 Hills												
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

Summary

Ecosystem services (ESs) are defined as the contributions that ecosystems make to human wellbeing and are increasingly being used as an approach to explore the importance of ecosystems for humans through their valuation. Although value plurality has been recognised long before the mainstreaming of ESs research, in practice socio-cultural valuation of ESs is still underrepresented in ESs assessments. Further, there are increasingly calls in ESs research and policy that operationalisation of the ESs approach for land use management needs to be further advanced. It is the central goal of this PhD dissertation to explore the ability of socio-cultural valuation methods for the operationalisation of ESs research in land use management. To address this central goal, I formulated three research objectives that are briefly outlined below and relate to the three research studies conducted during this dissertation.

The first objective relates to the assessment of the current role of socio-cultural valuation in ESs research. Human values are central to ESs research but in the past have been interpreted mostly in terms of their monetary value. Monetary valuation approaches have been criticised because they are limited in the expression of concerns relevant to the socio-cultural context at stake. At the same time, non-monetary socio-cultural valuation methods have been found underrepresented in the field of ESs science and were only recently put on the research agenda. Previous studies found socio-cultural values to have been conceptually conflated with cultural services within ESs assessments. Other studies recognised the importance of stakeholder participation for the assessment socio-cultural values but a large number of assessment studies did not include stakeholders in their valuation. Within this research and in regard to the unbalanced consideration of value domains and conceptual uncertainties, I perform a systematic literature review aiming to answer the research question: To what extent have socio-cultural values been addressed in ESs assessments.

The second objective aims to test socio-cultural valuation methods of ESs and their relevance for land use preferences by exploring their methodological opportunities and limitations. Socio-cultural valuation methods have only recently become a focus in ESs research and therefore bear various uncertainties in regard to their methodological implications. Also, the consideration of trade-offs and synergies of ESs was identified as a central challenge towards a multifunctional land use management. With the uptake of the ESs approach in landscape research, the ESs approach has been facilitated within various landscape preferences studies although the assessment tools have been contested. It is a challenge in ESs research to understand the implications of existing methodologies, how methods complement each other and to test the boundaries of ESs values and landscape preferences. To overcome methodological uncertainties and further explore the relationship between ESs values and land use preferences, I analysed responses to a visitor survey. The research questions related to the second objective were: What are the implications of different socio-cultural valuation methods for ESs values? To what extent are land use preferences explained by socio-cultural values of ESs?

The third objective addressed in this dissertation is the implementation of ESs research into land use management through socio-cultural valuation. Although it is emphasised that the ESs approach can assist decision making, there is little empirical evidence of the effect of ESs knowledge on land use management. In order to operationalise ESs research, it is advised to assess multidisciplinary perspectives from social sciences, natural sciences, and the humanities as well as to integrate local knowledge with other sources of information. As ESs have a spatial dimension, it is further identified as challenge to link spatial and participatory approaches to optimise the multifunctional use of ecosystems. I proposed a way to implement transdisciplinary, spatially explicit research on ESs by answering the following research questions: Which landscape features underpinning ESs supply are considered in land use management? How can participatory approaches accounting for ESs be operationalised in land use management?

The empirical research resulted in five main findings that provide answers to the research questions. First, this dissertation provides evidence that socio-cultural values are an integral part of ESs research. I found that they can be assessed for provisioning, regulating, and cultural services though they are linked to cultural services to a greater degree. Socio-cultural values have been assessed by monetary and non-monetary methods and their assessment is effectively facilitated by stakeholder participation. Second, I found that different methods of socio-cultural valuation (i.e. rating, weighting) revealed different information. Whereas rating revealed a general value of ESs, weighting was found more suitable to identify relative values and priorities across the ESs. Value intentions (i.e. self-oriented, other-oriented) likewise differed in the distribution of values, generally implying a higher value for others than for respondents themselves. Third, I showed that ESs values were distributed very similarly across groups with differing land use preferences. Thus, I provided empirical evidence that ESs values and landscape values are two concepts that should not be used interchangeably. Fourth, I showed which landscape features that are important for ESs supply in a Scottish regional park are not sufficiently accounted for in the current management strategy (i.e. water, bogs, land cover diversity, grassland, and areas considered wild). This knowledge is useful for the identification of priority sites for land use management and to account for a broader set of desired outcomes. Finally, I provide a novel approach to explore how ESs knowledge elicited by participatory mapping can be operationalised in land use management. I demonstrate how stakeholder knowledge and values can be used for the identification of ESs hotspots and how these hotspots can be used for site prioritisation when they are compared to current management priorities.

Interest in including diverse values for ESs has increased in international and national policy making over the last decade. Two of the Convention on Biological Diversity's strategic approaches, the Ecosystem Approach and Aichi Targets, emphasise the importance of public knowledge and values in order to either set biodiversity goals as priorities or to raise awareness and co-develop solutions to overcome barriers towards a sustainable land use management. These strategies have been adopted by the European Biodiversity Strategy, as

well as national strategies such as the UK Post-2010 Biodiversity Framework. The implementation into national policies and the emphasis on people's knowledge and values in decision-making processes open the way for the operationalisation of ESs research on socio-cultural values in real-world land use management.

This dissertation helps to bridge current gaps of ESs science by advancing the understanding of the current role of socio-cultural values in ESs research, testing different methods for socio-cultural valuation and their relevance for land use preferences, and implementing ESs knowledge into land use management. If and to what extent ESs and their values are implemented into ecosystem management is mainly the choice of the management which is driven by people. This choice requires societal discourse. An advanced understanding of socio-cultural valuation methods contributes to the normative basis of this discourse, while the proposal for the implementation of ESs in land use management presents a practical approach of how transfer this type of knowledge into practice. The proposed methods for socio-cultural valuation can support guiding land use management towards a balanced consideration of ESs and conservation goals.

Zusammenfassung

Das Konzept der Ökosystemleistungen (ÖSL) wird in der Wissenschaft seit einigen Jahren vermehrt verwendet, um die Beiträge von Ökosystemen zum menschlichen Wohlbefinden zu bewerten. Das Konzept der ÖSL sieht vor, dass dabei viele verschiedene Wertkategorien gleichberechtigt zum Tragen kommen. Dazu gehören etwa ökonomische, ökologische und sozio-kulturelle Werte, die zu integrieren sind. Diesem Anspruch zum Trotz wird jedoch bislang der Bereich der sozio-kulturellen Werte zugunsten monetärer Werte in der Wissenschaft weitgehend vernachlässigt. Zudem müssen Wege gefunden werden, das Wissen über ÖSL und deren Werte in der Landschafts- und Raumplanung umzusetzen und damit praktisch nutzbar zu machen. Es ist das Ziel der vorliegenden Dissertation, die Eignung von sozio-kulturellen Bewertungsmethoden für die Operationalisierung von ÖSL in Landschafts- und Raumplanung zu untersuchen.

Hierfür wurden drei Forschungsschwerpunkte verfolgt. (1) Es wurde untersucht, inwieweit gegenwärtige ÖSL-Bewertungsstudien sozio-kulturelle Werte berücksichtigen. (2) Verschiedene sozio-kulturelle Bewertungsmethoden für ÖSL wurden daraufhin geprüft, inwieweit sie geeignet sind, die Landschaftspräferenzen unterschiedlicher Nutzergruppen offenzulegen und (3) wurde ein Ansatz entwickelt, um die ÖSL-Forschung in die Landschafts- und Raumplanung zu implementieren.

(1) Mittels einer Literaturanalyse konnte gezeigt werden, dass sozio-kulturelle Werte bei der Bewertung von produktiven, regulierenden und kulturellen ÖSL erhoben werden, wobei ein engerer Zusammenhang zwischen sozio-kulturellen Werten und kulturellen ÖSL festgestellt wurde. Zwischen sozio-kulturellen Werten und kulturellen Leistungen konnten einige Überlappungen aber auch zahlreiche Unterschiede aufgezeigt werden, was auf eine Trennung der beiden Bereiche hinweist. Darüber hinaus konnte gezeigt werden, dass sich nicht-monetäre Bewertungsmethoden besonders für die Erhebung sozio-kultureller Werte eignen wobei auch monetäre Bewertungsmethoden sozio-kulturelle Werte erfassen, vor allem mittels simulierter Marktansätze (z.B. Zahlungsbereitschaft, Choice Experimente). Die Arbeit zeigte zudem, dass Studien, welche Stakeholder oder die Öffentlichkeit beteiligten, häufiger ebenfalls sozio-kulturelle Werte erhoben.

(2) Bei einer Besucherbefragung in einem schottischen Regionalpark führten unterschiedliche Methoden zu unterschiedlichen Ergebnissen. Die Bewertung von ÖSL auf einer 5-Punkteskala führte zu einer allgemeinen Einschätzung über die Wichtigkeit der verschiedenen ÖSL während eine Gewichtung der Leistungen (Verteilung von insgesamt 100 Punkten auf 9 ÖSL) eine relative Einschätzung über die Wichtigkeit der ÖSL und deren Prioritäten ermöglichte. Verschiedene Werteintentionen lieferten ähnlich unterschiedliche Ergebnisse, wobei persönliche Werte differenzierter und allgemein höher ausfielen als gesellschaftliche Werte. Zudem konnte gezeigt werden, dass sozio-kulturelle Werte für ÖSL ähnlich zwischen fünf Gruppen mit unterschiedlichen Landschaftspräferenzen verteilt waren. Die Arbeit liefert demnach empirische Belege

dafür, dass es sich bei ÖSL und Landschaftspräferenzen um zwei Konzepte handelt, die nicht untereinander austauschbar sind.

(3) Für die Entwicklung eines Ansatzes zur Implementierung von ÖSL-Forschung in die Landschafts- und Raumplanung wurde ein Methodenmix verwendet. Es wurden Ergebnisse eines Stakeholderworkshops verwendet bei dem ÖSL von Stakeholdern kartiert wurden. Mittels dieser Kartierung wurden Landschaftseigenschaften untersucht, die eine besondere Bedeutung für die Bereitstellung der ÖSL haben. Es wurde weiterhin untersucht, inwieweit diese Landschaftseigenschaften im derzeitigen Management Plan priorisiert werden. Die Diskrepanz zwischen Landschaftseigenschaften, die zentral für die Bereitstellung von ÖSL sind, und denen, die derzeit im Management Plan berücksichtigt werden, kann Aufschluss über mögliche Zielkonflikte geben und kann zudem dabei helfen, künftige Planungsprioritäten festzulegen, etwa indem Vorranggebiete für bestimmte ÖSL ausgewiesen werden.

Diese Arbeit untersucht die Eignung von sozio-kulturellen Bewertungsmethoden für die Operationalisierung von ÖSL in Landschafts- und Raumplanung. In diesem Zusammenhang liefert die Arbeit neue Erkenntnisse darüber, inwiefern derzeit sozio-kulturellen Werten in ÖSL-Bewertungsstudien berücksichtigt werden. Sie zeigt Möglichkeiten und Grenzen von verschiedenen anerkannten sozio-kulturellen Bewertungsmethoden auf und ermöglicht ein besseres Verständnis über deren Abgrenzung zu Landschaftspräferenzen. Schließlich präsentiert diese Arbeit einen komplexen methodischen Ansatz, um ÖSL-Forschung in die Landschafts- und Raumplanung zu integrieren.