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Mapping nature's contribution to people

Opportunities and limitations of crowdsourced data to identify place-based values and conservation concerns

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Summary

Nature provides people with a wide range of benefits, also known as nature's contributions to people (NCP). The NCP framework evolved from the Ecosystem services (ES) concept as a response to the critiques and misconceptions associated with ES over the last years. Broadening ES valuations that have been dominated by economic valuations, the NCP framework emphasizes a pluralistic approach to valuation of nature's contributions, necessary in order to account for contributions that are intangible and non-marketable. Balancing the conservation of nature with increased tourism can be challenging, especially due to the lack of appropriate data on how and where people experience and use nature. Crowdsourced data has been shown successful at identifying the values people ascribe to nature. However, there is a lack of guidelines on what type of crowdsourced data can better inform protected area (PA) managers.

This thesis investigates the opportunities and limitations of using crowdsourced data to identify spatially explicit place-based values and the use of nature by local, domestic- and international users of protected areas. I compare one passively generated data source; an online photo-sharing platform (i.e. Flickr), with two actively generated data sources; an online mapping platform (Public Participatory Geographic Information System – PPGIS) and a dedicated mobile application. Park managers and tourism stakeholders were consulted in the initial stages of the PPGIS survey and the mobile app development. The study area is located in Southern Norway, and includes Jotunheimen national park, Breheimen national park, Utladalen protected landscape and the surrounding landscape and settlements.

I show that spatially explicit values, generated through crowdsourced data gathering methods, can serve as non-economic valuation tools to understand nature's contributions to PA visitors. Furthermore, crowdsourcing provides an arena for an inclusive valuation of nature's contributions, as the datasets include a large body of visitors. Looking at the spatial distribution of values, I found they were clustered around major attractions (e.g. mountains and glaciers) and infrastructure (e.g. roads

and trails). International visitors differed from local visitors by the type of values ascribed to nature as well as the location they visit. International visitors appreciated clean and wild nature, whereas people living near these protected areas related to nature more through hunting, fishing, berry picking and cultural heritage. Despite relating to nature in different ways, there was low potential of conflict among user groups, as they tended to use different locations.

The three studied crowdsourcing methods offer opportunities and limitations for studying nature's contributions to visitors, and the data generated differ with respect to the type of place-based values mapped, the resolution of the data, the recruitment of participants and the costs of implementation. Flickr offers a large body of freely available georeferenced data. The drawback is that it cannot always provide the data needed as they are not customized to map specific values. PPGIS and mobile apps, however, can be tailored to the study to gather the desired data, but there are costs associated with the development of the platform and with recruiting participants. Dedicated mobile apps provide additional opportunities offered by built-in functionalities of smartphones, such as real-time tracking or *in situ* mapping. The integrated GPS of smartphones facilitates high-resolution georeferenced data. In contrast, PPGIS and Flickr provide data with lower and more variable resolution due to biases in the georeferencing of values.

Crowdsourcing provides cost-effective tools that can generate spatial data on place-based values and priority areas to understand NCP. Crowdsourced data collected over time can help monitoring changes and be used as an indicator for when management actions are required in the face of increasing visitation to PAs. The challenge remains in identifying values that are not necessarily connected to a specific place, and entail a broader experience, for which further research is needed.

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Paper II Muñoz, Lorena, Vera Helene Hausner, Claire Runge, Greg Brown, Remi Daigle. “Using crowdsourced spatial data from Flickr vs. PPGIS for understanding nature’s contribution to people in Southern Norway.” Accepted in *People and Nature*

Paper III Muñoz, Lorena, Vera Helene Hausner, and Christopher A Monz. 2019. “Advantages and Limitations of Using Mobile Apps for Protected Area Monitoring and Management.” *Society & Natural Resources* 32 (4). Routledge:473–88. https://doi.org/10.1080/08941920.2018.1544680.

Summary of papers

Paper I. Identifying Spatial Overlap in the Values of Locals, Domestic- and International Tourists to Protected Areas. Nature-based tourism is increasingly encouraged to support local socioeconomic development in and around protected areas, but managing protected areas for tourism could challenge existing park uses associated with self-organized outdoor recreation and local resource use. We used a web-based Public Participatory Geographic Information System (PPGIS) to identify the most important places and values of local, domestic, and international visitors to Jotunheimen national park and Utladalen protected landscape in Norway. Scenic and recreation values were prioritized by all groups, but local users mapped more values relating to hunting, fishing, gathering and cultural identity. While the three user groups overlapped in some places, we found that they self-segregated to some extent. Our study affirms the importance of spatially explicit analyses to support protected area management. Understanding the spatial distribution of values held by different user groups can aid in designing tourism management strategies that minimize intergroup conflict.

Paper II. Using crowdsourced spatial data from Flickr vs. PPGIS for understanding nature's contribution to people in Southern Norway. Crowdsourced data can provide spatially explicit data on the contribution of nature to people. Spatial information is essential for effectively managing the diverse relationships that people have with nature, but the potential and limits of using crowdsourcing data to generate maps for conservation purposes needs further research. Passive crowdsourcing tools include social media platforms where photos and user-generated tags are shared among users, while active crowdsourcing, such as Public Participatory Geographic Information System (PPGIS) provides an online platform for mapping place attributes such as values, experiences, and preferences.

In this study, we assessed the spatial information gained through using Flickr (a photo sharing platform) and PPGIS (online mapping platform) platforms for conservation planning to understand differences and similarities on the spatial distribution of values captured by the two platforms, and to identify what environmental and infrastructure variables correlate best with the distribution of values.

We test these tools in Southern Norway including protected areas and the surrounding landscape. We analysed non-spatial (chi-square and Spearman rank correlation) and spatial (clustering, Maxent and distribution overlap) data to identify differences between the two datasets and the values represented therein. We found large differences in spatial distribution using these two datasets. Flickr data were concentrated outside the protected areas and near roads, while PPGIS provided more fine scale data on diverse values in locations inaccessible by roads within the protected areas. Flickr can be used for generating regional scale data of scenic landscapes or routes, but PPGIS performs better for management of nature qualities appreciated by different user groups within protected areas. We discuss the pros and cons of using each data source and when each dataset is more suitable to use for protected area management.

Paper III. Advantages and Limitations of Using Mobile Apps for Protected Area Monitoring and Management. Digital technologies, including participatory Internet mapping, social media and smartphones, provide new avenues for research in out- door recreation and tourism. The potential to reach a greater audience and collect visitation data on a broader scale, with less costs than traditional paper surveys, are key advantages that have increased the use of these novel technologies. The use of mobile apps for data collection is still at the experimental stage. We evaluate previous attempts to use apps for monitoring recreation and tourism in protected areas, as an alternative to other in situ or online methods. We present a pilot study implemented in Jotunheimen national park (Norway), where we developed a mobile app for visitor monitoring and real-time mapping of values and experiences. We present the lessons learned, give suggestions on how and for what apps can be used, and discuss the advantages and limitations of using smart- phones for visitor monitoring in protected areas.

1 Introduction

1.1 Motivation for the study

Protecting land is an extensively used tool for conserving nature. The International Union for Conservation of Nature (IUCN) defines protected areas (PAs) as “a clearly defined geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values» (Dudley 2008). While the main goal of PAs is nature conservation, protected lands are also intended to assure benefits to people, including recreational benefits, the conservation of cultural landscapes, and sustainable resource use (Dudley 2008). This IUCN definition reflects the evolution of conservation framings such as the “people and nature framework”, that considers people and nature as integrated and affecting each other, and highlights that managing these people-nature relationships are increasingly a part of the conservation efforts (Mace 2014).

The visitors to PAs have increased in parallel with the number and extent of PAs (Balmford et al. 2009). This poses new challenges for PA managers, which in addition to conserving nature need to manage tourism to maintain the nature qualities and the reasons for visiting PAs in the first place (Lee, Jan, and Yang 2013; Tolvanen and Kangas 2016). For the purpose of this thesis, we define nature qualities as the natural processes (e.g. tree blossom) and elements (e.g. iconic species) which often are included in the purpose of the protection and that contribute with benefits to visitors at the same time (Arler 2000; Van den Bosch et al. 2015; Solberg 2009; Thomsen, Powell, and Monz 2018). People visit PAs for different reasons. The contribution of nature to their health, experience and enjoyment varies among user groups depending on their values and aspirations (Small, Munday, and Durance 2017). However, increased visitation to PAs might bring negative consequences, such as nature degradation, crowding and impacts on the surrounding local communities (Leung et al. 2018), and understanding what nature brings to diverse groups of people is therefore essential for managing PAs and for delivering long term conservation of biodiversity (CBD 2010; UN 2015). Managing the nature qualities that attract visitors to PAs requires new tools for visitor monitoring that can inform managers about the conservation efforts and infrastructure development that are needed to conserve nature while providing visitors with a satisfactory experience.

In general, monitoring contributes to a better understanding of complex systems and people-nature relationships by generating long-term data that are capable of identifying trends in the system and responses to management interventions (Lindenmayer and Likens 2009; Goldsmith 2012). Understanding the visitor behavior, distribution and experiences is necessary in order to predict the impacts that the increasing number of visitors to PAs could cause (Hadwen, Hill, and Pickering 2007). Muhar, Arnberger, and Brandenburg (2002) describe direct and indirect methods to monitor PA visitors, including interviews, on-site counters, aerial imagery and human footprint to determine visitor numbers, behavior and distribution. However, PA managers, especially those with limited capacity in terms of funding and staff, need more cost-effective methods to obtain visitor data that are reliable and capable of addressing management relevant issues, such as locating areas of high visitation or the reasons why people are attracted to specific places.

Traditional methods for monitoring and managing people-nature interactions are being increasingly complemented and even sometimes replaced by new technologies. The continuous development of technology and widespread use of internet generate crowdsourced data that are increasingly being used in research, monitoring and management of PAs (See et al. 2016). Crowdsourcing refers to data generated to a low cost by a large body of people by use of simple technological tools that do not demand high technical skills (Heipke 2010). The diversity of available technologies include sources of information that are passively generated, where the users share data with other users without the intent of participating in research or monitoring (See et al. 2016). Such data could be data generated in social media, or by mobile phone positioning records (Monz et al. 2019; Toivonen et al. 2019). Flickr is an example of a social media platform where users share their georeferenced photos and which are openly available if permission by the user is granted. Unlike passively generated crowdsourcing data, data collected through active participation by visitors are customizable to the purpose of the study, but require a recruitment strategy with logistic limitations (Bubalo, van Zanten, and Verburg 2019; Muñoz, Hausner, and Monz 2019). These include online surveys and mobile apps. Although crowdsourced data are increasingly used in PAs, there is a lack of consensus on the applicability and reliability of the different crowdsourced data gathering methods.

One of the major advantages of using crowdsourced data is the information richness that they capture. Crowdsourced data can provide information on visitor numbers, popular activities, areas of interest and landscape changes to name a few examples (Levin, Lechner, and Brown 2017; See et al. 2016; Norman and Pickering 2017). Furthermore, crowdsourced data provide a large body of georeferenced data that can capture changes in people-nature interactions (Tenerelli, Demšar, and Luque 2016). These spatially explicit data can identify areas that are important for protected area management (e.g. areas of high value for visitors or areas that may suffer from over-visitation). This can ease PA management by channelizing resources towards concrete places and actions mostly in need of management. Therefore, understanding the dimension of the spatial data gathered through crowdsourcing is of high management relevance.

Spatially explicit data obtained through crowdsourcing can capture visitation patterns and the nature qualities that make some locations more valuable for visitors than others. Priority places for different user groups can be identified by the values people ascribe to places. Different academic disciplines interpret “value” differently. In this thesis, I understand values as a combination of fundamental principles, cultural meanings and personal preferences for specific physical places (Muñoz et al. 2019). Thus, I use values to inform about people-nature interactions and to understand nature’s contribution to people in a PA setting (Pascual et al. 2017). The challenges of understanding the values and experiences of people make nature’s non-material contribution to people harder to monitor, and this dimension is therefore underrepresented in research and policy making (Feld et al. 2009). This thesis brings some insights on the opportunities and challenges of using crowdsourced data to monitor how people value and relate to nature's non-material contributions.

Crowdsourced data should be analyzed with caution as different types of crowdsourcing may capture the values of different groups of people and thus different forms of people-nature interactions (Norman and Pickering 2017; van Zanten et al. 2016). As such, images georeferenced in social media are an indicator of the presence of that particular user, but online mapping can provide values in areas that the participant has not visited but are nevertheless regarded as important (e.g. existence value). Therefore, key issues to consider when using crowdsourced data are to understand the information each data source provides and evaluate its relevance for management.

The increasingly available crowdsourced data have the potential to reduce some of the economic, temporal and personal constraints of traditional data gathering methods (Levin, Lechner, and Brown 2017; Muñoz, Hausner, and Monz 2019; Ahas et al. 2008), that are too costly to apply in PAs with limited resources and funding. However, the diversity and large amount of data produced through crowdsourcing requires careful use. A natural step forward is to understand the type of data that each method provides as well as the methods' opportunities and limitations. As such, in depth analyses and comparative studies are necessary in order to understand the degree to which crowdsourcing can contribute to the understanding of nature's contribution to people and the benefits to PA management.

1.2 Scope and research questions

The aim of this thesis is to analyze methods that can contribute to elucidating nature's contribution to people in remote PAs. This thesis compares and evaluates the use of crowdsourced data collection methods as tools to identify the areas people value most in PAs, and thus provide practical information on how and when to use different crowdsourced methods for management related issues. I analyzed the use of PPGIS, Flickr and a dedicated mobile app to capture the spatially explicit values people assign to different locations in PAs. I assess the relevance of the gathered data for management purposes, and the overlap and similarity in the data obtained by the different methods. The primary research question (RQ) of this thesis is:

RQ1. How can different crowdsourced data contribute to elucidate nature's contribution to people through identifying areas valued by visitors in remote PAs?

The primary research question is supported by the following secondary research questions:

RQ2. What kind of values do visitors map using an online mapping platform, and what are the main spatial and non-spatial differences among user groups (Paper I)?

RQ3. What kind of values are captured by using active (online mapping) and passive (Flickr) crowdsourced data to elucidate visitor values in PAs (Paper II)?

RQ4. How can a dedicated mobile app be used for monitoring visitors and for elucidating nature's contribution to people in remote PAs (Paper III)?

RQ5. What are the advantages and challenges of using the different crowdsourced data for monitoring visitors in remote PAs (Paper I-III)?

I tested three approaches (online mapping, social media and a mobile app) in the same mountainous landscape consisting of a network of protected areas. RQ2 and RQ4 were assessed with an online mapping platform (through PPGIS – Public Participatory Geographic Information System) and a dedicated mobile app specifically developed for the study region (Papers I and III). Flickr was used as passive crowdsourced data from which publicly available georeferenced images were downloaded using an API. Flickr data, in combination with PPGIS data were used to assess RQ3 (Paper II). Together, the three studies contribute to identify the advantages and challenges of using crowdsourced data for protected area monitoring and management (RQ5).

1.3 Structure of the thesis

In section 2 the key concepts that define the framework of the thesis are introduced, including protected areas, the concept of nature's contribution to people and the debate around this concept, the use of spatial data for protected area management and examples of crowdsourced data that have previously been used for monitoring visitors. Section 3 contains more specific description of protected areas in Norway and the study area, followed by the methods and statistical analyses used for the studies. Results and discussion are in Section 4, together with the contribution to management and the limitations of this thesis, followed by the conclusions in section 5.

2 Background

2.1 Protected areas

Protected areas (PAs) are among the tools to protect nature and secure the well-being of people (CBD 2019). PAs were initially designated to preserve intact nature for the enjoyment of visitors and to safeguard some areas against land development. Nevertheless, the purpose of PAs has changed over time. Nowadays there is a wide range of reasons to designate PAs, from conserving biodiversity and habitats to protecting ecosystem services (Dudley 2008).

The IUCN developed a list of PA categories to capture the diversity of designation objectives (Dudley 2008). While strict PAs generally do not permit extractive activities in the park, less restrictive PAs allow and encourage sustainable use of resources. The urge to conserve nature through PAs together with the widening of reasons to designate PAs have enabled an increasing number of designated PAs (UNEP-WCMC and IUCN 2018). The Aichi Target 11 in the Strategic Plan for Biodiversity 2011-2020 decided upon by the Convention on Biological Diversity (CBD), aim at increasing the PA coverage to 17 % of terrestrial surface and inland water and 10 % of coastal and marine areas, but under the condition that these areas are effectively managed and ecologically representative (CBD 2010). Although the area covered by protection has increased over the last decades, the number and extent of PAs provide superficial indicators of conservation efforts (Chape et al. 2005), and the effectiveness of such conservation efforts is uncertain. Furthermore, protecting remote areas with low accessibility and use has been a common practice, which makes PAs a less effective tool for nature conservation (Joppa and Pfaff 2009). Resources and funding for PAs have also been shown to be insufficient (Watson et al. 2014), which are among the major limitations to effectively manage PAs (Hockings 2003). The lack of funding for PA rule enforcement in many PAs, also known as paper parks, makes it unclear whether PAs are meeting their designated goals. Logistically easy and inexpensive methods that allow evaluating the progress of PAs are therefore increasingly needed.

The effectiveness of PAs in halting biodiversity loss and nature degradation has been contested. Despite of the positive correlation between PAs and reduced human pressures, their effectiveness is influenced by factors such as protection category, accessibility, local involvement and funding (Bruner et al. 2001; Pfeifer et al. 2012; Joppa, Loarie, and Pimm 2008; Oldekop et al. 2016). Furthermore, PAs act as attractors for tourism, increasing the use of these areas for recreation and enjoyment of nature (Reinius and Fredman 2007). Tourism is also increasingly encouraged to provide revenue for managing PAs or to support local development (Norwegian Ministry of Trade Industry and Fisheries 2017; Leung et al. 2018). The impacts derived from increasing visitation to PAs can jeopardize the nature qualities that attract visitors (Leung et al. 2018; Tolvanen and Kangas 2016; Lee, Jan, and Yang 2013). While sustainable resource use in PAs is often accompanied with socioeconomic benefits (Oldekop et al. 2016), unsustainable tourism can cause environmental and socio-cultural impacts, for example by reducing the nature qualities, worsening the experience of visitors or by negatively affecting local communities (Leung et al. 2018; Oldekop et al. 2016; Tolvanen and Kangas 2016; McLaren 2003). Areas with intensive visitation have suffered from vegetation loss, soil degradation and wildlife disturbance among other impacts (Hammitt, Cole, and Monz 2015). The impacts can also occur in PAs with lower visitation, as visitors may disperse more and create informal trails (D'Antonio and Monz 2016). Thus, there is a need for monitoring programs that assess the progress of PAs at meeting objectives and understanding the changes in people's perceptions and their interactions with nature.

Small scale intensive monitoring efforts have been widely implemented to understand visitation and its impacts on habitats, wildlife and non-living features (Beeco et al. 2013; Marion et al. 2018). However, monitoring on a landscape scale is costly, time consuming and with logistic constraints (Muhar, Arnberger, and Brandenburg 2002). Furthermore, data on recreation and its impacts is often lacking (Cole and Wright 2004), which hinders our understanding of visitors and their relation with nature. Therefore, managers need tools to monitor visitors and their interaction with nature to overcome some of the limitations mentioned above.

2.2 Nature's contribution to people and place-based values

The ways in which people and nature interact are diverse. The framing of conservation has also changed over time, from conserving intact nature to explicitly incorporating humans and their needs as a part of conservation (Mace 2014). The first conservation efforts were directed towards protecting wild and intact nature for the enjoyment of visitors and to develop tourism in low visitation areas (Phillips 2004; Kareiva and Marvier 2011). Yellowstone national park, the first official national park established in 1872, was designated to preserve the nature and serve for the enjoyment of visitors (Yellowstone national park 2019). However, the degradation of nature and nature's contributions to people have during the past 50 years reached an unprecedented rate in human history (Díaz et al. 2019). Halting this accelerating loss has become a priority in international environmental policies, for the sake of nature, but also for assuring a good quality of life for people at present and in the future. For example, Tribot et al. (2016) found that areas with higher species diversity are preferred by people. Similarly, Lindemann-Matthies et al. (2010) found that areas with high diversity of species and low level of management were preferred over production landscapes with low diversity of species. The potential impacts that loss of biological diversity can have on the quality of life for people, is reflected in the increased popularity of the concept of ecosystem services subsequent to the publication of the Millennium Ecosystem Assessment in 2005 (Millenium Ecosystem Assessment 2005). Biological diversity can, as explained by Mace, Norris, and Fitter (2012), act as a regulator for ecosystem processes (e.g. nutrient cycling by microorganisms), as a final ecosystem service (e.g. wild species diversity), or as a good (e.g. scenic places).

The ES concept, defined as the benefits that people obtain from ecosystems, conveys how changes in ecosystems could affect human well-being (Ehrlich and Ehrlich 1981; Costanza 2008). The concept encourages valuation of nature's benefits to people and incorporates nature's value in policy making, both in monetary and non-monetary terms (Costanza et al. 2017), which by some have been interpreted as an attempt to commodify nature and to promote utilitarian values. Among ES, cultural ecosystem services (CES) have recently received more attention in research, but they have been often ignored in natural resource management and national- and international decision-making processes (Hirons, Comberti, and Dunford 2016; Chan, Satterfield, and Goldstein 2012). CES are defined as "the non-material benefits people obtain from nature" (Millenium Ecosystem Assessment 2005). CES arise from complex interactions between ecosystems and humans, and the boundary between CES and other ES is not clear as they are often intertwined and overlapping (Gould et al. 2015; Hirons, Comberti, and Dunford 2016; Chan et al. 2016). Fish, Church, and Winter (2016) define CES as "*relational processes and entities that people actively create and express through interactions with ecosystems*" and "*the contributions ecosystems make to human well-being in terms of the identities they help frame, the experiences they help enable and the capabilities they help equip"*. This definition elaborated the need to understand how people relate to nature to capture the value of nature.

The ES framework has been criticized for the unclear and confusing definitions (Potschin and Haines-Young 2016), and also because of dominance of economic valuation. Commodification and monetary valuation of ES has been questioned as 1) it facilitates loss of interest in what people value if services are interchangeable, 2) may change the intrinsic values of people, and 3) favors the preferences of the rich and powerful (Hirons, Comberti, and Dunford 2016). Moreover, most of the CES have often been left out of ES assessments and valuations due to the difficulties in valuing CES (Chan et al. 2016). Challenges rise because they are rarely marketable, they are difficult to quantify, and economic valuation often fails to capture the complexities of human well-being, ecosystems, and the plurality of values (Wegner and Pascual 2011). Also, CES often overlap with other ES (Hirons, Comberti, and Dunford 2016), which needs to be accounted for to capture the full contribution of the given nature quality. For example, wild plants are generally categorized as provisioning services as they can be consumed by people, but gathering these plants can also serve as cultural services. Although the ES concept has been a step forward in incorporating nature into policymaking, the criticism and misconception around the ES and CES framework has given rise to new frameworks to understand human-nature interactions (Schröter et al. 2014; Díaz, Pascual, Stenseke, Martín-López, Watson, Molnár, Hill, Chan, Baste, Brauman, et al. 2018).

The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) recently launched the concept of “Nature’s contribution to people” (NCP) as an attempt to connect the positive and negative contributions of nature to people’s quality of life (IPBES 2017, page 23). As stated by Díaz et al. (2018), the NCP concept builds on the Millennium Ecosystem Assessment and the ES approach, but NCP is an attempt to include a wider perspective of disciplines and knowledge and avoid the criticisms directed towards the ES approach over the last decades (Díaz, Pascual, Stenseke, Martín-López, Watson, Molnár, Hill, Chan, Baste, Brauman, et al. 2018). However, at this early stage of the NCP approach there is a debate on whether the NCP concept brings new insights and how it differs from the ES approach. The NCP concept has been criticized for de-emphasizing ecosystems by replacing ecosystems with nature (Peterson et al. 2018), being unidirectional through the focus on contributions to people thereby ignoring the human impact on nature (Kenter 2018), and for not being a paradigm shift, rather a repair of the ES concept (Faith 2018), or a synonym of ES (de Groot et al. 2018; Pires et al. 2020). Furthermore, scholars have also argued that NCP does not guarantee a better incorporation into decision making than ES, nor does NCP represent a shift in terms of including social sciences, which has already been incorporated in the ES scholarship (Braat 2018).

Kadykalo et al. (2019) reviewed the literature on ES and NCP to disentangle the differences and similarities between these two concepts. They concluded that some of the claims made by the NCP concept do not diverge from ES research (i.e. including culture, incorporating social sciences and humanities, accounting for indigenous and local knowledge, addressing negative contributions of nature, having a generalizable perspective/classification, and accounting for non-instrumental values). However, they found five claims where the NCP introduces novelties compared to the ES framework: embracing diverse worldviews in addition to western science, accounting for context-specific views, including relational values, allowing fuzzy and fluid categories of NCP, facilitating communication across groups.

Díaz, Pascual, Stenseke, Martín-López, Watson, Molnár, Hill, Chan, Baste, and Brauman (2018) responded to the critiques by further explaining that the concept NCP embraces ES, and extends it by including a more thorough consideration of different knowledge systems and values into the framework. In an attempt to solve critiques derived from ES categories, the NCP approach classifies contributions into three categories (material, non-material and regulating contributions) but recognizes that these overlap and have fuzzy boundaries depending on the cultural context (Díaz, Pascual, Stenseke, Martín-López, Watson, Molnár, Hill, Chan, Baste, Brauman, et al. 2018). The NCP concept also advocates for a pluralistic value approach, which has often been simplified to a dichotomy of instrumental and intrinsic values.

Values are the means through which people express the meaning and importance of NCP for them. In the critique of the concept, Kenter (2018) highlights that only values can be directly incorporated in the decision-making process by the importance people ascribe to contributions or services. Therefore, governance practices need a good understanding of the importance of nature and the elements that are relevant to protect. The values people ascribe to nature can be interpreted differently and depend on academic disciplines (Pascual et al. 2017). Pascual et al. (2017) listed value definitions as "*a **principle** associated with a given worldview or cultural context, a **preference** someone has for a particular state of the world, the **importance** of something for itself or for others, or simply a **measure***". For example, a **preference** can be expressed by the desire to protect of wildlife, whereas **importance** would represent how important a forest is for habitat creation. Value as a **measure** is, for example, how much habitat a tropical forest provides for wildlife. In this context, the **principle** behind these value examples would be conservation of nature. Value as a principle has also been termed "held value", which reflects the fundamental ideas and orientation people have and that affect their behavior and choices (T. C. Brown 1984). Held values are often shaped by life experiences and cultural background, and are more stable than other value types (Lockwood 1999). The term “assigned values” unifies value as a preference and importance, which express the importance or worth of a feature relative to others through people’s preferences to choose a place over another (T. C. Brown 1984). This can be understood as a measure of how much an ES is worth or prioritized. Assigned values are less persistent than held values, and largely depend on the local context. To exemplify, held values are honesty, liberty and responsibility, while assigned values are the worth of a scenic view or the worth of recreation opportunities.

Values can also be understood in the nexus of held and assigned values under the term “relational values” (Chan, Gould, and Pascual 2018). Chan et al. (2016) and Arias-Arévalo, Martín-López, and Gómez-Baggethun (2017) defined relational values as the importance of relationships and interactions that people have with nature. This concept differs from the term cultural ecosystem services, as CES can have both instrumental and relational values, and relational values can be ascribed to both material and non-material benefits (i.e. to all ES) (Chan, Gould, and Pascual 2018). For instance, recreation (CES) can be valued economically (e.g. travel costs) or in relational terms (e.g. visiting this place is important for me as a person). Also, gathering berries (relational value), can be a provisioning service (the berries) or a non-material benefit (e.g. maintaining the cultural identity of gatherers) (Figure 1). Relational values can be values **of** nature (e.g. responsibility people hold towards nature) and **about** nature (e.g. contribution of harvesting to people) for a good quality of life (Chan, Gould, and Pascual 2018).

Understanding values as relations has been proposed as a framework to better inform ES assessments and conservation efforts as they deviate from the intrinsic vs. instrumental value debate and reflect the connections between people and nature (Klain et al. 2017). The intrinsic value of ecosystems represents the value of nature as the worth of nature itself, independent of humans. Opposing to this view is the instrumental value of ecosystems, which considers the utilitarianism of nature for humans and is often measured through monetary valuation. However, scholars increasingly advocate for a pluralistic value approach in sustainable management as different values and valuation types can be attributed to the same ecosystem and its components (Arias-Arévalo, Martín-López, and Gómez-Baggethun 2017). Transdisciplinary science, good communication, and choosing the right valuation methods are some of the steps needed to allow for a pluralistic valuation of ES (Jacobs et al. 2016). Also, there is a lack of methods for socio-cultural valuation of nature's contributions with a spatially explicit approach, which act as a barrier to understanding the contribution that ecosystems and landscape structures have to peoples' values (Scholte, van Teeffelen, and Verburg 2015). Nature's contributions are delivered differently over time and space, which translates into temporal and spatial differences in socio-cultural valuations that need to be considered in decision making (Oteros-Rozas et al. 2014). The capability to observe changes in NCP and place-based values for different groups of people over a broad spatiotemporal scale is necessary to progress this field of research.

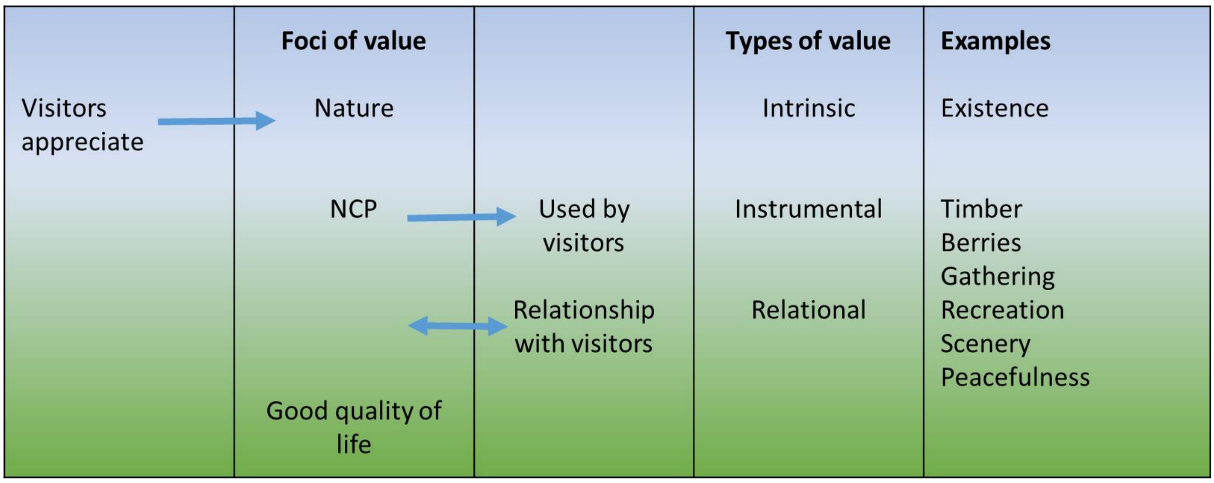

Figure 1. A simplified example of value types and how they relate to nature, NCP and good quality of life. The background gradient indicates that boundaries are fuzzy and concepts are intertwined. Adapted from Pascual et al. (2017).

In this thesis I explore how crowdsourced data can be used to discover how different groups of people relate to and value nature across space. I aim to capture relational values in PAs as they have traditionally been neglected in policy making and fall outside the intrinsic vs. instrumental value debate that often has ruled policy making. I will do this by using a spatially explicit approach of visitors' values to find how visitors relate to the environment.

2.3 Spatial data for protected area management

The ecosystems that PAs aim to conserve hold a range of nature qualities that attract visitors. Together with park infrastructure, the spatial distribution of the different elements in the landscape influence the spatial behavior of visitors (Orellana et al. 2012) that prioritize the attractions that are most valued by them. For example, Sonter et al. (2016) found that visitors to conserved land prefer big conservation areas with little forest cover, high trail density and opportunities for winter sports. The different visitor groups can value nature qualities differently. For example, van Riper et al. (2012) found that visitors participating in non-consumptive activities (e.g. hiking) assigned biological diversity value to places with steep slopes placed close to trails, contrary to visitors involved in consumptive activities (e.g. fishing) who associate biological diversity values to flat areas close to trails and water bodies.

PA managers need to deal with different demands and needs that can potentially cause a conflict. These conflicts can be originated by differences between local use- and conservation- interests, between local- and visitor- use interests, and between visitor use- and conservation- interests (Stolton et al. 2015). For example in a study conducted in northern Finland among residents, holiday home owners and visitors, Brown et al. (2017) found that locals and visitors supported increased tourism development and snowmobile use more than holiday home owners. Also, residents and holiday home owners mapped a strong preference to increase reindeer herding, while visitors emphasized nature conservation more than the other two groups. The authors hypothesize that these differences might reflect differences in perceived impacts and place attachment. In many parts of the world, PAs have indigenous- and local people who have a strong connection to the land and relational values associated with traditional livelihoods, uses, and memories that have been passed down through generations. In a study in the Chilean Patagonia, Serenari et al. (2015) found that tourists generally support strict conservation of wildlife, whereas locals are more supportive of mixed protection-use value and do not appreciate policies that negatively impact local livelihoods. Tourists are more prone to value PAs for their intrinsic value, whereas residents whose livelihoods are connected to the PAs have a different relationship to nature. This thesis explores these differences by comparing how tourists and residents relate to nature.

Co-existence of different user groups in the park depends on the spatial distribution of nature qualities, the spatial behavior of the visitors and how compatible the different uses are (Wray, Espiner, and Perkins 2010; Riungu et al. 2018; Muñoz et al. 2019; Beeco, Hallo, and Brownlee 2014). Monitoring visitors at PA level is insufficient for an adequate management and understanding of visitation, and therefore a finer spatial resolution is needed (Hadwen, Hill, and Pickering 2007). Identifying where visitors go to and why, the areas most likely impacted by visitors, and how visitors are segmented in PAs, are important data that can inform PA management in designing, planning and zoning among other management actions (Riungu et al. 2018; Pietilä and Fagerholm 2019). However, generating the amount of data needed for representative sampling of user groups can be costly, time consuming and logistically challenging to perform at the landscape level. Finding new ways of collecting spatial information on visitation to PAs that have low costs, but can inform managers about emerging problems or simply a change in the nature qualities that new user groups value, are therefore needed (Beeco and Brown 2013).

Below I summarize some of the methods that are used for gathering spatial visitor data in PAs, starting from traditional methods that include interviews and travel diaries, followed by modern methods that employ advanced technological tools and platforms for data gathering.

Interviews, surveys and travel diaries

Interviews and self-report travel diaries have traditionally been used to spatially assess movement patterns and places that people visit. Travel patterns of households in the day-to-day basis have been used to understand what activities people conduct, how they use the time and what routes they follow. The type of data that can be obtained is very diverse, as travel routes, trip duration, and travel origin and destination might differ. Such collection methods have been used by different disciplines, including city planning, psychology and tourism research. Visitor surveys are valuable for understanding how tourism and local recreation depends on culture, the specific environment, age, and social status. For example, by synthesizing survey results Paracchini et al. (2014) found most European citizens to travel less than 8 km to most recreational areas, while they would occasionally travel longer to visit more undisturbed sites. While such results could be used to model the distribution of nature's contributions, the unique nature qualities that attract people to specific locations in PAs is not easy to capture by travel movement patterns.

These methods are usually time consuming for respondents and require a large group of researchers to conduct the interviews and recruit participants. In addition, the surveys are rarely completed in real-time, which increases the chances of imprecise and erroneous reporting because they are highly dependent on the respondents' memory and willingness to participate. These methods have rapidly evolved to incorporate newer technologies that would ease data collection, such as phone interviews and electronic questionnaires.

Passive positioning

The use of mobile phones has spread over the last decades. With cheaper roaming prices and SIM cards, tourists are nowadays more likely to use their mobile phones when they are travelling. This has brought the opportunity to study spatial and temporal patterns of visitors without requiring any other inputs from the visitors. Furthermore, this method offers a big amount of data as the use of mobile phones is constantly being registered by mobile operators.

Ahas, Aasa, Roose, Mark, & Silm (2008) studied the passive mobile positioning of international tourists to Estonia. Based on call activity, they determined from where and when visitors were entering the country, the travel patterns between different locations and the activity level during the day. Similarly, Monz et al. (2019) validated mobile device locational data as an estimate of use level in PAs. These studies suggest that passive positioning data is a tool for identifying spatial and temporal patterns of visitors in less visited areas, where conducting interviews becomes challenging due to the low density of visitors.

The downsides of this method relate to at least four aspects. First, data is often provided by a company that processes data from mobile operators and can be economically costly to obtain. Second, since the method consists of passively gathering data, non-spatiotemporal data on visitors cannot be collected, except their origin. Also because data processing companies anonymize the data in accordance with customers' privacy. Third, visitor distribution is not enough to understand what nature qualities are important for people and what the nature's contribution to people is. Lastly, the method is not suited for areas with limited phone coverage, which often is the case for remote PAs.

Georeferenced social media

Social media platforms offer a passive positioning method for monitoring visitors. Some social media platforms allow users to either automatically (GPS functionality integrated on the phone or camera) or manually geotag images, which are thereby stored on the platform. This method allows for studying spatial and temporal distribution and travel patterns of visitors, as well as the relationship between the visitors and the surroundings they visit, and who those visitors are (Minin, Tenkanen, and Toivonen 2015). There is a growing interest for social media generated data in environmental research, especially for assessing CES, for which Twitter and Flickr are the platforms that have been used the most (Ghermandi and Sinclair 2019).

Different platforms have been used for tourism research and monitoring, such as Flickr, Twitter, Panoramio and Instagram. Wood et al. (2013) found that the number of pictures uploaded in Flickr was positively correlated with empirical visitor counts in recreation sites. Furthermore, these databases can be used for modelling visitor distribution using models such as MaxEnt, similar to Walden-Schreiner, Leung, and Tateosian (2018), who found infrastructure to be a major predictor for visitor distribution in Hawaii Volcanoes national park. However, a general advice is to combine several platforms in order to avoid biases introduced by differences in what people use these platforms for (Tenkanen et al. 2017).

Disadvantages of using social media databases include the lack of other variables that are not recorded by the platform, such as the country of origin of the user. This makes it difficult to identify cultural differences on values attached to landscape features. Moreover, manual geotagging can be imprecise due to unfamiliarity with the area, or lack of memory due to *a posteriori* tagging.

GPS receivers

Increasing the accuracy of measurement has been a major issue in research of spatial and temporal distribution of tourism. Thus, GPS devices have been implemented as an accurate data collection method (Montini et al. 2015). Visitors that enter e.g. a PA are given a GPS device that they will carry during their visit. Data obtained from the GPS devices are accurate with respect to temporal and spatial location of the visitor, departure and arrival time, attractions visited and walking speed among others (Shoval, Isaacson, and Chhetri 2014; Hallo, Manning, and Valliere 2004). This method also allows identifying off-trail use and important visitation hotspots (D'Antonio et al. 2010).

GPS devices can be used as a way to classify tourists according to how they allocate time and space when travelling (Grinberger, Shoval, and McKercher 2014). Beeco et al. (2013) combined it with paper surveys and trail design indicators to assess trail condition and predict the deterioration of trails. However, GPS data alone do not provide information on the location of nature's contributions to people and visitors' values. In an attempt to attribute additional data to specific locations, Birenboim et al. (2015) combined the data from GPS devices with real time SMS feedback on the experiences people had when visiting a zoo.

The accuracy of GPS devices has been shown to be better than other methods (Hallo, Manning, and Valliere 2004). However, the number of participants and the scale of the data are more limited than with other methods, because it requires specific devices to be carried by participants, therefore limiting the number of GPSs and the recovery possibilities (Shoval and Ahas 2016; D'Antonio et al. 2010). Moreover, combining GPS data with a survey is needed if additional information on the visitor is wanted (Hallo et al. 2012), such as demographic variables, the activities conducted, or the values attached to landscape features.

PPGIS

Web Public Participatory Geographic Information System (PPGIS) is based on an online participatory platform where the general public and stakeholders can drag and drop markers on a map. The markers vary according to the study aim, which can include e.g. place values, management preferences, visitor experience and satisfaction, and ecosystem services (van Riper et al. 2012; Pietilä and Fagerholm 2016; G. Brown, Montag, and Lyon 2012). The spatial data gathered can be used to create maps of visitor behavior through identifying areas of high density, potential conflicting zones, areas with more/less acceptance towards certain activities, and locations valued by visitors (Muñoz et al. 2019; Wolf, Brown, and Wohlfart 2018; Karimi and Brown 2017). Web-PPGIS can be combined with an online survey to provide more variables, such as demographics, so that visitors can be classified based on their origin or attachment to the area to understand the potential differences among visitors (Muñoz et al. 2019).

The use of web-PPGIS eases the recruitment of respondents in areas with low density of visitors and increases the time people can devote to answering the survey, as this is completed after visiting the surveyed area and not in the field. An additional advantage is that the recruitment is not affected by the weather, as is the case of *in situ* questionnaires and GPS tracking.

The spatial quality and accuracy of Web-PPGIS is a concern as the survey is completed after an event/activity is over, which introduces imprecision and memory dependency when locating the markers on the exact location or remembering past feelings and values. Although subjective judgements as values cannot be tested for spatial accuracy, Brown (2012) found respondents to accurately map physical landscape features.

Mobile apps

Mobile applications are increasingly being used as means to collect spatial data on visitors. Built-in functionalities in smartphones allow combining several of the above-mentioned methods, such as GPS tracking, real-time or *a posteriori* mapping and a survey. Thus, the spatial data gathered through mobile apps can include visitor distribution, start and stop time and place, time spent at different locations, and location of values and experiences.

The rapid development of mobile apps eases the use of already existing apps to monitor visitor distribution. Kim et al. (2018) used a popular exercise tracking mobile app to study spatial-temporal variations in a national park in South Korea, where they found differences in visitor hotspots between seasons, and between weekdays and weekends, which serve as indicators for crowding. Norman and Pickering (2017) found differences between existing mobile apps (GPSies, MapMyFitness and WikiLoc) in the data provided and the representativeness of the users, and concluded that careful use of the data is needed depending on the setting (e.g. different mobile apps are recommended for understanding urban and backcountry recreation). However, the development of dedicated mobile apps for tourism monitoring is just in the beginning (Pickering et al. 2018). For example, Kangas et al. (2015) developed a dedicated mobile app (Tienoo) for participatory forest planning, and concluded that the use of mobile apps can accurately provide georeferenced opinions and real time data to be used for recreation management in forests.

The opportunities that mobile apps bring to collecting spatial data on visitors to PAs are diverse, and include those already mentioned for GPS tracking and PPGIS (Muñoz, Hausner, and Monz 2019). Moreover, visitors are meant to use their own mobile device, which reduces the need for face-to-face contact or collecting devices back. Also, differences in spatial patterns between user groups can be studied if data on e.g. the origin of the visitor or activity type conducted are collected. However, the existing research using mobile apps is mainly directed to understand the spatial distribution of visitors, most often lacking the reasons for why people are attracted to particular sites and what nature qualities are important for that.

As highlighted by Beeco and Brown (2013) there is a general lack of spatial explicit data on peoples' values used for other purposes than visual and descriptive statistics. Therefore, in this thesis I use spatially explicit data on visitor values to identify areas highly valued by visitors and differences between visitors (paper I), and to understand how the values are correlated with environmental and infrastructure features (paper II).

2.4 Crowdsourced data

Crowdsourced data is created by a large body of users which are actively or passively involved in problem solving or creating content (Doan, Ramakrishnan, and Halevy 2011; Levin, Lechner, and Brown 2017). The development of the Web has eased recruitment and data collection (Doan, Ramakrishnan, and Halevy 2011), providing large datasets at low logistic, economic and temporal costs, which can facilitate visitor monitoring in landscape scale areas where recruitment is challenging (Wood et al. 2020). Thus, crowdsourced data can be gathered through some of the methods mentioned above, such as passive mobile positioning, social media, PPGIS and mobile apps.

The contribution users do to create data can be active or passive. Actively generated data include explicit participation of people, where the aim of the study is known by them and they voluntarily participate in data creation or gathering (See et al. 2016). These include platforms specifically designed for addressing a given issue, as could be the case of PPGIS and dedicated mobile apps. Passively generated data refers to when data is implicitly generated and collected, such as the case of social media or passive mobile positioning (Doan, Ramakrishnan, and Halevy 2011; Birenboim and Shoval 2016). In this case, users generate content that is not purposely intended for solving a known problem; rather the data is based on user traces (e.g. georeferenced images on social media).

Crowdsourced data and the use of the Web can overcome some of the challenges of traditional monitoring methods, such as face-to-face interviews and travel diaries. *In situ* collection of data can be limited by factors such as the amount of fieldworkers, weather, time of the day, or popularity of the surveyed area. Online platforms reduce the need for in-field recruitment and retention of participants, which can access a platform at a later stage and answer a survey, or generate data on their cell phone along their trip. Moreover, areas that are remote and sparsely visited are difficult to survey. This can be solved by adding *ex situ* recruitment strategies, such as advertising the study in social groups, traditional media and social media (Ridding et al. 2018; Wolf, Brown, and Wohlfart 2018).

3 Study area, design and methods

3.1 Protected areas in Norway

Similar to the global conservation trend, Norwegian PAs are increasing in number and extent. While 17.4 % of the mainland is protected, the distribution of PAs is skewed towards mountainous areas, with little protected coverage of the forest, the coastline and the sea (Miljødirektoratet 2019). Management of these areas has historically concerned nature conservation, and it was not until recently that human activities and user interests were incorporated into management of PAs (Higham et al. 2016).

Unlike other non-Scandinavian countries, Norwegian PA policies are strongly shaped by the concept *friluftsliv* (Higham et al. 2016), which is rooted in the Norwegian outdoor tradition. *Friluftsliv* refers to the tradition of self-organized outdoor recreation, and often includes hunting, fishing and berry picking. The Right of Public Access supports this tradition, by allowing free access to public- and private lands, given that no harm or disturbance is caused to people, animals, plants or any economically valuable resource (Kaltenborn et al. 2017; Tolvanen et al. 2005). PAs generally allow traditional rural uses such as fishing, hunting, grazing and traditional outdoor recreation. However, increasing tourism in PAs may pose challenges on the continuation of these activities, and traditional rural stakeholders advocate for a cautious tourism development (Haukeland, Daugstad, and Vistad 2011; Tolvanen et al. 2005).

The number of visitors in Norway has increased over the last decades (Innovation Norway 2017; Norwegian Ministry of Trade Industry and Fisheries 2017). This has been accentuated by the strategy launched by the Norwegian Government in 2012, which aimed at developing sustainable tourism in Norway, highlighting the value of nature and PAs as tourist destinations (Norwegian Ministry of Trade and Industry 2012). Shortly after, the Norwegian Environment Agency published a guideline for developing visitor management strategies that increase the value of PAs and assure a good experience to visitors (Miljødirektoratet 2015). The guidelines stress the importance of gaining spatial knowledge on values, tourism and nature users as an essential part of visitor management strategies.

The infrastructure and tourism facilities offered at Norwegian PAs are usually low and restricted. The amount of infrastructure demanded by visitors varies among different visitor segments, while some visitors seek as little infrastructure as possible, others are more comfort-oriented and demand more infrastructure related to recreational opportunities (Vistad and Vorkinn 2012; Veisten et al. 2015). However, further developing PAs and increasing tourism is not only limited by law but also by the impacts that these can cause in the environment, as for example wild reindeer displacement (Gundersen et al. 2019). Thus, PA management is challenged by tradeoffs of increasing tourism, accommodating visitors' needs and conserving the nature qualities for which PAs are designated.

3.2 Study area

I located our study area in southern Norway, and included several PAs and their surrounding areas (Figure 2). Established in 1980 for its wilderness and untouched nature, Jotunheimen national park (1151 km^2, herein Jotunheimen NP) is home for the highest peaks in Scandinavia (over 2000 m a.s.l.). Its distinct peaks and glaciers foster long trails that attract an increasing number of visitors for hikes, glaciers and cabin-to-cabin trips, and is one of the most visited national parks in Norway. In the same year, the neighboring Utladalen Protected Landscape (314 km^2, herein Utladalen PL) was established for its ecological and cultural importance. Utladalen PL covers one of Norway's deepest valley and highest waterfall, where cultural landscapes have been shaped over centuries, and offers popular hiking trails along the river. Breheimen national park (1691 km^2, herein Breheimen NP) is the youngest and largest of the three PAs in our study area, designated in 2009 for its distinctive ecosystems and lowly impacted landscapes. Similar to Jotunheimen NP, Breheimen NP holds some of the highest peaks in Norway and is well known for its glaciers and caves, but are less visited than the iconic Jotunheimen NP and Utladalen PL which receive more recreationists. The PAs are covered by an extensive net of marked trails and cabins maintained by the Norwegian Trekking Association, which are visited by hikers, climbers and nature enthusiasts. Moreover, wildlife and vegetation are also important visitor attractions, especially the wild reindeer populations and fish found in rivers and lakes.

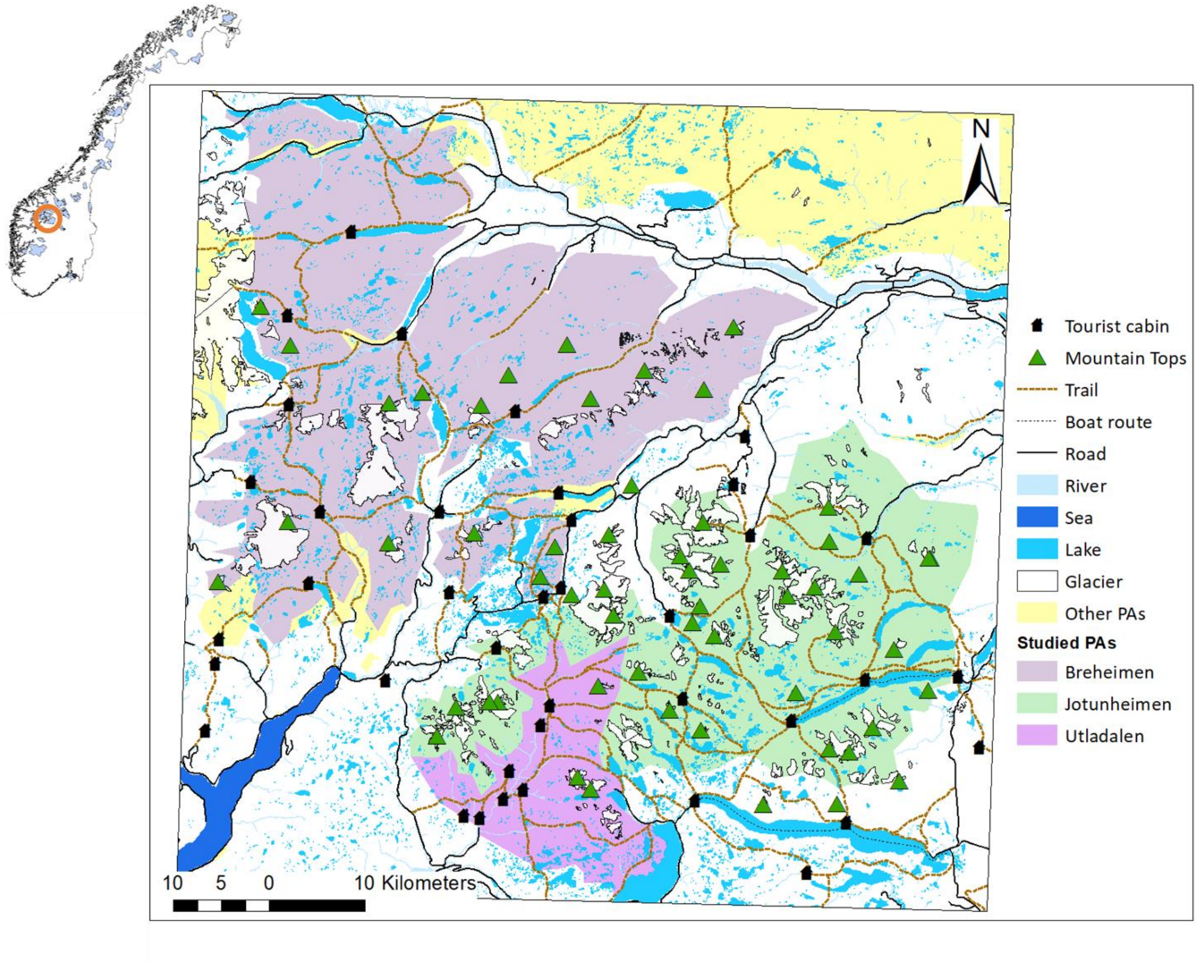

Figure 2. Map over the study area. On the top left map of Norway with the study area marked with a red circle. On the bottom right a detailed map of the study area with the selected PAs (Breheimen NP, Jotunheimen NP, and Utladalen PL).

There are several entrances to each of the PAs, most of them consisting of parking lots with no facilities. These remote PAs are located in a mountainous region, surrounded by rural settlements, for which tourism is an important income. People living in the area have a strong attachment to the surrounding nature, not only for recreation but also for traditional hunting, fishing, forestry and farming (Hausner, Brown, and Lægreid 2015). These uses persist from the 9th-10th century village commons, where locals were allowed to use resources for subsistence on land owned by the Crown (Higham et al. 2016). The recent melting of perennial snow patches due to climate warming in

Jotunheimen and the surrounding mountains has also uncovered ancient traces of these activities, such as arrows or clothes buried under the ice (Pilø et al. 2019). This adds to the area which is not only a natural attractor, but also an opportunity to learn from cultural heritage and climate change (Vistad et al. 2016). Today, experiencing nature, wilderness and stunning landscapes are the dominant reasons for visiting this area (Vistad, Selvaag, and Wold 2016).

The visitor strategy developed in 2012 for Jotunheimen NP and Utladalen PL is threefold and aims to deliver a good experience to visitors, contribute to local development and conserve the natural values of the PAs (Fylkesmannen i Oppland and SNO Jotunheimen 2012). However, increasing tourism may carry potential natural and social impacts. Although there is a common understanding and acceptance of extensive tourism development, traditional local users and local tourism businesses have different opinions on the way in which this should be managed (Haukeland, Daugstad, and Vistad 2011). As found by Haukeland, Daugstad, and Vistad (2011), while traditional users are more protective of their fishing and hunting activities, local tourism businesses advocate for more tourism infrastructure to accommodate the increasing tourism. Furthermore, Norwegian visitors use the inside of these PAs to a larger degree than international visitors, whereas international visitors optimize their time by travelling longer distances by motorized vehicles and hiking shorter time (Fylkesmannen i Oppland and SNO Jotunheimen 2012). According to visitor surveys, about half of the visitors are Norwegians and half internationals, with a 1:1 ratio of males and females, and between 44-54 % first time visitors (Vorkinn 2011; Vistad, Selvaag, and Wold 2016). As the amount of visitors increases and the opportunities of tourism spread, managers need a holistic understanding of how visitors use and value the landscape in order to avoid conflicts between the different user groups and impacts on nature.

3.3 Crowdsourced data

I analyzed three crowdsourced data gathering methods in order to assess how they can contribute to PA management by providing the spatial distribution of the values that people assign to the environment, and the nature qualities that are important for visitors (Figure 3). Using large datasets from diverse sources could reveal unexpected patterns that are not easily identified through single or traditional data gathering methods (Pan and Yang 2017). My thesis is grounded in online crowdsourcing to overcome some of the challenges of face-to-face interviews and surveys in remote areas, where recruitment is difficult due to low encounters with visitors and the lack of main entrances to the park (Ahas et al. 2008). Online crowdsourcing methods allow both remote recruitment of participants (e.g. through online or traditional media advertising) and face-to-face recruitment. Moreover, using big data, as is the case of crowdsourced data, has the potential to identify behavioral changes in the short-term (Pan and Yang 2017). However, the representativeness of the participants needs to be considered with caution, as it has been shown that the use of social media can be biased depending on the computational skills, gender, age, nationality or education of the users (Blank 2016).

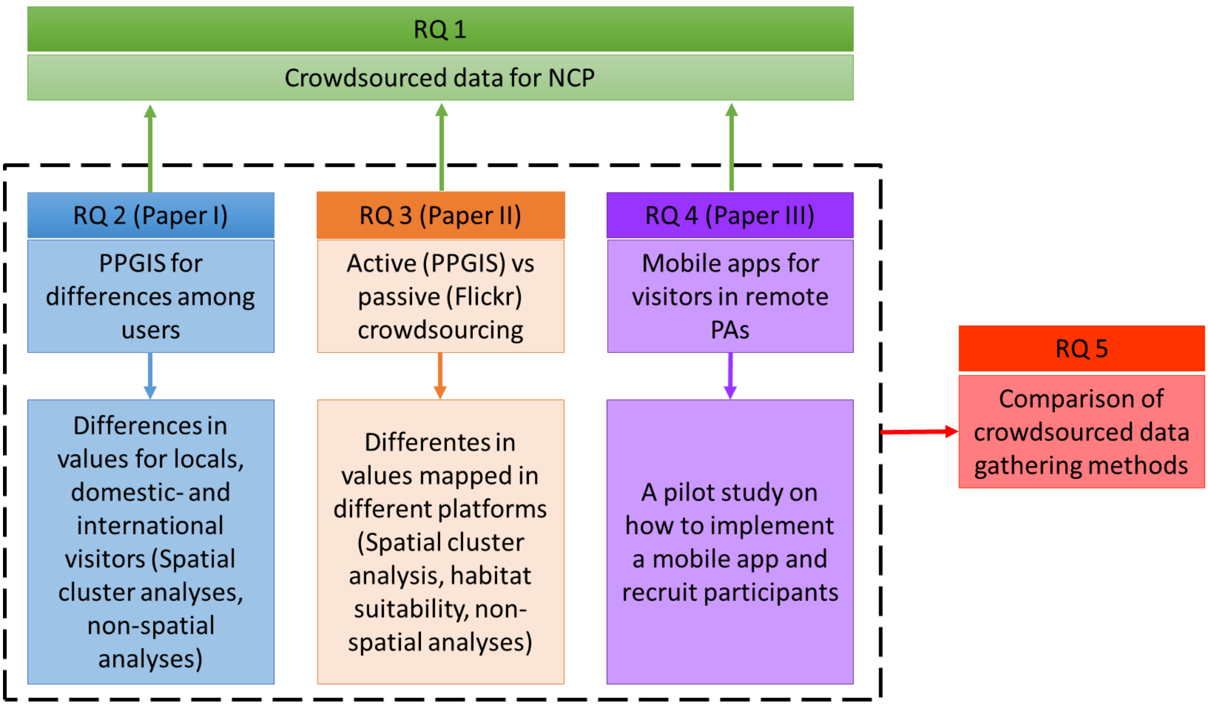

Figure 3. Conceptual map of the research questions and the methods used to analyze the data and answer the research questions.

3.3.1 PPGIS

Public Participatory Geographic Information System (PPGIS) is a mapping platform for the public or stakeholders to identify special areas. I used a PPGIS online platform to answer our RQ2: What kind of values do visitors map using an online mapping platform, and what are the main spatial and non-spatial differences among user groups (Paper 1)?

The advantage of PPGIS over passive crowdsourced data gathering methods is that it allows gathering other variables than the spatial data, such as demographic variables. In this study, I used the country of origin of the participants to test differences between them, as the cultural background, residence and attachment to a place can influence the perceived values in nature and management preferences (Brown 2017; Gundersen et al. 2015). Moreover, although online PPGIS requires a higher time commitment than the *in situ* surveys, it has a higher sampling efficiency (Wolf et al. 2015).

Brown (2017) showed that the efforts participants put into PPGIS surveys is higher for those that have a high attachment to the landscape, either because their livelihoods are related to the area or because they are familiar with it. I combined several recruitment strategies in order to gather a wide diversity of participants, from strong enthusiasts to one time visitors, including people with a strong attachment to the landscape and repeated visitors. In order to do so, I combined traditional and social media recruitment, household contact and *in situ* contact with PA visitors.

Response rates for the household and *in situ* contact were similar (around 14 %). However, the labor used for recruiting participants *in* situ at the PAs was higher than that used for household contact. Both recruitment strategies were necessary in order to include a big sample of locals, domestic- and international visitors, which would otherwise: 1) include only locals (if only the household recruitment was done) or 2) mainly include domestic and international visitors (if relying only on the *in situ* recruitment) as locals are not easy to recruit in high touristic season when they are on holiday somewhere else.

3.3.2 Flickr

Flickr is a free picture sharing platform where people can upload, tag and georeference their photos. I used Flickr to answer our RQ3: What kind of values are captured by using active (online mapping) and passive (Flickr) crowdsourced data to elucidate visitor values in PAs (Paper 2)?

Sharing content on social media is a generalized practice, not only on a daily basis but also for sharing travel experiences (Munar and Jacobsen 2014). Sharing visual content on social media with others is often motivated by the aim of helping other visitors, and photo albums are often posted after the trip is finalized (Munar and Jacobsen 2014). I selected the Flickr platform over Instagram, which is used more for posting in real-time (Hausmann et al. 2018). Also, compared to Panoramio it captures non-material benefits better (Oteros-Rozas et al. 2018). Furthermore, the content in Flickr can be downloaded for free by using an API, opposite to Facebook and Instagram (Ghermandi and Sinclair 2019).

One advantage of using Flickr for content analysis of the photos is that there is a large dataset available with no recruitment of participants needed, over a long period of time. This makes the data gathering process very quick and does not require any programming skills from the researcher/manager, opposite to e.g. mobile apps (Shoval, Isaacson, and Chhetri 2014). Although social media platforms have been used for visitor monitoring and value mapping at large scales (Mancini, Coghill, and Lusseau 2018; van Zanten et al. 2016), there is a need to test the usefulness of these for depicting the importance of specific landscape features, which requires a higher resolution than large-scale studies (Richards and Friess 2015).

In this thesis, I compare Flickr with PPGIS to find whether there are differences in the distribution of values in the landscape, and discuss possible reasons that may drive these differences.

3.3.3 Mobile apps

I developed a dedicated mobile app to monitor visitors to PAs and gathered spatial data on visitor values to answer RQ4: How can a dedicated mobile app be used for monitoring visitors and for elucidating nature's contribution to people in remote PAs (Paper 3)?

Generally, previous studies used existing mobile apps to monitor visitor movement and activities (e.g. Norman and Pickering (2017), Kim et al. (2018)). However, developing dedicated mobile apps for visitor monitoring is still rare. One of the few available examples is the study conducted by Kangas et al. (2015), who developed an app for mapping location specific preferences regarding aesthetics and recreation in a forest. In this study I developed a dedicated mobile application whose functionality was independent from phone coverage, which is often unstable in remote areas. This was one of the reasons why we chose remote recruitment, so participants could download the mobile app when they had internet connection. On the other hand, visitors that are about to start a trip in nature might not be willing to dedicate time to hear about the study, download a mobile app and make it work at once. Thus, I chose other recruitment methods that did not require encountering visitors *in situ*, such as newspaper articles, social media contact, leaflets and posters.

An advantage of using smartphones for data collection is the diversity of built-in functionalities that these devices include. Although being less accurate than GPS devices, smartphones have a high potential for spatial tourism monitoring as they are always carried by people and the built-in functionalities ease data collection (Shoval, Isaacson, and Chhetri 2014; Birenboim and Shoval 2016). I discarded including a GPS automatic tracking of the activity in the mobile app to prevent battery drainage, which can be a limitation of using mobile apps for tourism research (Shoval, Isaacson, and Chhetri 2014).

This dedicated mobile app included a real-time value mapping and a questionnaire to capture both spatial and non-spatial values of visitors to PAs. I chose the values based on the Common International Classification of Ecosystem Services and on previous studies on the disservices or negative values people ascribe to nature (European Environmental Agency 2018; Mackay and Campbell 2004; Plieninger et al. 2013). Also, I conducted interviews with owners of accommodation venues, tourists and park managers to test an initial version of the questionnaire.

3.4 Statistical analyses

3.4.1 Spatial cluster analysis

The spatial arrangement of georeferenced points can be randomly distributed or can form clusters. Density-based cluster analysis is an analytical tool to find groups of points that form high-density clouds of points (i.e. clusters or hotspots). The areas outside clusters contain a low density of points, which are typically referred to as noise (Kriegel et al. 2011) or coldspots. Identifying value hotspots can benefit management in directing conservation efforts as it identifies the areas that people value most (e.g. van Riper et al. (2012)). Moreover, clusters can inform about where conservation efforts are most needed in a heterogeneous landscape (Bagstad et al. 2016). Values that are outside clusters are more difficult to delineate and require careful spatial planning in order to maintain them (Fagerholm et al. 2019).

Clusters are formed by points that are near each other. I used the Density-based spatial clustering of applications with noise (dbscan) algorithm (Ester et al. 1996), which forms irregular shaped clusters of points. This algorithm classifies points in three classes, core points, border points and noise points. Core points are defined as those points that contain at least a threshold amount of points in their search radius. The threshold amount of points is set by the researcher based on the data structure and the studied system. The search radius is determined by the threshold generated on the density plot of the nearest distances between the points (k-nearest neighbor distances). The points that are within the search radius of core points, but are not surrounded by the minimum amount of points, are classified as border points. These, together with core points form clusters. The remaining points, i.e. noise points, are outside the search radius of core points, and are not surrounded by the minimum amount of points needed to classify as a core point.

3.4.2 Nature qualities and habitat suitability modelling

In order to identify the nature qualities that are valued by visitors, I examined the correlation between the values assigned to different locations, and environmental and infrastructure variables across the landscape. For that purpose, I use a modeling approach that is widely used for analyzing species distributions that compares the probability densities of a "species" occurring in a specific "habitat" (Elith et al. 2011). I use the term "habitat" as a reference to the original concept of the MaxEnt model. This allows assigning a given species to a set of environmental variables: in our case, the "species" are substituted by the georeferenced values that people mapped and the "habitat" is defined by the environmental and infrastructure variables, such as distance to mountain peaks, lakes, cabins and roads.

MaxEnt has traditionally been used for species modeling, although it has been proven successful in modeling social media photographs with regards to habitat characteristics (Richards and Friess 2015; Walden-Schreiner et al. 2018). Its robustness in such applications has resulted in opening the possibility to identify the nature qualities that are valued by people, and is therefore an interesting tool to use in the assessment of the spatially explicit values related to their surrounding environment. An advantage of MaxEnt over other habitat modeling approaches is that it performs well with presence only data (Elith et al. 2011), which is the case of value mapping. This means that areas where values are not mapped do not necessarily lack the value, it may rather be an unreported presence of a given value. One of the most interesting applications of MaxEnt is the predictive ability of the model, which provides the predicted probability of each value being present in a given location.

3.4.3 Non-spatial data analyses

I used Spearman Rank correlation, Pearson's chi-square test and non-parametric Kruskal-Wallis tests to identify differences in the types of values that were important for different user groups. I classified user groups according to their country of origin, as the cultural background of the visitors can affect how they relate to and behave in nature (Vorkinn 2011; Brown et al. 2015). Also, locals have a different attachment to their surroundings, and this could affect their relationship with nature (Gundersen et al. 2015). I used Spearman Rank correlation to compare how similar user groups were in their ranking of mapped values ranging from the most to the least mapped values. To account for differences in the relative amount of values mapped by each user group, I used Pearson's chi-square test, which shows that for standardized residuals higher than 2, the value has been mapped significantly more than expected, whereas standardized residuals lower than -2 indicate that the value has been mapped significantly less than expected. I used the Kruskal-Wallis test for finding significant differences in the frequencies of mapped values by each user group.

4 Results and discussion

In this thesis I answer the overall research question "How can different crowdsourced data contribute to elucidate nature's contribution to people through identifying areas valued by visitors in remote PAs?". To answer this question I have used three different crowdsourcing methods to map nature qualities that are important to people. My results provide new insights into how values are spatially distributed depending on the user groups and the data source used. All three methods had the potential to incorporate NCP into PA planning through spatially explicit values, as they can capture highly valued areas by diverse user groups on a large scale.

4.1 Crowdsourced data for NCP

This thesis aligns with the need for a diversification in values highlighted by the NCP concept, far from the more simplistic instrumental vs. intrinsic value debate, which has often been used in decision-making (Ellis, Pascual, and Mertz 2019). Relational values inform about how people relate to nature, and how nature contributes to a good quality of life (Chan, Gould, and Pascual 2018). I found scenic landscapes and recreation to be the most reported values by visitors, both in the PPGIS survey and the Flickr photos, which aligns with other visitor studies (Fagerholm et al. 2019; Oteros-Rozas et al. 2018; van Riper et al. 2012). This means that the contributions of nature that most often contribute to visitors' experiences are enjoying scenic landscapes and the recreational opportunities. Analyzing the spatial distribution of NCP can help prioritize visitor management efforts. For example, I found that people ascribe values to areas that are accessible by motorized vehicles or by foot, as infrastructure facilitates the proximity between people and nature. Also, values are typically located in high density clusters such as around famous mountain tops, glaciers and scenic hiking routes.

Crowdsourced data provides a large dataset to understand the values of different user groups and grasp the different ways in which people connect to nature. Such data can be challenging to obtain from interviews if respondents have not previously reflected on the nature qualities in a specific area

(Gould et al. 2015). Moreover, the way people value ES can be influenced by their knowledge of the given ES and the experience of the respondents (Scholte, van Teeffelen, and Verburg 2015). The diversity in crowdsourced data generating methods allow capturing the values of a variety of people, and can be complementary to other methods to reduce representation biases (Brown 2017; Bubalo, van Zanten, and Verburg 2019).

Using crowdsourced data for elucidating NCP provides the possibility of conducting socio-cultural valuation studies over a large sample of people. Either by passive or active crowdsourcing methods, the number of people that can be reached is higher than those recruited by more traditional methods that need face-to-face contact. For example, thousands of pictures are posted on social media by visitors to PAs sharing their experiences and preferences when visiting natural areas (Hausmann et al. 2018). This contributes to increasing the inclusiveness in nature management and conservation strategies that have previously been costly and complex to conduct.

4.2 Hotspot mapping and visitor groups (Paper I):

In Paper I, I answered the question "What kind of values do visitors map using an online mapping platform, and what are the main spatial and non-spatial differences among user groups?" by using an online PPGIS platform and analyzing the values mapped by visitors to Jotunheimen NP and Utladalen PL.

I found 83 % of the mapped values to belong to 13 value hotspots. These differed in the values contained and in the users who mapped them. Local users mapped more values on the western and central part of the study area, whereas domestic and international visitors mapped more values on the most iconic cabins, mountain peaks and trails on the eastern and northern parts of the study area. Overall, domestic and international visitors were more similar to each other in the values mapped and the distribution of these, mapping significantly more biological diversity and clean water values than local users, who mapped more points associated with cultural identity, hunting and fishing, and gathering.

The identified value hotspots can inform management about how important each of these are for people and why they are valued, and help them in prioritizing necessary management actions (Pietilä and Fagerholm 2019). Values that include direct use, such as recreation, can inform about the use of the landscape and infrastructure (Kulczyk, Woźniak, and Derek 2018). However, from the values that are not related to direct use, such as spirituality or special places, we cannot infer the visitation levels, as these values do not necessarily mean presence of people. Moreover, areas outside hotspots may receive the same visitation as those areas highly valued but they might not be considered as highly valued by visitors. In order to understand visitor movement, the online PPGIS platform would need to include a functionality to register the trail used, or combine it with a GPS tracking device, which can inform about the most crowded areas and areas in need of more intense management efforts (Korpilo, Virtanen, and Lehvävirta 2017). In addition to hotspots, areas with more scattered values cannot be ignored, as they may indicate important values for people and with high ecological relevance (Bagstad et al. 2016).

Studying how visitors use the landscape can inform management about potential conflict areas (Pietilä and Fagerholm 2019), which is vital for managing tourism, as is the case of Norwegian PAs. For example, Gundersen et al. (2015) found local and non-local visitors to differ in their management preferences. Shultis (1989) and Wray, Espiner, and Perkins (2010) highlighted the need to manage the needs of the different visitor groups, so that domestic visitors are not displaced when international tourism increases. Similarly, Brown et al. (2015) found that Norwegians prioritize direct use values more than Polish visitors to PAs, who prioritize more typical conservation values. Furthermore, the nature values and preferences of visitors affect the places they visit (Selvaag, Aas, and Gundersen 2020). Our study unravels a similar trend in the type and distribution of values, and strengthens the need to account for the differences between user groups when managing PAs. Unlike other studies that directly address conflicts between users through PPGIS (Wolf, Brown, and Wohlfart 2018), I did not specifically test whether values were in conflict. However, the spatial segregation of values mapped by people indicates that although user groups hold different values, these might be well segregated in space, with low potential for conflict. In conclusion, the PPGIS survey provides a range of benefits for informing PA management, in which the novel feature of our study is capturing the differences among locals and tourists in terms of both the values they map and their spatial distribution.

4.3 Infrastructure and nature qualities (Paper II)

In Paper II I answered the question “What kind of values are captured by using active (online mapping) and passive (Flickr) crowdsourced data to elucidate visitor values in PAs?” by comparing two crowdsourcing platforms in Jotunheimen NP, Breheimen NP, Utladalen PL and the surrounding landscapes and settlements.

I found that Flickr and PPGIS capture different locations that are highly valued by visitors. The values in the Flickr dataset are more clustered, compared to PPGIS, which in addition to hotspots also contains areas with low density of values (Plieninger et al. 2013; van Riper et al. 2012). When comparing the distribution correlation of values with respect to infrastructure and environmental variables, I found that the areas close to infrastructure capture the highest densities of values in the Flickr dataset, whereas PPGIS values were more concentrated around trails and nature attractions (i.e. mountain peaks and glaciers). However, the datasets show a good overlap in the predicted spatial distribution probability of values, especially for recreation and scenery values. Despite of the higher importance of motorized access, nature attractions and trails are still important variables that determine the spatial distribution of pictures in the Flickr dataset, which resemblances the results found by Walden-Schreiner, Leung, and Tateosian (2018).

In addition to the difficulties encountered by managers and policy-makers to elucidate and value NCP, the data gathering method chosen to study nature's contributions can introduce new challenges that affect the outcome. Passive crowdsourced data, as Flickr, can offer a large dataset with no recruitment effort and allow studying changes in values over seasons or years, which is often lacking in visitor monitoring studies (Pietilä and Fagerholm 2019). Mancini, Coghill, and Lusseau (2018) found the photos uploaded to Flickr to be a good indicator of spatial and temporal variations of nature-based recreationists at a coarse scale. However, Flickr does not capture a broad range of values associated with PAs (Levin, Lechner, and Brown 2017), which I also show in Paper II.

The differences in the placement of values between the two methods could be due to several reasons. Georeferencing Flickr images is an implicit process, where geotagging is optional and often automated (Bubalo, van Zanten, and Verburg 2019). Introducing the actual coordinates of where the photo belongs to is not obligatory, and the coordinates assigned to the photo often belong to the place where the picture was taken rather than the actual feature, thus reducing the accuracy of the posted content (Zielstra and Hochmair 2013). This can also be the reason why Flickr photos are more clustered than PPGIS values. Moreover, mapping values on a dedicated platform, such as PPGIS, allows users to tag places that have not been visited, but are still important for them, especially non-use values such as spiritual places. Although both methods can inform about the spatial values people have in PAs and their surroundings, the scale at which these are informative is different. While PPGIS can capture values at a fine resolution, Flickr performs best at coarser resolutions.

The different nature of the methods used to gather information, i.e. Flickr vs. PPGIS, show how values relate to different infrastructure and environmental features in each of the datasets. If only the Flickr dataset was assessed, then one could conclude that roads are most important for the value distribution. However, when comparing the two datasets, values are in areas that are quite accessible for people, not only around roads but also around trails. Other studies also found that the benefits that people obtain from nature and what they value, do not only depend on the ecological features, but also on social constructs and infrastructure (Daniel et al. 2012; Richards and Friess 2015). Moreover, Kulczyk, Woźniak, and Derek (2018) found that nature is the main attraction on a regional scale, but infrastructure significantly affects the distribution of recreational values on the local scale. Thus, infrastructure is a facilitator of cultural ecosystem services that allows people to experience the nature's contributions. This does not mean that building infrastructure will automatically increase the non-material contribution to people. Fagerholm et al. (2019) found that recreational values were most abundant close to settlements and roads, whereas the abundance of aesthetic and cultural values increased with distance from respondent's home. Also, Brown, Helene Hausner, and Lægreid (2015) found that people mapped social and therapeutic values closer to settlements, while sparsely vegetated mountain areas were more valued for recreational fishing, undisturbed nature and scenery. Nature-based tourism requires access to areas of limited resource use, which means that there is a tradeoff between the amount of infrastructure and the values of visitors to natural areas (Raudsepp-Hearne, Peterson, and Bennett 2010). Moreover, new infrastructure can affect the provision of natural processes and features that contribute to the provision of non-material benefits, such as the opportunity to experience wild reindeer in the study area (Gundersen et al. 2019). But it is important to keep in mind that, as described by Fish, Church, and Winter (2016), nature's non-material contributions emerge from relations between people and nature. As summarized in Paper II, the scenery is often the most reported value, which could easily be degraded by infrastructure development.

4.4 A dedicated mobile app and recruitment (Paper III)

I addressed the question "How can a dedicated mobile app be used for monitoring visitors and for elucidating nature's contribution to people in remote PAs?" in Paper III by piloting a dedicated mobile app among visitors to Jotunheimen NP and Utladalen PL.

Traditional methods and passive crowdsourcing data for visitor monitoring in PAs entail several challenges regarding the type of information gathered, the amount of people reached, and logistic difficulties for data gathering. Many of these challenges can be solved by using a dedicated mobile app to gather the information needed from visitors. In Paper III I piloted a dedicated mobile app to test how such a tool can be used for depicting the nature qualities that people value. Although I retrieved a low amount of data due to technical and temporal challenges, I gathered enough information to develop a guideline on the options and limitations, and the challenges of recruiting participants.

There is a large body of mobile applications to supply tourists with information about travelling and destinations (Wang, Park, and Fesenmaier 2011). Although mobile apps can benefit PA managers by providing real-time feedbacks from visitors (Pietilä and Fagerholm 2019), tailored mobile apps for visitor monitoring are few and have not been widely used in research and management. . A more common practice is to use existing, generic mobile apps, such as those that track the activity of users. Korpilo, Virtanen, and Lehvävirta (2017) proved the validity of already existing apps for tracking visitor movement in recreational areas as tools to assess on- and off-trail use, and to identify visitor hotspots and subsequent degradation of trails. Volunteers were directly contacted in either person or online, to gather additional information on socio-demographic variables. This recruitment strategy does not take full advantage of the large body of data provided by such a crowdsourced data tool.

Dedicated mobile applications can make use of the diversity of built-in functionalities in smartphones that allow tracking visitors in space and time (Birenboim and Shoval 2016). Studies that combine various visitor monitoring methods (e.g. Korpilo et al. (2018)) can benefit from developing dedicated mobile apps, by combining a mapping exercise, a tracking activity and a survey in a single platform, thus combining data collection for many different purposes. Doherty, Lemieux, and Canally (2014) designed and tested a mobile app using GPS tracking, voice recording and close-ended questions to capture visitor movement, moods, emotions and experiences. They concluded that mobile apps can be engaging and retain participants through the surveying period (Doherty, Lemieux, and Canally 2014). Kangas et al. (2015) included useful information for visitors as well as a geocaching game in order to increase the engagement of participants in the app thereby providing feedback for managing the park.

One of the main challenges of using dedicated mobile apps, and a plausible reason of why they have not been widely implemented yet, is the recruitment of participants (Venturelli, Kieran, and Christian 2016), and therefore, studies with dedicated mobile apps are often pilot studies with a very limited number of participants (Doherty, Lemieux, and Canally 2014; Birenboim 2016). In this pilot study, I found that marketing the app in a local newspaper and directly contacting participants through social media are good recruitment strategies. Moreover, the posters and information leaflets distributed among accommodation venues and tourism information offices contributed to the downloads after the pilot study officially finished. Even though I had insufficient time to test the mobile app and develop a long-lasting collaboration with user organizations, two weeks of recruitment resulted in 123 participants. Emphasizing the contribution of participants, recognizing the relevance of the study for decision-making, and introducing incentives can increase participation and retention (Brovelli, Minghini, and Zamboni 2016). In summary, participant recruitment can be enhanced by including a diversity of channels to reach visitors, ensuring the usefulness of their contribution, and providing participants with benefits, either useful information or monetary or non-monetary incentives.

Another challenge that may hinder participation is the user-friendliness of the app. Developing a mature and user-friendly mobile app requires several optimization iterations that are time consuming and costly. Due to limited resources and time, I was unable to optimize the functionality of our mobile app, which resulted in visitors misunderstanding how the mobile app was intended to be used. From our pilot study, I suggest a testing period of the app with park managers, tourism stakeholders and visitors in order to optimize the functionalities and instructions provided in the app.

4.5 Comparison between PPGIS, Flickr and Mobile apps

Summarizing what I learned in Papers I-III, I answered the question "What are the advantages and challenges of using the different crowdsourced data for monitoring visitors in remote PAs (Paper I-III)?". The three crowdsourcing methods used in this thesis are successful at depicting the values that visitors to PAs assign to nature qualities. However, there are nuances in the type of data that each of these methods provide (Table 1).

Each of the methods is characterized by the capacities of the researcher/manager and the data that is generated. Flickr is the data source that requires the least amount of resources for recruiting participants and data gathering, and the technical skills needed are only with respect to downloading the data using an API. Another advantage is the large amount of users that the platform already has, and the large amount of geotagged content that people upload (Toivonen et al. 2019). This brings new opportunities for large-scale analyses (Ghermandi and Sinclair 2019). The platform was launched in 2004 and has since then collected data from thousands of users. This allows studying changes in visitors and values over time and over seasons (Mancini, Coghill, and Lusseau 2018; Walden-Schreiner et al. 2018). Also, social media images can be used to identify the nature qualities and infrastructure variables that relate most to the distribution of visitors. Similar to our study, Walden-Schreiner et al. (2018) and Richards and Friess (2015) found that infrastructure explains best the distribution of photographs, more than any other environmental feature. The downsides of using Flickr are that the available data is predefined by the platform and cannot be customized. Furthermore, the spatial location of the photos may differ between where the photo is taken and the actual location of the valued nature quality (Zielstra and Hochmair 2013). This reduces the resolution at which the data is meaningful, suggesting that the regional scale probably is the most reliable scale (Mancini, Coghill, and Lusseau 2018).

On the other end are PPGIS and mobile apps, both customizable platforms. PPGIS is a well-established method that has been used to map different spatial attributes, such as values, experiences and development preferences (Brown et al. 2015; Brown and Weber 2013; Wolf et al. 2015). Establishing the platform requires technical skills and costs, although increasingly more mapping platforms offer easy software to develop such a tool (e.g. maptionnaire.com). The data is actively generated by participants, which can be recruited either by direct contact or through advertising for volunteer participation (Brown 2017). Maps created through PPGIS surveys have been shown to be accurate at identifying landscape elements at local scale (Brown et al. 2018). PPGIS studies have usually been conducted as one-time studies, with little application to long-term mapping of changes. This could be because of the novelty of the method, or because of the short-term needs (e.g. informing policy-making about the areas with the least potential conflict for development).

Dedicated mobile apps for visitor monitoring can include a PPGIS mapping exercise and combine it with other built-in functionalities that smartphones offer. Thus, the type of data that can be collected is the most diverse, and can include tracking, voice recording, picture uploading, common surveys and generating real-time content (Birenboim and Shoval 2016). For example, the location of values can be compared to the GPS tracks of visitors in order to understand the relationship between values and movement. Also, the distribution of visitors can inform about their impacts on nature, such as changes in reindeer distribution (Gundersen et al. 2019). As there is a wide array of possibilities, the technical skills and initial costs for developing such a tool are the highest among the aforementioned methods. The recruitment strategy is also a key element of implementing mobile apps, which differs from PPGIS, as problems with downloading the app may occur due to the lack of or bad phone connection in remote areas. However, the data gathered using an app can be as accurate as the internal GPS sensor in the smartphone (Doherty, Lemieux, and Canally 2014), which allows depicting NCP at a fine scale. Moreover, once the mobile app is established a large body of participants can be reached, and if maintained over a long period of time, the app can serve as a spatial and temporal monitoring tool (Kim et al. 2018).

Table 1. Summary of advantages and limitations of Flickr, PPGIS and the mobile app learned from the literature and from our studies.

	Flickr	PPGIS	Mobile app
Types of values that can be mapped	Limited to what can be seen in pictures or keywords and interpreted by a coder	Unlimited, but too many attributes can result in lower recruitment of on-line mappers (Brown and Kyttä 2014)	Unlimited, but better to reduce the number to ease tagging time
Scope of spatial locations represented	Only the place visited by the user	Allows people to assign values to unvisited areas e.g. due to their existential value	Only place visited if tagging while tracking, also unvisited areas if *a posteriori tagging*
Scale and spatial extent	Up to continental scale, fine scale in cities or highly visited and accessible areas only (Mancini, Coghill, and Lusseau 2018; van Zanten et al. 2016)	Usually limited by cost to local or regional scale	Unlimited, depending on the recruitment strategy
Additional data on demographics, socioeconomics	Very limited (home location provided by some users, no data on gender, age etc)	The survey can be customized to include e.g. demographic questions, preferences, opinions related to protected area management or impacts of development (Brown et al. 2015; Kivinen, Vartiainen, and Kumpula 2018)	The survey and the functionalities used can be customized
Accuracy	From meters to over a kilometer (Zielstra and Hochmair 2013) The automatic geotagging of pictures can reduce the location accuracy by e.g. geotagging pictures to a predefined list of places, instead of the accurate GPS location (Kim et al. 2019)	Not possible to assess the accuracy of values because there is no "true" distribution, but PPGIS data has been shown to be quite accurate for conservation (Brown and Kyttä 2014; Brown 2012; Cox et al. 2014; Brown et al. 2018)	Up to a few meters depending on the accuracy of the built-in GPS (Doherty, Lemieux, and Canally 2014)
Number and diversity of users	Large diversity, but unknown who they are (Kim et al. 2019)	Dependent on the recruitment strategy but can target both specific stakeholders and the general public	Dependent on the recruitment strategy but can target both specific stakeholders and the general public
Time-series	Many years of data now available (Flickr since 2004) (Kim et al. 2019; Mancini, Coghill, and Lusseau 2018) but values may not be comparable between years due to changing user base or marketing strategy of social media platform	Usually one-time survey	As long as the app is active
Logistic costs	Data collection costs low (Kim et al. 2019)	Dependent on the recruitment strategy, which can be *in-situ*, postal contact or through media advertisement	Costs related to developing and testing the app, and the recruitment strategy

4.6 Contribution to management

This thesis provides insights on how managers and policy makers could benefit from different methods to elucidate NCP and the values people hold on nature qualities. I suggest a stepwise approach to deciding which method is the most convenient in each case, depending on the type of data needed, the scale of the study, the budget and the resolution. Figure 4 represents the tradeoffs between the characteristics of each data gathering method, explained further below.

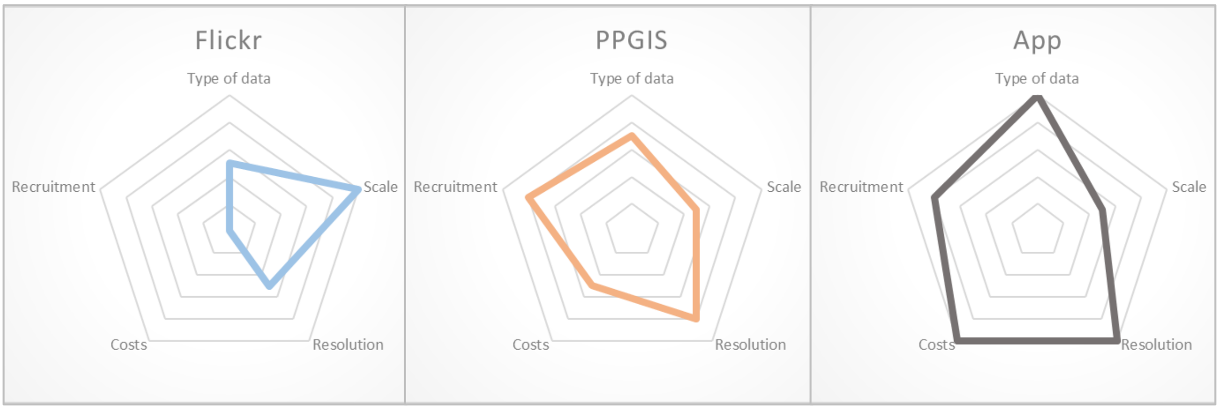

Figure 4. Tradeoffs between type of data, spatial scale, resolution, costs and recruitment effort for Flickr, PPGIS and mobile apps.

One of the main characteristics to consider for choosing a crowdsourcing method is the data we want to collect. The three studied methods can be placed in a gradient from non-customizable and predetermined data to rich-customizable data. Social media offers non-customizable data, which is determined by the chosen platform. In the case of Flickr, geotagged pictures can be downloaded with tags and some demographic variables about the user. However, not all users include their country of origin nor use tags in each photo, and therefore requires interpretation of the pictures. PPGIS platforms are customizable in the type of spatial data gathered and the additional questions added. The difference between a mobile app and PPGIS is the option to include real-time data (e.g. real-time mapping) and passively generated data (e.g. activity tracking), which are not possible with an online PPGIS platform. Dedicated mobile apps have the largest potential to collect many different types of data, with active or passive input from the participant thanks to the diversity of built-in functionalities of smartphones (Birenboim and Shoval 2016). In addition, a single platform can combine several data input modes, for example as I did with questionnaires and real-time mapping. Additional functionalities can be used depending on the data needed, such as GPS tracking of the route followed by the user to identify the areas visited and off-trail use (D'Antonio et al. 2010).

Flickr requires no recruitment, but includes contributions from a large group of citizens as thousands of users use such platforms daily. For example, van Zanten et al. (2016) used social media data to study landscape values across Europe. Social media has also been used to compare human-nature relationships at municipality level across different countries in Europe (Oteros-Rozas et al. 2018). Although passively generated data cover vast areas, PPGIS has also been used to collect data at the regional level, including several municipalities and even across countries (Brown et al. 2015; Fagerholm et al. 2019). However, recruiting participants in such a big area is more costly. Norwegian PAs could benefit from remotely gathering data, as the many entrances and remoteness of PAs hinder face-to-face recruitment.

The degree to which PAs can implement management actions and monitoring programs is often limited due to lack of financial support (Watson et al. 2014). In these cases, a passive crowdsourced data platform can provide management relevant information at very low or no cost. On the contrary, developing a dedicated mobile app has higher initial costs. However, the costs of developing new software are decreasing with the open data initiative, where developers publicly share their code source so others can contribute to it or use it further. Furthermore, there are online services that offer a template PPGIS platform that can be customized at a low price (e.g. maptionnaire.com). Although the initial economic costs of creating a dedicated platform are decreasing, there are additional temporal and monetary costs of using such platforms that entail the recruitment strategy. Whether participants are recruited by direct contact or indirect advertising, recruiting enough visitors can be costly. Furthermore, the visitor sample needs to be considered with caution, as the use of internet and social media is often not representative of the whole population (Blank 2016). Thus, combining either of these methods with traditional methods can inform about the representativeness of the sampled visitors.

The resolution of spatial data varies with the method chosen. Mobile apps can use the built-in GPS in smartphones to create spatial logs, the accuracy of which will be very high, up to few meters depending on the phone, where the phone is stored, and satellite visibility (Hardy et al. 2017). There are additional built-in functionalities that can provide data on the spatial location of the phone, for example phone coverage, Wi-Fi and Bluetooth signals (Birenboim and Shoval 2016). However, these are better suited for urban environments where wireless connection, transmitters and phone coverage are reliable (Birenboim and Shoval 2016). Thus, location records based on GPS is the most reliable spatial information source as it only depends on the satellite connectivity. Pictures uploaded in Flickr may also include accurate GPS locations provided by the device with which the picture is taken. However, the problem arises when the features in the picture are far from the place where the picture is taken, introducing inaccurate locations (Zielstra and Hochmair 2013). Furthermore, social media data can be manually or automatically geotagged, which reduces the accuracy of the content. Studies by Gliozzo, Pettorelli, and Haklay (2016) and Mancini, Coghill, and Lusseau (2018) have shown the reliability of Flickr data at resolutions of 1 km and 10 km respectively. PPGIS platforms often consist on manually placing markers in maps, either on paper or online. While people can accurately identify areas of conservation concern (Brown et al. 2018), the accuracy of the entries may vary with knowledge about the area or time dedicated to zooming in the map. For managers that need an overall picture of a region, social media is sufficient. However, if the aim is to detect off-trail use or to identify areas of concern for conservation, then a dedicated mobile app would be more appropriate.

In summary, this thesis can guide managers in choosing the best crowdsourced data gathering method to inform PA management based on the needs and resources of each case.

4.7 Limitations

There are inherent limitations in the presented studies.

First, the lack of information on visitors to our study area, and incomplete demographic information on Flickr users made me unable to assess whether sampled visitors are representative of all visitors. Using crowdsourcing methods might introduce multiple biases (Bubalo, van Zanten, and Verburg 2019). For example, different social media platforms are used by different population sectors (Ruths and Pfeffer 2014), older visitors might participate in surveys while younger ones publish on social media (Heikinheimo et al. 2017), and wealthier visitors may share less in social media (Hausmann et al. 2018). In a study comparing Twitter users and the US population, Mislove et al. (2011) found an overrepresentation of males and underrepresentation of less populated areas. As summarized by Brown and Kyttä (2014), the spatial data on PPGIS studies can be influenced by age, knowledge about the area, level of education and place of residence. Moreover, Brown, Kelly, and Whitall (2014) concluded that the recruitment strategy and motivation to participate can affect the type of data gathered. They found that while volunteers lived further away and mapped more forest utilization preferences, local households preferred preservation of nature qualities. Thus, basic visitor statistics and demographic variables play an important role in assessing the representativeness of participants in studies using new technologies.

Second, I could only pilot the mobile app for a short period of time. The survey was developed with feedback from park managers, tourists and tourism accommodation venues, which tested an initial version of the survey to identify the most important information to incorporate in the survey. Although an advantage of using smartphones for visitor monitoring instead of other dedicated devices is to be a user-friendly method (Korpilo, Virtanen, and Lehvävirta 2017), I did not have the time to optimize our mobile-app and to make it smarter. Moreover, the recruitment strategy and instructions to participants on how to use of the mobile app are key to ensure the right completion of the study requirements (Hardy et al. 2017). Our short recruitment period did not allow for follow up contact with study participants, which hindered optimizing the app based on participant feedback. Consequently, the data generated was limited and the mapping exercise did not provide data on spatial values.

Third, there are a number of non-spatial values that are not captured in such spatially explicit studies as PPGIS and Flickr studies, for example inspiration, learning and health. These nature's contributions might be provided by a combination of experiences in nature rather than by a specific location. We tried accounting for this in the mobile app. Including a PPGIS survey in a mobile app can perform well at capturing both spatial and non-spatial values by using a mapping exercise combined with follow up questions that e.g. rate non-spatial values.

Fourth, privacy is a special concern when personal sensitive data is collected in scientific research. For example, studies that interview citizens may have information that may identify the interviewee. In Norway the Norwegian 2000 Personal Data Act obliges researches to treat data anonymously and does not allow the publication of such sensitive data without consent. Even when sensitive data might not be collected, the questionnaire/interview questions have to be evaluated by an ethical committee that will give or reject permission to conduct the research. At the European level The Regulation (EU) 2016/679 on protection of personal data regulates how personal sensitive data has to be handled (European Parliament and Council 2016). Despite of assurances of anonymous treatment of data, visitors can feel uncomfortable sharing their location in real time (Hardy et al. 2017).

Lastly, PAs need long-term monitoring programs to evaluate the sustainability of recreation (Manning et al. 2011), which could be hindered by the rapid development of new technologies that gather crowdsourced data on visitation. A large body of research has compared crowdsourced data with data obtained through traditional methods, concluding the validity of emerging methods for visitor monitoring (e.g. Monz et al. (2019), Mancini, Coghill, and Lusseau (2018), Levin, Lechner, and Brown (2017)). However, new technologies evolve rapidly, and the crowdsourced data platforms may change in the future. New methods need to be validated to ensure that the methods produce comparable data so the long-term validity of the data is not compromised.

4.8 Future work

This thesis shows the usefulness of crowdsourced data for visitor monitoring, the opportunities and limitations of each method, and their contribution to spatial planning. All three methods have potential for mapping NCP, but I highlight the potential of mobile apps to gather relevant information for spatial planning and monitoring on PAs.

User-friendly apps that have recruited participants through a thorough recruitment strategy and used incentives to motivate participation and retention, have been shown effective at tracking visitors in natural areas (Hardy et al. 2017; Kangas et al. 2015). Developing a mobile app that is available in different languages and that provides touristic information to visitors would benefit from a higher retention of participants. Moreover, a dedicated mobile app can include data gathering methods similar to social media and PPGIS, by incorporating the possibility to upload images in real-time or mapping values *a posteriori*. Due to the wide range of possibilities offered by mobile apps and the fact that a high percentage of the population uses smartphones, mobile apps facilitate custom data collection. Moreover, PAs with limited funding for monitoring can benefit from such a tool, as it only needs an initial investment for developing the app, but can thereafter be used in following years at low maintenance costs (e.g. updates, database storage).

5 Conclusions – Implications for conservation

PAs are one of the most used tools to conserve nature and to assure the long lasting of nature's contributions to people. However, increasing visitation to PAs could impact the natural features that the PAs are intended to protect and the nature's contributions that attracted visitors to the PA in the first place. Therefore, PA managers need methods that can monitor management relevant issues, such as visitor distribution, highly valued areas and visitors' experience. Lack of funding and resources in PAs has often hindered monitoring efforts, and therefore the development of cost-effective methods that can provide information at management relevant scales is of pivotal importance. These PAs could greatly benefit from obtaining spatial data on visitors, which provide the necessary information to direct management efforts to specific areas inside the PA at hand.

Crowdsourced data gathering methods are capable of providing management relevant spatial data on visitors to PAs. As shown in this thesis, both active and passive crowdsourcing platforms can provide data relevant for PAs. The most appropriate platform would depend on the resources available, the scale and resolution of the data needed, and the type of information required. Crowdsourced data can also be used in combination with traditional surveys, which could provide insights on the representativeness of visitors recruited in crowdsourcing methods.

The contribution of this thesis is that it clarifies the differences between crowdsourcing data gathering methods, and the opportunities and limitations of each of them as tools to capture how people relate to nature through the values PA visitors ascribe to it. This information is key when using such tools for PA management and decision-making. In addition to contributing to PA management, this thesis also proved the potential of crowdsourcing methods to provide relevant information to elucidate NCP and contribute to socio-cultural valuation assessments. The values people ascribe to nature can inform about the areas most valued by people and the infrastructure and environmental variables most important for the distribution of these. For example, in Paper II we found that values are clustered around main mountain tops, glaciers and accessibility infrastructure. Moreover, the study of visitor values can identify how user groups differ with respect to how they relate to nature. As we found in Paper I, local visitors differ from domestic and international visitors in their values, as locals relate more to cultural values, hunting and fishing while domestic and international visitors relate more to clean water, biodiversity and therapeutic values.

The crowdsourcing methods analyzed in this thesis can create large high quality datasets in a short period. Crowdsourced data can capture how people respond to alterations in the landscape or variations in the profiles of visitors to PAs. In either case, these methods allow managers to identify changes fast and react to new visitor dynamics like never before. However, there is need for further research on dedicated mobile apps to understand their full potential and opportunities to gather visitor related data over time and overcome some of the limitations of other crowdsourcing methods. Also, the rapid development of the smartphone technology promises new and better functionalities to generate information on how people relate to nature.

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Papers I-III

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Identifying spatial overlap in the values of locals, domestic- and international tourists to protected areas

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ABSTRACT

Nature-based tourism is increasingly encouraged to support local socioeconomic development in and around protected areas, but managing protected areas for tourism could challenge existing park uses associated with self-organized outdoor recreation and local resource use. We used a web-based Public Participatory Geographic Information System (PPGIS) to identify the most important places and values of local, domestic, and international visitors to Jotunheimen National Park and Utladalen Protected Landscape in Norway. Scenic and recreation values were prioritized by all groups, but local users mapped more values relating to hunting, fishing, gathering and cultural identity. While the three user groups overlapped in some places, we found that they self-segregated to some extent. Our study affirms the importance of spatially explicit analyses to support protected area management. Understanding the spatial distribution of values held by different user groups can aid in designing tourism management strategies that minimize intergroup conflict.

1. Introduction

Though early protected areas largely ignored or excluded local residents in pursuit of protecting wilderness, iconic landscapes, and wildlife for public enjoyment, protected area management has over time become more inclusive of traditional uses and local cultures (Dudley & Stolton, 2010; Linnell, Kaczensky, Wotschikowsky, Lescureux, & Boitani, 2015; Nepal, 2002). Modern protected areas are expected to fulfil multiple and sometimes conflicting objectives (Dudley & Stolton, 2010; IUCN, 2017; Manning, Anderson, & Pettengill, 2017). Many protected areas share dual mandates of providing access to recreational areas for the public and of protecting biological diversity and resources for future generations. Protected areas are also increasingly expected to provide community benefits primarily through attracting more tourists to generate new jobs and stimulate local development (Murphy, 1988; Simpson, 2008; Weaver & Lawton, 2017). This brings with it new and complex challenges for management, such as offering high quality experiences to a broader range of visitors and generate income and livelihood benefits to communities, whilst minimizing adverse impacts on the environment and on the traditional users of protected land (Bushell & Eagles, 2006).

The rapid increase of nature-based tourism during the last decades (Balmford et al., 2009) coupled with the diversification of protected area objectives (Stolton & Dudley, 2010), implies that a broader range of values need to be handled and weighted by protected area managers (Chape, Spalding, & Jenkins, 2008). Conservation conflicts are often more about values, perceptions and attitudes than about facts (Dickman, 2010). Assessing users' values and priorities in protected areas is crucial for avoiding antagonism between user groups. Protected area management is also inherently spatial. Mapping users' values and experiences to specific places provides managers with information about the destinations that are preferred by tourists as well as their potential overlap with areas valued by local communities. Spatially mapped values can also be combined with biophysical data to identify potential threats to biodiversity conservation priorities (Gosal, Newton, & Gillingham, 2018; Whitehead et al., 2014).

Web-based Public Participatory Geographic Information System (PPGIS) is one of the tools that has been used to identify protected area values (G. Brown & Weber, 2011; van Riper, Kyle, Sutton, Barnes, & Sherrouse, 2012). PPGIS allows the general public and stakeholders to identify and map their place-based values and preferences using an online platform, thereby gathering spatially explicit information about

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the places valued by different individuals and groups. PPGIS has been used in a wide range of applications for protected areas G. Brown and Fagerholm (2015) and G. Brown, Montag, and Lyon (2012), including to identify park qualities from a visitors perspective including online mapping of visitor experience and satisfaction (Pietila & Fagerholm, 2016), identify value hotspots within park boundaries (Van Riper & Kyle, 2014a), and map of tourism preferences regarding development in or near park boundaries (G. Brown & Raymond, 2006; G. Brown & Weber, 2013). Few PPGIS studies have examined the spatial value distribution of both visitors and locals with the aim of identifying spatial overlap between user groups in highly valued areas, though such information is crucial to managing conflict between user groups.

The purpose of this study was to identify areas highly valued (i.e., value hotspots) by locals, domestic, and international visitors to assess the potential management challenges of attracting more tourists to Jotunheimen National Park and Utladalen Protected Landscape protected areas. These areas were recently included in a pilot study to improve visitor management and increase the value of park-related tourism (Norwegian Environment Agency, 2014). Customary rights to grazing, fishing, hunting, and gathering deriving from the pre-medieval ages persist in this region, and recreational consumptive uses are popular (Hausner, Brown, & Lægreid, 2015). Norway has a long history of self-organized outdoor recreation (Friluftsliv) often coupled to hunting, fishing, and berry picking. These activities have been supported by the Right of Public Access allowing free access to both public- and private land, including small-scale harvest as long as causing no harm to people, fauna, flora or economically valuable resources (Kaltenborn, Haaland, & Sandell, 2001; Sandell & Fredman, 2010; Tolvanen, Forbes, Wall, & Norokorpi, 2005). Given that the surrounding local communities have a strong cultural attachment to the uplands, we hypothesized that residents and visitors to the protected areas would differ in the areas that they value highly. Jotunheimen has an iconic status among domestic visitors as a popular outdoor recreation destination going back to the early 19th Century (Snøtun, 2011). Previous surveys conducted in the study area have indicated that Norwegian domestic visitors differ from international visitors in travel pattern, accommodation and recreational activities (Vorkinn, 2011). We therefore also expect domestic- and international visitors to value places differently, and assign different values to places.

We first defined and reviewed the concept of place-based values and how spatial mapping of values could be used to inform management of protected areas. Then, we examined differences in spatial priorities among visitors and local communities to identify potential management strategies for each group in the two protected areas. We used a two-step approach where we first identified the most valued hotspots, and secondly, analyzed the values identified by the different groups within and between the hotspots.

Our research was guided by the following research questions:

1. What types of place-based values are most important to the three groups of users: locals, domestic- and international visitors?
2. How are place-based values spatially distributed among the three user groups within the protected areas (i.e., dispersed vs. clustered)?
3. Are there spatial valuation zones associated with user groups that indicate incompatibility in the use of the park?
4. Given the results, what are the implications for protected area management that seeks to integrate local values with increasing tourism demand?

2. Place-based values and protected area management

Values are defined and interpreted differently depending on academic disciplines. In psychological and sociological literature, values are typically conceptualized as fundamental ideas and enduring principles that inform peoples' judgements and guide park users' choices and actions. (T. C. Brown, 1984; Rokeach, 1973; Schwartz, 1994). Such held values (also referred to as the *underlying values* (Ives & Kendal, 2014)), affect how users perceive the places they are visiting and the activities deemed appropriate in those areas (Rossi, Byrne, Pickering, & Reser, 2015; Zeppel, 2010). For example, Rossi et al. (2015) found deeply held environmental values to underlie park users' perceptions of other visitors and their recreational activities. In that study, park users with ecocentric value orientations (i.e., valuing nature for its own sake) were more negative to motorized activities than people valuing nature because of the material or physical benefits it can provide for humans (i.e., anthropocentric value orientation). Held values underpin whether people oppose or favor activities or management actions in protected areas, but has also been used to explain visitors motivation to undertake pro-environmental behaviors. For example, Curtis, Ham, and Weiler (2010) found using the theory of planned behavior that eliciting park users' beliefs is a requisite to understand their behavior and to manage for impact reduction through persuasive communication targeting beliefs instead of imposing management actions. Similarly, van Riper and Kyle (2014b) used value-belief-norm theory to understand how protected area users' value-orientation together with personal norms and beliefs influence their engagement in pro-environmental behavior.

Another way of understanding values, and one that has become particularly popular in resource economics and in non-market valuations of ecosystem services (i.e., the benefits that people derive from nature (Díaz et al., 2015)), is what T. C. Brown (1984) referred to as assigned values, that is, “expressing the importance or worth of the object relative to one or more other objects”. While held values could be understood as the *values of people,* assigned values is how places, species and/or ecosystems are *valued by people* (Ives & Kendal, 2014). Assigned values may be related to the underlying environmental concerns and worldviews that people hold (Rossi et al., 2015; Van Riper & Kyle, 2014a), but in contrast to held values, individuals express qualities of the protected areas through their preferences for specific physical places, goods and services relative to others (Reser & Bentrupperbäumer, 2005; Seymour, Curtis, Pannell, Allan, & Roberts, 2010). The value attached to features and places in protected areas depends on context and is therefore less persistent than held environmental values, but useful for identifying places in protected areas highly prioritized by different user groups. Seymour et al. (2010) proposed that assigned values could be a better predictor of spatial behavior than held values, as held values, together with beliefs and norms, influence assigned values, and therefore are only indirectly linked to environmental behavior. The spatial behavior of visitors to protected areas refers to the use of the landscape they make, such as following designated trails, camping at designated campsites and respecting the minimum distance to wildlife. Several studies have used GPS tracking of visitors to uncover visitor distribution and behavior (Beeco, Hallo, & Brownlee, 2014; D'Antonio & Monz, 2016; Orellana, Bregt, Ligtenberg, & Wachowicz, 2012). However, coupling visitors' spatial behavior to values is still limited.

The values that park users attach to places also depend on symbolic meanings of places and an individuals' life experiences. These shape how and whether people think about a place as important (Cerveny, Biedenweg, & McLain, 2017; Van Riper & Kyle, 2014a). Thus, *place-based* values integrate *assigned* values with *held* values toward nature. Place-based values could be considered as *relational* values because values are shaped in interaction with the physical landscape (G. Brown & Weber, 2012; McIntyre, Moore, & Yuan, 2008). Relational values reflect that people could have strong bonds to places, species or ecosystems that influence their preferences for uses in a location as well as their attitudes towards management actions (Chan et al., 2016). For example, Klain, Olmsted, Chan, and Satterfield (2017) propose that relational values can better inform policy making than other approaches and alleviate the tensions introduced by intrinsic-instrumental value driven policy making, which tend to focus more on tangible values. Relational values acknowledge that use of protected areas cannot necessarily be separated from its cultural meaning. For example, for

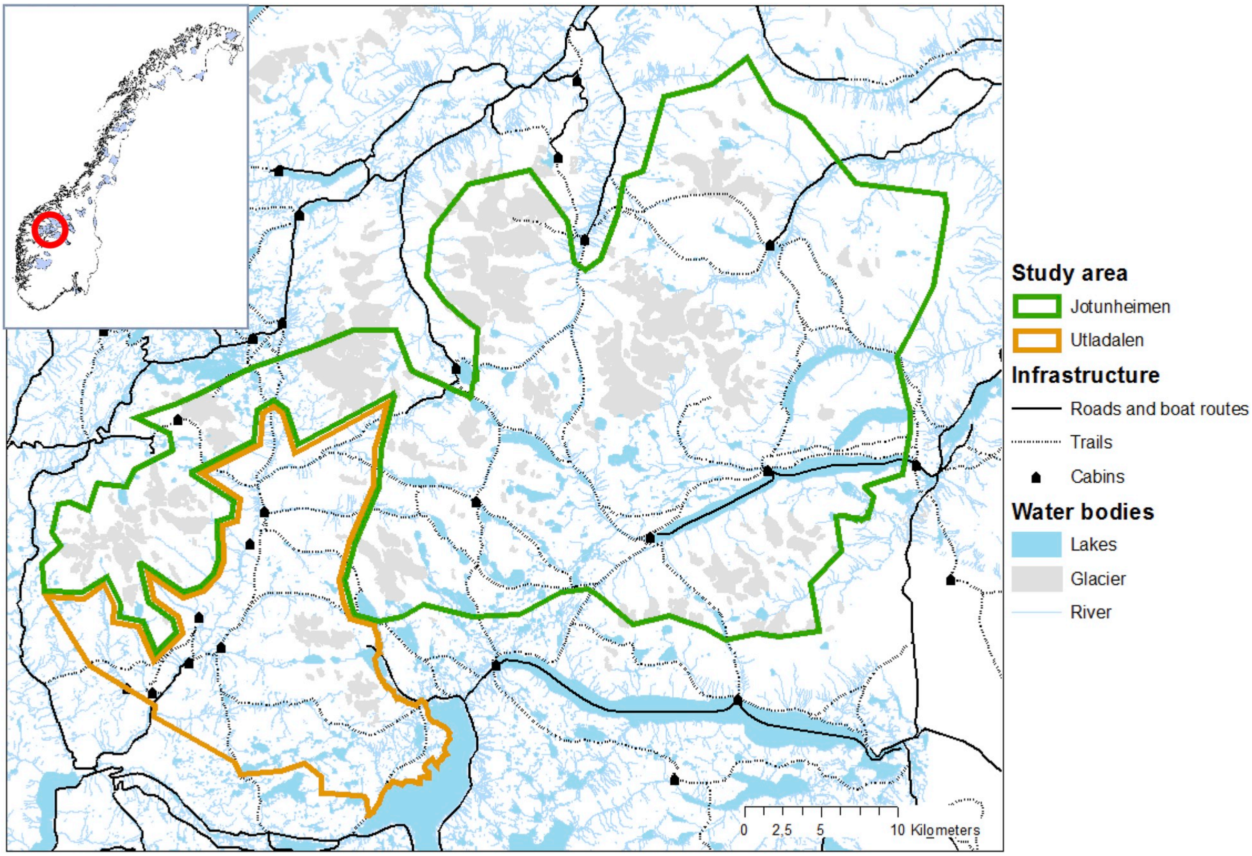

Fig. 1. The study area is located in southern Norway (map on the top left corner). Map over the study area including Jotunheimen NP and Utladalen PL.

many local communities, harvesting is not purely about provisioning of food, it is also deeply embedded in their culture. As noted by Ingold (2000, p. 192): "*a place owes its character to the experiences it affords to those who spend time there—to the sights, sounds and indeed smells that constitute its specific ambience. And these, in turn, depend on the kinds of activities in which its inhabitants engage. It is from this relational context of people's engagement with the world, in the business of dwelling, that each place draws its unique significance.*".

There is a rich literature on how pro-environmental behavior is linked to different conceptualizations of value (e.g. Seymour et al. (2010); Van Riper and Kyle (2014a, 2014b)). Visitor use patterns are not, however, purely determined by values (Gosal et al., 2018), but also depend on accessibility, infrastructure and knowledge about an area (Kulczyk, Woźniak, & Derek, 2018; McIntyre et al., 2008; Seymour et al., 2010). Understanding how individuals are attracted to and use space and time e.g., through the location visited, travel routes and time spent in an area (e.g. Ellegård and Svedin (2012); Hagerstrand (1966); Manning (1979)) is equally important for visitor management as understanding how places are valued. In this line, Beeco and Brown (2013) advocate for the use of spatial indicators that allow integrating social, ecological, infrastructural and economic factors in order to benefit protected area management. For example, Chardonnel and Knaap (2002) explore the spatial and temporal use of trails in protected areas and stress the need to create spatial tools that map tourists' recreational behavior in space and time. Such analyses provide information about where people are or have been, but not necessarily which area they appreciate the most. Planning for increased tourism in protected areas would benefit from both identifying spatial valuation zones for both local users and visitors to separate, limit, disperse or channelize tourism into desired locations (Leung & Marion, 1999). Spatial value mapping, as those performed by web-based PPGIS, provides insights into how different user groups value different places in the protected area, which is most likely related to their actual use of the locations. However, it is also possible that people value an area without physically interacting with the place, for example by appreciating the existence of iconic peaks in a park without actually visiting the place.

Protected area planning and management can benefit from mapping spatially explicit place-based values by elucidating most valued areas, potential local conflicts and impacts, and actual use of protected areas. Identifying areas representing place-based values of different user groups is important for establishing visitor strategies that have the least impact on other users and that benefit multiple user groups in protected areas (McIntyre et al., 2008). Furthermore, the spatial location of values held by protected area users can help identify landscape features that are important for users (G. Brown & Raymond, 2014). Also, mapping preferences for land use (e.g. development) in protected areas along with spatial values can identify where conflict might arise around rules governing land use (Brown & Raymond, 2014).

The potential for conflict among user groups not only depends on place-based values, but also on whether the places valued by the different groups overlap spatially. Increased international tourism in places that are culturally important for local residents or destinations that are perceived as iconic by domestic visitors can result in loss of value for local and domestic park users (Wray, Espiner, & Perkins, 2010). Conflicts may also arise from increasing tourism in areas where local users prioritize other activities such as farming and forestry (Bragagnolo, Pereira, Ng, & Calado, 2016). However, if tourists are attracted to places which are less highly valued by local park users, then tourism development is less likely to have a negative impact on local park use.

3. Methods

We collected data from survey questions and mapping through PPGIS. We examined whether the three user groups (locals, domestic, international) shared similar place-based values (non-spatial analysis) using data collected through the mapping without considering the spatial location. To investigate the spatial overlap in place-based valuation (spatial analysis), we used data collected by explicit mapping through PPGIS which included coordinates. In the non-spatial analysis we used Chi-square statistics and Spearman rank correlation to determine whether there were significant differences in the frequency of different place-based values assigned by the three user groups, regardless of where those place-based values were mapped in the landscape. In the spatial analyses, we assessed whether the user groups mapped their place-based values in different locations using nearest neighbor statistics. To identify and map clusters of valuation we implemented the algorithm Density-Based Spatial Clustering of Applications with Noise (DBSCAN).

3.1. Study area

Our study was conducted in Jotunheimen National Park (hereafter Jotunheimen NP) and the adjacent Utladalen Protected Landscape (hereafter Utladalen PL) (Fig. 1). Jotunheimen NP was established for its "wilderness and untouched nature" and covers 1151 km^2 of mountainous and alpine vegetation, including several glaciers and lakes. Utladalen Protected Landscape was designated to protect scenic cultural landscapes (Klima-og miljødepartementet, 2014). In Jotunheimen NP, traditional outdoor recreation has been pursued by domestic visitors since the mid-19th century, and today it is particularly valued for the climbing areas and for cabin-to-cabin hikes provided by the Norwegian Trekking Association (Directorate for Nature Management, 2007). The NP is located on state commons where people have enjoyed subsistence rights to livestock grazing, hunting, fishing, and firewood since pre-mediaeval times (Hausner et al., 2015). It is a national symbol as it holds the highest peaks in Norway, and together with Utladalen PL, contains approximately 300 km of trails which connect several mountain lodges managed by the Norwegian Trekking Association. One of the most visited parts of Jotunheimen NP is the Besseggen ridge with over 30,000 visitors per year (Besseggen Tourism, 2014), located on the eastern side of the park.

3.2. Data collection

We recruited study participants by three methods: i) a household survey, ii) volunteers recruited through social media and traditional advertising, and iii) in-person recruitment at park entrances. *In-situ* and household surveys were combined in order to balance the representativeness of the three user groups studied. Data was collected during October–December 2014 and July–September 2015. A local household survey (available at http://www.landscapemap2.org/norwaysouth/) was performed in 2014 by sending invitation letters to Norwegian residents living in municipalities surrounding Jotunheimen NP and Utladalen PL (Voss, Sogndal, Luster, Skjåk, Vågå and Aurdal). Letters were sent to a random sample of 10% of the adult population (3104 households over 18 years of age). The survey also included volunteer recruitment by inviting local organizations on email, newspaper, and social media. A reminder was sent by post two weeks after the first contact.

During July–September 2015, the peak of the tourism season, visitors to Jotunheimen NP and Utladalen PL were recruited at the major entrances Those interested in participating were subsequently sent an email containing the link to the online visitor survey (available at http://www.landscapemap2.org/southnp/). Two reminders were sent to visitors. Feedback from respondents was used to develop an instructional video and "Frequently Asked Questions (FAQ)" answering the most common problems encountered by respondents which were attached on the second reminder.

Both surveys were conducted using web-based PPGIS method that collects the georeferenced locations of a set of markers representing different place-based values. We used a list of 12 place-based values that could be dragged and dropped by respondents onto a Google base map. Both PPGIS surveys were piloted on park managers and their feedback was used to improve the design and functionality of the PPGIS interface. The survey was granted ethics approval by the Norwegian Centre for Research Data under the Personal Data Act 2000. The opening screen provided for entry of a unique identifier provided to household survey recipients that was used to track responses. In the case of non-household surveys, a unique, dynamic access code was allocated through a "request" access button. These access controls allowed the tracking of people recruited by the random household surveys, through social media and invitation to organizations, and by onsite recruitment in the parks. The second screen included an informed consent for participation. The following screen contained instructions for the mapping activity which allowed participants to drag and drop place-based value markers on a Google® map interface. Respondents were informed that participants usually map 20 markers, but the number of markers was not constrained. A list of 12 place-based values were developed based on a value typology adapted from G. Brown and Reed (2000) using feedback from park managers (Table 1). The description of each value was available within the survey as a pop-up text box. In the last screen, a short questionnaire asked participants for socio-demographic information, their familiarity with the study area and the number of visits to the study area.

3.3. Statistical analysis

We classified respondents into three groups according to their residence: 1) locals, referring to inhabitants of the municipalities adjacent

Table 1
Definition of place-based values used in PPGIS mapping. Adapted from Brown and Reed (2000) to the Norwegian context.

Place-based values	Description
Biological diversity	Areas are important because they provide a variety of plants, wildlife and habitat
Clean water/air	Areas are important because they provide clean water/air
Cultural value (including cultural identity)	Areas are important because of their historical value, or for passing down the stories, myths, knowledge and traditions, and/or to increase understanding of the way of life of our ancestors
Gathering (mushroom and berry picking)	Areas are important for berries, mushroom or collecting herbs/plants
Hunting/fishing	Areas are important because of hunting and/or fishing
Scenic landscapes	Areas are important because they include beautiful nature and/or landscapes
Social value	Areas are important because they provide opportunities for social activities (e.g. associated with fireplaces, picnic tables, ski- or alpine arrangements, shelters, shared cabins, cabin complexes)
Spiritual value	Areas are important because they are valuable in their own right or have a deeper meaning; emotionally, spiritually, or religious
Therapeutic	Areas are valuable because they make me feel better, either because they provide opportunities for physically activities important for my health and/or they give me peace, harmony and therapy
Recreation	Areas are important for outdoor recreation activities (e.g. camping, walking, skiing, alpine snowmobiling, cycling, horse riding)
Wilderness and undisturbed nature	Areas are relatively untouched, providing for peace and quiet without too many disturbances
Special place	Please describe why these places are special to you

to the NP, 2) domestic visitors, which are Norwegian visitors from areas not in the municipalities surrounding the NP, and 3) international visitors, defined as visitors from a country other than Norway. For the purpose of this study, we selected respondents that mapped at least one value inside Jotunheimen NP or Utladalen PL. We assessed differences in mapped place-based values, particularly focusing on how local cultural values (local users) and traditional Norwegian outdoor recreational activities (domestic visitors) differ from the place-based values of international tourists.

To assess the non-spatial consistency in the frequency of place-based values mapped among user groups, we ranked the place-based values from 1 to 12 in descending order of frequency for each user group and calculated the Spearman rank correlation coefficients between pairs of user groups. In addition, we conducted a non-parametric Pearson's chi-square analysis using a contingency table for the user groups and place-based values (3 user groups x 12 place-based values). Pearson's chi-square tests on standardized residuals were used to identify statistically significant differences between observed and expected cell frequencies. Expected frequencies were calculated by multiplying the cell's row- and column-total counts and dividing the product by the total table counts. Standardized residuals were examined to assess statistically significant differences ($\pm$ 2.0) between observed and expected frequencies.

For spatial analyses, we calculated the median Euclidean distance between the geographic locations of place-based values to identify the degree of overlap between user groups. We first calculated the median distance between the nearest neighbor place-based values mapped by the users. Then we calculated the median distance between the nearest neighbor place-based values of two user groups at a time (i.e., local-domestic, local-international and domestic-international). The distance was calculated between pairs of points from different user groups. In addition to the measured median distance, we simulated a group-independent median distance to test whether differences in point distributions are based on user groups or belong to landscape features. For this, the user group label for each point was randomly replaced and the median distance between the nearest neighbor points was calculated. We report the 95% confidence interval for 9999 such simulations.

We implemented a Density-Based Spatial Clustering of Applications with Noise (DBSCAN) algorithm (Ester, Kriegel, Sander, & Xu, 1996) to find areas where people had mapped the highest density of place-based values (i.e., clusters), regardless of user group. The advantage of using DBSCAN is that one can identify clusters of irregular shapes that does not require the analyst to specify the number of clusters to be detected (Ester et al., 1996). In addition, it discards noise points, which are points that are sparse and relate to no cluster. It also reduces losing idiosyncratic data as in the case of methods that use clustering of cells based on density (McIntyre et al., 2008). We first generated a density plot of the distances between all mapped points (k-nearest neighbor distance), independent of user groups. Second, we chose a search radius distance for clusters by visually inspecting the threshold of the k-nearest neighbor distance plot. Third, we used the DBSCAN algorithm to identify clusters by searching for a minimum number of points located within the search radius of core points. A core point was defined as a point where a minimum of 10 points fell into the search radius; the minimum number of points was set to 10 in order to identify clusters with a diversity of place-based values between locals, domestic- and international visitors. Border points were defined as points that fell within the search radius of a core point but whose own search radius contained fewer than 10 points. Points classified as core and the corresponding border points formed clusters. Points not classified as core- or border points belong to no cluster and reflect dispersed points.

We then explored the differences in place-based values held by the different user groups within and outside clusters using a non-parametric Kruskal-Wallis test to avoid biases due to low cell values. We identified divergences from the expected frequencies of each value by calculating standardized residuals for each cluster that displayed significant variation in the distribution of place-based values between user groups. We also estimated the similarity in mapped place-based values between clusters using Spearman rank correlation for clusters that differed by place-based values mapped by user groups.

All analyses were conducted in R software (R Core Team, 2015), and the main libraries used were MASS (Venables & Ripley, 2002) for chi-square analyses, spatstat (Baddeley, Rubak, & Turner, 2015) for point pattern analyses and nearest neighbor distances, and dbscan (Hahsler, 2016) for cluster analysis. We enclosed the data and the R script in Appendix 5 and Appendix 6 respectively.

4. Results

4.1. Demographic variables and mapped value frequency

The household PPGIS survey was completed by 14% of the invited participants (440 responses) of which 117 participants mapped at least one value in the study area. A total of 1812 visitors to Jotunheimen NP and Utladalen PL were contacted at gateways during the visitor survey of which 14.7% completed the survey.

A total of 377 survey responses were included in our analyses (see Appendix 1) with a nearly even distribution of respondents from each visitor groups, i.e., locals, domestic- and international visitors. Among international visitors, Germans, Danish and Czechs comprised 41% of the respondents. The gender distribution of all respondents was 56.8% males and 43.2% females. The age of respondents varied from 18 to 78 years, with an average of 41 years. The majority of the respondents held a university degree or equivalent. Most of the respondents had visited the study area only once. The number of visitors with more than one visit was too low (13.5%) to allow separate analyses. Respondent knowledge about the area was mostly reported as average and low (see Appendix 1 for more details). A total of 2479 place-based values were mapped using PPGIS. The most frequently mapped place-based values were “Recreation” and “Scenic landscapes” (Table 2) in all three user groups, constituting 32.7% and 31% of the total mapped place-based values respectively.

4.2. Non-spatial analyses

There was strong consistency in the frequency of place-based values mapped by the different user groups (Table 2). The Spearman rank correlation coefficients between groups were accordingly relatively high, ranging between 0.61 (local vs. international visitors) and 0.94 (domestic vs. international visitors) (Table 3).

Despite the consistency among user groups in how they ranked values, there were significant differences in the number of place-based values mapped by the three groups (Table 2; Pearson's chi-squared test: Chi-squared = 174.16, degrees of freedom = 22, p value $< .05$, 0% cells with expected counts < 5). Local users mapped cultural values, undisturbed nature and consumptive values (gathering, fishing and hunting) more than expected, while they mapped biological diversity and clean water to a lesser extent (Table 2). Domestic visitors mapped biological diversity and scenery more often than expected, but mapped consumptive, spiritual and wilderness values less than expected. International tourists mapped clean water, spiritual values and wilderness values more than expected, while the frequency of mapped cultural values, hunting and fishing, scenery and therapeutic values were lower than expected.

4.3. Spatially explicit analyses

The median distances between nearest value markers mapped by each user group showed that domestic- and international visitors had higher clustering (i.e., shorter median nearest neighbor distance within the user groups; 159 and 141 m) than local visitors (273 m) (Table 3). Domestic- and international users were significantly more separated from locals (i.e., longer median nearest neighbor distances) than expected from the Monte Carlo simulations (Table 3). This suggested that

Table 2
Summary of the place-based values mapped by locals, and domestic- and international visitors. Perc. is the percentage of times a value was mapped. Rank is the ranking of place-based values in descending order of frequency. Residual is the standardized residual from the Chi-square analysis where color indicates if the frequency was significantly larger (blue italics) or smaller (red italics) than expected. The table is sorted by the sums of ranks with the most frequently mapped place-based values on the top.

	Local			*Domestic*			*International*		
	Perc.	Rank	Residual	Perc.	Rank	Residual	Perc.	Rank	Residual
Scenic	30.45 %	1	-0.35	33.98 %	1	*2.40*	28.51 %	2	*-2.05*
Recreation	29.55 %	2	-1.86	32.84 %	2	0.32	34.13 %	1	1.39
Clean water	6.12 %	5	*-3.58*	9.51 %	3	-0.11	12.20 %	3	*3.40*
Wilderness	9.10 %	3	*2.37*	3.85 %	5	*-4.69*	8.75 %	4	*2.47*
Biological	3.43 %	7	*-2.37*	6.68 %	4	*2.54*	4.97 %	5	-0.34
Special place	3.28 %	8	0.38	3.06 %	6	-0.02	2.92 %	6	-0.33
Cultural	4.18 %	6	*2.85*	2.94 %	7	0.65	1.30 %	10	*-3.26*
Social	2.69 %	9	-0.18	2.94 %	7	0.36	2.70 %	7	-0.20
Therapeutic	2.54 %	10	0.57	2.94 %	7	1.71	1.40 %	9	*-2.21*
Hunt/fish	6.27 %	4	*9.53*	0.34 %	11	*-4.29*	0.32 %	12	*-4.50*
Spiritual	1.19 %	11	-0.75	0.79 %	10	*-2.14*	2.38 %	8	*2.80*
Gathering	1.19 %	11	*2.81*	0.11 %	12	*-2.11*	0.43 %	11	-0.49

Table 3
Summary of the Spearman rank correlation and nearest neighbor distances (in meters). Spearman rank correlation coefficient was calculated based on value frequencies for user group pairs. The median distance between nearest neighbor place-based values was calculated for each user group and for pairs of user groups. The measured median distance was calculated by computing the distance between the nearest neighbor points. The Monte Carlo simulated median distances were calculated by computing the distances between nearest neighbor points on samples with randomly shuffled user group labels. Median and 95% confidence intervals were calculated from 9999 randomly shuffled samples.

	Spearman rank correlation rho	*p-value*	*Measured median distance (m)*	Monte Carlo simulated median distance (m) (95% CI)	
Local			272.7		
Domestic			158.9		
International			140.6		
Local-Domestic	0.71	< 0.05	351.3	193.8	(171.5; 218.1)
Local-International	0.61	< 0.05	463.1	188.9	(167.6; 213.6)
Domestic-International	0.94	< 0.05	205.6	188.7	(169.8; 208.9)

the spatial distribution of the place-based values of locals differed from the values of domestic and international users. The median distance between domestic and international users was however much shorter (206 m versus 351 m and 463 m), and fell within the Monte Carlo simulated confidence interval (Table 3), suggesting that the place-based value markers from these two user groups were not significantly separated. In short, locals mapped place-based values in locations that differed significantly from domestic- and international visitors.

The DBSCAN algorithm identified 13 clusters (Fig. 2) with a minimum number of search-radius-points set to 10 and the search distance set to 1100 m. We selected 1100 m as the search radius by visually inspecting the density plot of the k-nearest neighbor distances (see Appendix 2). An additional cluster 14 was dismissed as the border points of this cluster were shared and grouped with cluster 9, and therefore it contained only 3 points.

Most of the mapped points were located around popular trails, cabins and mountain peaks (see caption in Fig. 2). Locals mapped more place-based values in the westernmost part of our study area (clusters 1, 2 and 3) and in the Memurubreen glacier area (cluster 4). Domestic- and international tourists placed the majority of the points in the Besseggen trail and on the iconic peaks and glaciers in the north, including the highest peak in Norway, Galdhøpiggen (clusters 6 and 8) (Fig. 2, right).

We found significant differences in mapped place-based values by user groups in the two most visited locations, cluster 1 (Utladalen Valley, Kruskal-Wallis test: Chi-squared = 20.05, degrees of freedom = 11, p value < .05, 52.8% cells with expected counts < 5) (Appendix 4) and cluster 6 (the Besseggen trail, Kruskal-Wallis test: Chi-squared = 60.71, degrees of freedom = 11, p value < .05, 22.2% cells with expected counts < 5) (Table 4). However, the Spearman rank correlation indicated that ranking of place-based values in clusters 1 and 6 were significantly correlated (rho = 0.82, p value < .05). There were some differences, for example, where international visitors mapped more typical park recreation values than both domestic and local users (see Appendix 4 for more details).

Differences among user groups were most evident at Cluster 6 (Besseggen). Local users mapped more cultural and hunting and fishing values than expected. Domestic visitors mapped scenery and therapeutic values to a larger extent, while hunting and fishing were less mapped than expected. International tourists mapped more points representing spirituality and wilderness values than expected, while cultural values, and hunting and fishing were less frequent. We found no significant difference in mapping for the three groups when mapping biological, clean water, gathering, recreation, social values or special places (Table 4).

Of all points mapped, 17.1% did not fall within any clusters (i.e., noise) in the analysis. An analysis of these points (results in Table 5) revealed significant differences in mapped place-based values by user groups (Kruskal-Wallis test: Chi-squared = 47.16, degrees of freedom = 11, p value < .05, 52.8% cells with expected counts < 5). Again, local users mapped more fishing and hunting than the other groups, while domestic visitors mapped more biological diversity values. International visitors mapped significantly more clean water and wilderness values than the other user groups.

5. Discussion

Our study demonstrates that spatially explicit mapping of place-based values can identify distinct patterns in place-based values by user

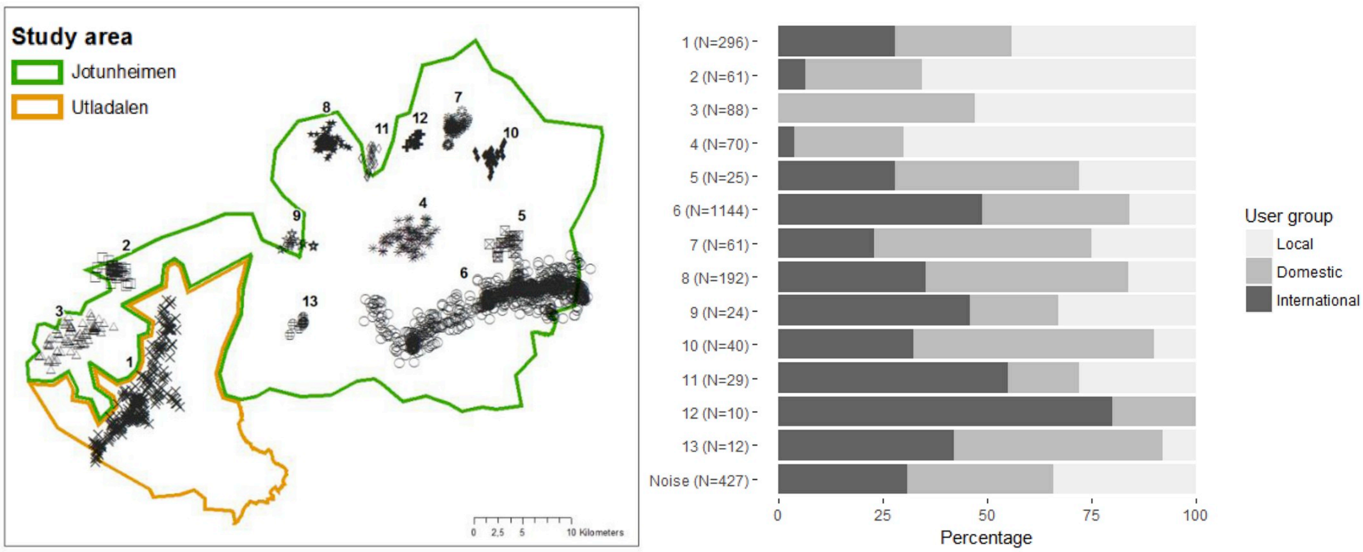

Fig. 2. Left: map of the clusters identified in the cluster analysis. Different clusters are represented by different shapes and numbers. A total of 13 clusters were identified. Right:Barplot showing the proportional contribution of each user group to each cluster. The numbers in parantheses correspond to the sum of all mapped place-based values in the cluster. Noise refers to the points that due to high dispersion, did not fall inside any cluster. A table with each ecosystem value per cluster can be found in Appendix 3. Cluster names: 1- Utladalen valley, 2- Helgedalen valley, 3- Hurrungane mountain range, 4- Memurububreen glacier, 5- Besshø mountain, 6- Bessegen trail, 7- Glittertind mountain, 8- Galdhøpiggen mountain, 9- Leivassbu cabin, 10- Glitterheim cabin, 11- Spiterstulen cabin, 12-Leitjønne lake, 13- Olavsbu cabin.

groups of protected areas. We found that locals and tourists valued some of the same places (Fig. 2), but held different values for those places (Table 4). The results were consistent with previous findings by Munro, Kobryn, Palmer, Bayley, and Moore (2017) where local residents mostly prioritized the same values as visitors, but differed somewhat with respect to the importance of consumptive uses and the locations mapped.

Non-spatial analyses showed that the three user groups ranked values similarly, and for most values, there were only minor differences among user groups. Locals differed from visitors by mapping more consumptive (i.e. gathering, fishing and hunting) and cultural values which could reflect a stronger identity associated with the state commons and subsistence-oriented recreation such as gathering, fishing and hunting (Hausner et al., 2015). Munro et al. (2017) also found that local residents mapped fishing values more frequently than non-residents in the Kimberley region in Australia. We found wilderness values to be held by locals and international visitors more than domestic visitors. This is consistent with previous studies from Norway which show that local recreational hunters and non-Scandinavian tourists share preferences for undisturbed nature, although each group value and perceive wilderness differently (Vistad & Vorkinn, 2012). Other studies have also found that domestic visitors value wilderness less than international visitors, which could be explained by the different expectations created by marketing strategies (Higham, Kearsley, & Kliskey, 2001).

Local residents mapped place-based values in significantly different locations than visitors. Furthermore, the place-based values of domestic- and international visitors were spatially closer to each other compared to locals, and the distance in locations mapped were largest between local and international visitors. Although value compatibility analysis conducted by Moore, Brown, Kobryn, and Strickland-Munro (2017) assumed conflicts between consumptive and non-consumptive

Table 4
For cluster number 6, summary of the different place-based values mapped by locals, domestic- and international visitors. Perc. is the percentage of times a value was mapped. Residual is the standardized residual from the Chi-square analysis where color indicates if the frequency was significantly larger (blue italics) or smaller (red italics) than expected.

	Local		*Domestic*		*International*	
	Perc.	Residual	Perc.	Residual	Perc.	Residual
Biological	2.21 %	-1.60	4.27 %	-0.22	5.31 %	1.38
Clean water	7.73 %	-1.28	9.80 %	-0.49	11.68 %	1.40
Cultural	4.97 %	*3.09*	2.01 %	0.00	1.06 %	*-2.26*
Gathering	0.00 %	-0.61	0.25 %	0.45	0.18%	0.02
Hunt/ fish	12.71 %	*9.99*	0.50 %	*-3.02*	0.35 %	*-4.42*
Recreation	30.94 %	-0.74	30.65 %	-1.39	35.93 %	1.86
Scenic	25.97 %	-1.76	37.19 %	*2.99*	29.38 %	-1.56
Social	4.42 %	1.25	3.52%	0.79	2.12 %	-1.67
Spiritual	0.00 %	-1.63	0.50 %	-1.62	2.12 %	*2.74*
Therapeutic	1.66 %	-0.61	3.77 %	*2.48*	1.42 %	-1.92
Wilderness	4.42 %	-0.75	4.02 %	-1.69	7.08 %	*2.16*
Special place	4.97 %	1.01	4.97 %	-0.20	3.36 %	-0.55

Table 5
For noise (dispersed points), summary of place-based values mapped by locals, domestic- and international visitors. Perc. is the percentage of times a value was mapped. Residual is the standardized residual from the Chi-square analysis where color indicates if the frequency was significantly larger (blue italics) or smaller (red italics) than expected.

	Local		*Domestic*		*International*	
	Perc.	Residual	Perc.	Residual	Perc.	Residual
Biological	3.40 %	-2.83	16.78 %	4.36	5.38 %	-1.59
Clean water	7.48 %	-0.89	6.71 %	-1.27	13.85 %	2.24
Cultural	2.04 %	0.80	0.67 %	-0.94	1.54 %	0.15
Gathering	1.36 %	1.95	0.00 %	-1.04	0.00 %	-0.94
Hunt/ fish	9.52 %	4.86	0.67 %	-2.34	0.00 %	-2.61
Recreation	27.89 %	-1.85	38.26 %	1.53	34.62 %	0.33
Scenic	31.97 %	1.22	28.86 %	0.25	23.08 %	-1.53
Social	0.68 %	-0.41	2.01 %	1.69	0.00 %	-1.33
Spiritual	0.00 %	-1.46	0.67 %	-0.42	2.31 %	1.95
Therapeutic	1.36 %	0.25	1.34 %	0.24	0.77 %	-0.51
Wilderness	12.93%	1.08	3.36 %	-3.78	17.69 %	2.79
Special place	1.36 %	0.65	0.67 %	-0.42	0.77 %	-0.24

uses, in our case, the consumptive - and cultural values mapped by locals were significantly less abundant than other place-based values at this site. Also, the potential for user group conflict is strongly influenced by the intensity of use, not just the mere spatial overlap of potentially conflicting values (Wolf, Brown, & Wohlfart, 2017).

Whether or not the different place-based values (and associated uses) held by the different user groups at each place translates into conflict or diminished satisfaction is unclear. Further studies that spatially map people's preferences for different uses as described in G. Brown, Kangas, Juutinen, and Tolvanen (2017) are needed to clarify the potential for conflict. While the different user groups mostly shared the same values, differences in place-based values can be summarized as consumptive and cultural values (locals) versus conservation values (domestic and internationals). Hunting, fishing and gathering are generally accepted by locals in most protected areas in Norway (Hausner, Engen, Bludd, & Yoccoz, 2017), and domestic visitors might perceive these activities as acceptable even though they themselves do not prioritize these activities. We found that consumptive values are mainly present in cluster 6 (Fig. 2) and are otherwise dispersed throughout the protected areas. Over 17% of mapped place-based values were dispersed (i.e., not included in any cluster) reducing the value overlap between user groups, and potential conflicts. In a study on hunter typologies, Wam, Andersen, and Pedersen (2013) found that hunters differ in their tolerance to seeing other hunters, which may explain the mixed pattern of clustered and dispersed mapping of consumptive values. The different character (e.g., clustered vs dispersed) of different place-based values may require spatially distinctive management strategies, such as those defined by Leung and Marion (1999).

Study limitations and future research. Data on park visitor profiles and number of visitors per year is scarce, and we were unable to test the representativeness of visitors in our sample. However, the demographics of visitors in our sample were similar to previous studies. Vorkinn (2011) found that Jotunheimen NP and Utladalen are highly visited by international tourists, and 44% of their respondents were first time visitors. They also found that over three-quarters of the respondents had a university degree or professional education. Access to the internet and internet literacy may prevent certain users from responding the survey, or bias responses towards younger participants (Kaplowitz, Hadlock, & Levine, 2004). Our study reported a lower average number of mapped points (place-based values) per respondent than previous studies (G. Brown, 2017). One explanation may be that the majority of the respondents, especially the domestic and international visitors, are one-time visitors with less knowledge of the landscape. We increased the representativeness of local users by conducting a household survey in addition to *in-situ* recruitment of visitors. It may be possible to get an even more representative sample of park users by conducting both online PPGIS and *in-situ* mapping. A more intuitive web interface could also lower the potential for non-completion of the full online survey.

There were also inherent limitations in the spatial analyses performed. There are many different approaches and subjective parameter choices involved in value hotspot mapping (see Bagstad, Semmens, Ancona, and Sherrouse (2016); Beeco et al. (2014); Karimi and Brown (2017)). We used a combination of subjective hotspot parameter specification (i.e., minimum of 10 points in a cluster) and statistical methods (DBSCAN) to identify distinct clusters, but the choice of parameters and statistical methods can influence the results. Finally, our analysis focused on value hotspots, thus ignoring place-based values in remote and scattered locations which might be high-value areas important for conservation (Bagstad et al., 2016).

Further research could explore the associations between mapped place-based values and biophysical features in order to identify the places that are most valuable to park visitors and that have high ecological value, and thus contribute to policies that include ecosystem service valuation. For example, Alessa, Kliskey, and Brown (2008) used value mapping to identify socio-ecological hotspots, i.e., areas of high ecological importance and social value, showing the link between place-based values and ecosystem services. In addition, combining the mapping of place-based values with mapping of development preferences and visitors' experiences could increase our understanding of differences between user groups and inform management decisions in a wider context (e.g., G. Brown and Raymond (2006)). A next step that could more easily integrate place-based values of different users with the time-space movements and behavior of tourists in recreational areas (Chardonnel & Knaap, 2002) is mapping using smartphone-based technologies which could increase the accuracy of mapping while tracking the visitor use in the parks (Doherty, Lemieux, & Canally, 2014).

6. Recommendation for national park planning and management

The use of web-based PPGIS provided the opportunity to collect a large amount of data to identify areas that were most valued by locals, domestic- and international visitors. The methods we demonstrate here can inform strategies to avoid conflict or reduce overuse. For instance spatial zoning of national park users could be achieved via information and marketing, directing conflicting users to the areas we identify as less important for user groups with different values (Day, 2002; Tranel & Hall, 2003).

Our study could inform the new visitor strategy and paradigm for

Norwegian national parks where tourisms needs to increase in protected area to sustain the parks financially and/or support livelihood and development of local communities. Attracting more tourists to protected areas means satisfying a broader range of visitors without impacting conservation values or traditional users (Bushell & Eagles, 2006). Web-based PPGIS can identify park values on a sufficiently large scale to differentiate among user groups, both in terms of how they rank values and the specific places appreciated. Understanding value differences between locals and visitors is important for managing national parks (Gundersen, Mehmetoglu, Inge Vistad, & Andersen, 2015), particularly where an increased focus on economic revenue from park tourism could challenge the long-term local use of the area. Reassuringly, our spatial explicit analyses revealed that different user groups were self-segregating to some degree in the study area. As a result of this self-segregation, and with thoughtful management, it is possible that the continued push to increase rates of tourism in Norway's protected areas may be achieved without degrading the place-based values of local people.

Contribution

VH and GB initiated the study. LM conducted the fieldwork. LM and VH defined the hypothesis. LM conducted the main analyses. All authors discussed the results and contributed to the final manuscript.

Acknowledgements

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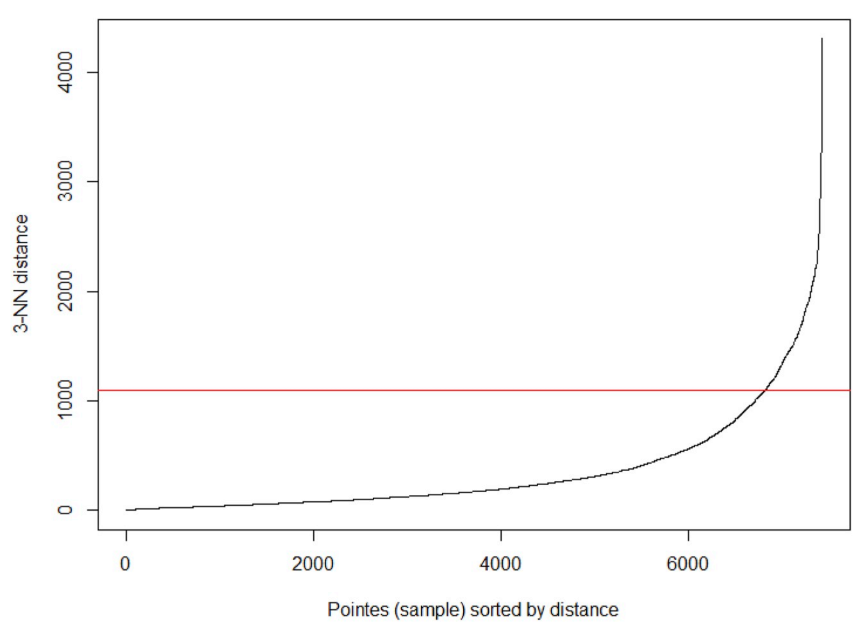
Appendix

Appendix 1

Summary of demographic variables of respondents by user group. Some questionnaires were incomplete, and therefore the sum of percentages might not be 100 in all cases below.

		Local	Domestic	International
Visitors	Total	117	127	133
Gender	Male	52.1%	57.5%	59.4%
	Female	47.0%	42.5%	39.9%
Age	Mean	46	42	36
Education	Secondary or lower	39.3%	14.1%	14.3%
	University degree or professional education	59.0%	85.0%	85.0%
Times visited	Median	1	1	1
	Mean	2.8	1	1
Knowledge	Good	19.66%	14.2%	26.3%
	Average	60.7%	43.3%	27.8%
	Low	19.66%	42.5%	43.6%
Mapped values	Total	670	883	926
	Average per person	6	7	7

Appendix 2



Plot of the k-nearest neighbor distances for all mapped values. k was defined as (2*dimension)-1.

Appendix 3

Amount of markers added by each user group in the clusters identified by the DBSCAN algorithm.

	Biological	Clean water	Cultural	Gathering	Hunt/fish	Recreation	Scenic	Social	Special place	Spiritual	Therapeutic	Wilderness
Cluster 1: Utladalen												
Local	9	8	6	3	3	25	47	4	4	1	6	15
Domestic	7	12	11	0	0	17	27	2	1	0	1	5
International	3	10	1	2	0	26	27	5	0	2	0	6
Cluster 2: Helgedalen												
Local	1	1	1	0	0	14	15	0	3	1	2	2
Domestic	1	1	0	0	0	8	5	2	0	0	0	0
International	0	0	0	0	0	2	1	1	0	0	0	0
Cluster 3: Hurrungane												
Local	0	1	2	0	0	19	17	1	3	1	0	3
Domestic	1	4	0	0	0	19	12	0	3	1	0	1
Cluster 4: Memurububreen												
Local	2	3	3	2	0	10	12	1	0	2	4	10
Domestic	1	2	0	0	0	3	5	1	0	1	2	3
International	0	0	2	0	0	0	0	0	0	0	0	1
Cluster 5: Besshø												
Local	1	3	0	0	1	1	0	0	0	1	0	0
Domestic	1	3	1	0	0	2	4	0	0	0	0	0
International	0	1	0	0	0	2	2	0	0	0	0	2
Cluster 6: Bessegen												
Local	4	14	9	0	23	56	47	8	9	0	3	8
Domestic	17	39	8	1	2	122	148	14	14	2	15	16
International	30	66	6	1	2	203	166	12	19	12	8	40
Cluster 7: Glittertind												
Local	0	0	2	1	0	5	6	0	0	0	0	1
Domestic	0	1	0	0	0	13	16	1	0	0	0	1
International	0	1	0	1	1	2	7	0	0	0	1	1
Cluster 8: Galdhøpiggen												
Local	0	0	2	0	0	15	9	1	1	2	0	1
Domestic	4	5	3	0	0	31	31	1	8	2	6	2
International	2	8	1	0	0	20	19	1	6	4	2	5
Cluster 9: Leivassbu												
Local	0	0	0	0	0	5	3	0	0	0	0	0
Domestic	0	0	0	0	0	3	2	0	0	0	0	0
International	0	2	0	0	0	3	4	0	1	0	0	1
Cluster 10: Glitterheim												
Local	0	0	0	0	1	1	1	0	0	0	0	1
Domestic	1	5	2	0	0	9	4	1	0	0	0	1
International	1	2	0	0	0	5	1	3	0	0	0	1
Cluster 11: Spiterstulen												
Local	1	0	0	0	0	5	0	2	0	0	0	0
Domestic	0	1	0	0	0	2	2	0	0	0	0	0
International	1	3	0	0	0	8	2	1	0	0	0	1
Cluster 12: Leirtjønne												
Domestic	1	1	0	0	0	0	0	0	0	0	0	0
International	2	2	0	0	0	0	2	0	0	1	1	0
Cluster 13: Olavsbu												
Local	0	0	0	0	0	1	0	0	0	0	0	0
Domestic	0	0	0	0	0	4	1	1	0	0	0	0
International	0	0	0	0	0	0	3	2	0	0	0	0
Noise												
Local	5	11	3	2	14	41	47	1	2	0	2	20
Domestic	25	10	1	0	1	57	43	3	1	1	2	5
International	7	18	2	0	0	45	30	0	1	3	1	23

Appendix 4

For cluster number1, summary of the different place-based values mapped by locals, domestic- and international visitors. Perc. is the percentage of times a value was mapped. Residual is the standardized residual from the Chi-square analysis where color indicates if the frequency was significantly larger (blue italics) or smaller (red italics) than expected.

	Local		*Domestic*		*International*	
Biological	6.87 %	0.28	8.43 %	0.88	3.66 %	-1.20
Clean water	6.11 %	*-2.05*	14.46 %	1.54	12.20 %	0.73
Cultural	4.58 %	-0.96	13.25 %	*3.22*	1,22 %	*-2.17*
Gathering	2.29 %	0.71	0.00 %	-1.41	2,44 %	0.62
Hunt/ fish	2.29 %	1.95	0.00 %	-1.09	0,00 %	-1.08
Recreation	19.08 %	-1.42	20.48 %	-0.64	31,71 %	*2.21*
Scenic	35.88 %	0.57	32.53 %	-0.36	32,93 %	-0.27
Social	3.05 %	-0.54	2.41 %	-0.74	6,10 %	1.34
Spiritual	0.76 %	-0.38	0.00 %	-1.09	2,44 %	1.52
Therapeutic	4.58 %	*2.23*	1.20 %	-0.82	0,00 %	-1.66
Wilderness	11.45 %	1.44	6.02 %	-1.05	7,32 %	-0.55
Special place	3.05 %	1.62	1.20 %	-0.40	0,00 %	-1.40

Appendix 5

Data.

Appendix 6

Statistical analyses (script).

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Title: Using crowdsourced spatial data from Flickr vs. PPGIS for understanding nature's contribution to people in Southern Norway

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Abstract

1- Crowdsourced data can provide spatially explicit data on the contribution of nature to people. Spatial information is essential for effectively managing the diverse relationships that people have with nature, but the potential and limits of using crowdsourcing data to generate maps for conservation purposes need further research.
2- Passive crowdsourcing tools include social media platforms where photos and user-generated tags are shared among users, while active crowdsourcing, such as Public Participatory Geographic Information System (PPGIS) provides an online platform for mapping place attributes such as values, experiences, and preferences.
3- In this study, we assess the spatial information gained through using Flickr (a photo sharing platform) and PPGIS (an online mapping platform) platforms for conservation planning to understand differences and similarities on the spatial distribution of values captured by the two platforms, and to identify what environmental and infrastructure variables correlate best with the distribution of values. We test these tools in Southern Norway including protected areas and the surrounding zones.
4- We analyzed non-spatial (using chi-square and Spearman rank correlation) and spatial (using clustering, Maxent and distribution overlap) data to identify differences between the two datasets and the values represented therein.
5- We found large differences in spatial distribution using these two datasets, with Flickr data concentrated outside the protected areas and near roads, while PPGIS provided more fine scale data on diverse values in locations inaccessible by roads within the protected areas. Flickr can be used for generating regional scale data of scenic landscapes or routes, but PPGIS performs better for management of nature qualities appreciated by different user groups within protected areas. We discuss the pros and cons of using each data source and when each dataset is more suitable to be used in protected area management.

Keywords: Cluster analysis, Management, Maxent, Nature qualities, Protected area, Social media, Values, Visitors

Introduction

As anthropogenic pressures on nature increase across the globe, raising awareness of nature's contribution to people (NCP) has become one of the approaches for integrating conservation into policy (Pascual et al. 2017). Despite the growing body of research on the nonmaterial contribution of nature to a good quality of life (Hirons, Comberti, and Dunford 2016), tools for mainstreaming non-material contributions into ecosystem services assessments and decision-making are still under development (Costanza et al. 2017; Small, Munday, and Durance 2017). The natural processes and features appreciated by people that positively contribute to their life are often referred to as nature qualities (Arler 2000; Van den Bosch et al. 2015) and are a central component of NCP. Bringing in diverse perspectives and values into conservation planning is costly, time-consuming and logistically challenging, but is important to find solutions that balance the needs of people with conservation objectives.

A wide range of methods and approaches have been used to elucidate the diverse perspectives on the cultural benefits provided by nature (Tew, Simmons, and Sutherland 2019; Teff-Seker and Orenstein 2019; Small, Munday, and Durance 2017). Among these are crowdsourcing methods which have the potential to deliver spatial information of NCP from a diverse range of citizens at a large scale of relevance to conservation (Bubalo, van Zanten, and Verburg 2019). There are two main crowdsourcing approaches that have gained popularity in recent years: passive and active crowdsourcing. Passive crowdsourcing derives data from users leaving traces online on location and activity by sharing material on social media or by simply using their cell phones (See et al. 2016; Birenboim and Shoval 2016). Social media derived from people sharing text or photos on an online platform, such as Flickr, has become particularly important for mapping recreation and aesthetic values appreciated by people in nature (Richards and Friess 2015; van Zanten et al. 2016). Combining several content sharing platforms has been suggested for monitoring protected area popularity and temporal visitation patterns, by using for example Instagram, Twitter and Flickr (Tenkanen et al.

2017). Active crowdsourcing, on the other hand, depends on users actively contributing with data through online platforms specifically designed to collect data about users or nature qualities (Wolf, Brown, and Wohlfart 2018; Ridding et al. 2018). Data collection through online platforms could either openly recruit anyone to participate (volunteered geographic information - VGI), or it could be based on targeted sampling of individuals to ensure representation of the population of interest (e.g., Public Participation Geographic Information System - PPGIS) (Brown, Kelly, and Whitall 2014).

Although social media and online PPGIS platforms have both been shown to be useful tools for assessing the spatial distribution of values, each has their pros and cons. Social media data are less costly to collect and therefore allow the elicitation of values from a much larger pool of potential users on a broader scale (Toivonen et al. 2019). Social media data have been used to quantify nature-based tourism and recreation (Wood et al. 2013), tourism flows (Hawelka et al. 2014) or for mapping destinations and events that are highly visited by the public (Kisilevich et al. 2013). The tags can also inform about how people value nature, how those values are distributed, and the contribution of nature to the qualities appreciated by people (van Zanten et al. 2016). The photos can represent diverse activities and values including aesthetics, recreation, wildlife viewing, and bio-cultural heritage (Toivonen et al. 2019). Moreover, photos taken by several people at a specific location can be associated with specific environmental characteristics of that area (Dunkel 2015). Content analysis of photographs shared on social media have also been used to model the spatial distribution of values and nonmaterial benefits with respect to landscape characteristics and infrastructure, and to indicate how changes in the landscape and infrastructure development can affect the overall visitor experience and distribution (Walden-Schreiner, Leung, and Tateosian 2018; Tenerelli, Demšar, and Luque 2016). However, social media have been shown to be unreliable at capturing some indirect-use and non-use values, whereas PPGIS is capable of capturing a wide range of values (Levin, Lechner, and Brown 2017). The primary benefit of PPGIS surveys is the possibility to customize the tool to collect information on spatial values, preferences and experiences that are of direct relevance to protected area management (e.g., Brown and Weber 2011). For example, PPGIS has been used to identify areas of value hotspots and the overlap of different user groups, to understand land use preferences, to address conflicts between different user groups, and to monitor tourism development preferences (Muñoz et al. 2019; Engen et al. 2018; Wolf, Brown, and Wohlfart 2018; Brown and Weber 2013). Participatory mapping surveys are customized for each case, which makes them suitable for surveying a wide range of people, which can include stakeholders, locals, visitors, experts, the general public and decision-makers (Brown and Kyttä 2014). Thus, PPGIS can include voluntary participation (similar to social media), as well as targeted recruitment of a representative sample.

While the use of social media data has been compared to visitor data on a regional scale previously (Tenkanen et al. 2017; Graham and Eigenbrod 2019), spatial data and the values identified by using passive and active crowdsourcing tools have not been extensively evaluated using the same location. One exception is Levin, Lechner, and Brown (2017) who compared the visitor density and values mapped by crowdsourcing tools in multiple protected areas. No one has to date compared the potential of active and passive crowdsourcing tools to provide spatial information of nature qualities on a finer scale of relevance to protected area management (i.e., within protected areas). The spatial distribution at this scale will depend on the profile of users captured by the different tools, the values people ascribe to nature, and the spatial accuracy of the geolocations mapped using different platforms. If these tools are to be used to guide protected area management, it is important to understand the conditions that influence the results generated by each tool at this scale.

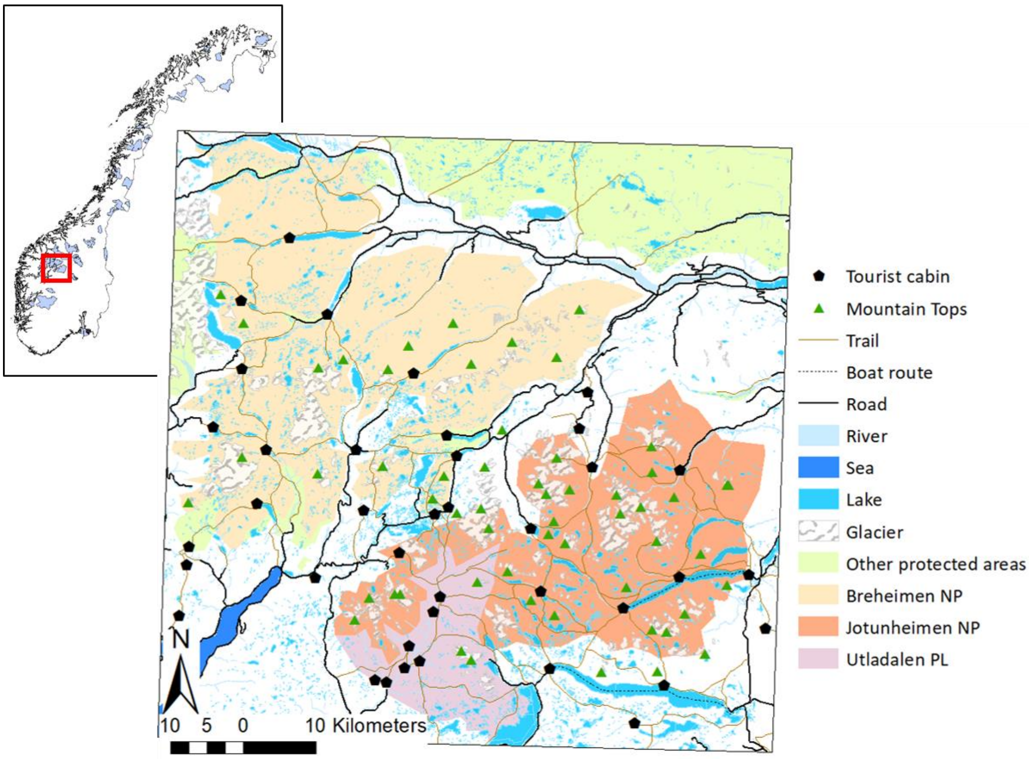
Here we examine the spatial distribution and the type of values generated by the two crowdsourced tools (Flickr and PPGIS), and their usefulness for informing protected area managers about the nature qualities that are important for different groups of people. We tested the crowdsourcing tools with respect to how they perform in capturing spatial information of the nature qualities that people care about in an iconic mountainous landscape in Norway, encompassing a cluster of protected areas that are visited by different domestic- and international groups of people. Our study differs from previous comparisons of Flickr data to visitor data by i) the explicit focus on spatial information of relevance to protected area management, ii) the comparison of the values derived from using these two crowdsourcing tools, and iii) their relationship to the locational profile of the Flickr/PPGIS users and environmental and infrastructure characteristics. We asked: 1) Does the spatial distribution of values generated by Flickr versus PPGIS data differ? 2) How does the distribution of values using these two tools correlate with environmental and infrastructure variables? 3) How much do values overlap using Flickrversus PPGIS?, and 4) Do international and domestic visitors map different attributes using the two tools? Finally, we discuss the pros and cons of using these tools for assessing NCP to inform protected area management.

Methods

i. Study area

This study was conducted in southern Norway and included Jotunheimen national park (Jotunheimen NP), Breheimen national park (Breheimen NP), Utladalen protected landscape (Utladalen PL) and the non-protected area surrounding these areas (Figure 1). Jotunheimen NP and Breheimen NP were originally designated for their wilderness and untouched nature covering 1151 and 1691 km^2 respectively, and have become major nature attractions in Norway. They are dominated by alpine vegetation and hold the highest peaks in Scandinavia and several glaciers and lakes. In 1980, at the same time as Jotunheimen was designated national park, the neighboring area Utladalen was declared protected landscape with the aim to protect cultural landscapes (Ministry of Climate and Environment 2014). The major difference between national parks and protected landscapes is the uses allowed. National parks are mainly designated to protect ecosystems and biological diversity allowing low levels of human use, whereas protected landscapes aim at conserving natural and cultural landscapes with high ecological and cultural values, and traditional use is an inherent objective for protection (Ministry of Climate and Environment 2019). The study area has for a long time been used for traditional outdoor recreation, attracting visitors for the cabin-to-cabin hikes and climbing opportunities. The study area also includes several villages (e.g., Øvre Årdal, Beitostølen and Lom), which host a variety of cultural and recreational activities all year round, both in and around protected areas, such as music, film and food festivals, and guided tours by foot, bike, horse, dog-sledding or rafting (Jotunheimen 2019).

Figure 1. Map of the study area. Top left: Map of Norway with national parks shaded in blue and a red box indicating the study area location. Bottom left: Our study area with protected areas shaded in green. The main touristic attractions are shown in the map (mountain tops, touristic cabins, and glaciers).



ii. Data acquisition

i. Flickr

Flickr is a free photo management and sharing platform where users can upload their pictures, geotag them and share them privately or publicly (Flickr 2019). We retrieved information associated with 6255 publicly available geotagged Flickr images on 4th April 2016 for our study area using the flickRgeotag R package (Daigle and Dunnington 2018). The metadata that accompanied the images included de-identified (key-coded) photos and user ID codes, the country of origin of the Flickr user, text-based tags associated with each photo (which can be either user-specified or selected by Flickr's automated tagging algorithm), the coordinates (latitude and longitude in WGS84) of the image, and the URL link to the photo. For the purpose of this study we used the country of origin, the coordinates and the photo URL. For those users that did not report their country of origin (268 users), we estimated the contributors' home country from the median coordinates of all uploaded pictures. The photographs were taken between 2007 and 2016 with 34 % of the images dated 2014-2015. Although social media data can identify changes in visitation from year to year (Tenkanen et al. 2017), we aggregated the data from 9 years for this study as Flickr data is temporally sparse in this region, so that we could ensure sufficient sample to make robust conclusions. Also, we were not focusing on the changes over time in this study, but values that change more slowly (see Brown and Weber (2012).

A detailed list of values was developed by five experts who had previous experience with Flickr and the case study area. We used the CICES V4.3 framework (Haines-Young and Potschin 2013) to identify categories to code. A detailed definition of each value was discussed and agreed between the experts to avoid overlap between categories (see List 1 for the full list of values coded). Codes were trialed iteratively until agreeing upon a final list of values that could be extracted from the pictures. We knew from previous studies that recreation and scenic nature are the primary reasons for visiting protected areas (Levin, Lechner, and Brown 2017; Muñoz et al. 2019), and biological diversity, wilderness and learning are the traditional international objectives of protecting land. Protected mountainous landscapes in southern Norway also include traditional uses associated with historical land tenures (Hausner, Brown, and Lægreid 2015). We therefore included harvesting, livelihood, social and heritage values relating to nature as possible qualities that visitors may appreciate.

Each value reflects the primary subject of the photograph. After the coding system had been developed, the content of each picture was manually examined and coded (by the author L.M.). We assigned one code to each picture based on the dominant feature of the picture, which could show, for example, an activity, wildlife, or a landscape. After the content analysis, only the pictures taken in a natural setting were retained (4038 photos) and those showing portraits, built environments, and extractive activities were discarded from further analyses. From pictures taken in natural settings, 4 values had a similar definition and sufficient number of photos to compare with the PPGIS dataset (values 1-4 in List 1).

List 1. The values used for coding Flickr photos adjusted from the CICES V4.3 framework. Only values 1-4 were used for comparisons with the values mapped in PPGIS.

(1) **Biological diversity**: Dominant feature of the picture is plants, animals or other important ecosystem features. E.g., pictures of wild animals or plants.

(2) **Recreation:** Dominant feature of the picture is people doing physical recreational activities. E.g., Walking, hiking, climbing, boating.

(3) **Scenic landscapes**: Dominant feature of the picture is an important place that is scenic, a distinctive landscape, wilderness or natural settings (could include people, but not the main focus). E.g., scenic drives, scenic cruises, mountains, fjord, wilderness. Could be symbolic/spiritual values, which need to be determined ad hoc.

(4) **Social**: Pictures taken primarily of social activities in natural setting, including organized activities. E.g., alpine arrangements, bonfires, picnic.

(5) **Harvest**: Dominant feature of the picture is people engaging in recreational harvest. E.g leisure hunting, fishing, picking berries etc.

(6) **Heritage**: Dominant feature of the picture is related to historical use of nature. E.g., evidence of historical fishing and hunting, summer farms, etc.

(7) **Learning**: Dominant feature of the picture is scientific or educational activities in nature or related to natural features. E.g., school trips, field research, etc.

(8) **Livelihood**: Dominant feature of the picture is related to local livelihoods/economy. E.g., sheep farming, reindeer herding, subsistence hunting and fishing.

ii. PPGIS

PPGIS is a GIS tool to map spatial attributes and important locations in an area. We conducted two online PPGIS surveys: a household survey combined with voluntary participation of locals, and a visitor survey with in-situ recruitment in the study area in October-December 2014 and July-September 2015 respectively. For the first survey, we invited a randomly selected set of 10 % of the households in the municipalities in the study area to participate in the web-PPGIS study, contacting them by regular post. A reminder letter was sent two weeks after the first contact. Additionally, we used local organizations, newspaper and social media to recruit volunteers. During the peak visitor season to our study area in 2015, we recruited respondents to the second survey at recreational parking spots, either by direct contact, or through leaflets placed on cars. Two reminders were sent by email to visitors recruited in the field.

In the PPGIS survey, we asked respondents to drag and drop georeferenced markers that represent one of the 12 values (see List 2 for the full list of values) onto a Google® map view, by zooming in and out as needed. People could place as many markers as they wanted, but were encouraged to place at least 20. They were free to place markers for as many, or as few, values as they wished. We refer to "mapped value" as the georeferenced marker placed by participants on the map. We piloted the surveys on park managers whose feedback was used to improve the PPGIS platform. The Data Protection Official for Research for all the Norwegian universities and research institutes (Norwegian Centre for Research Data) approved the ethical treatment of the data in the project (CultES no. 230330/E50/2014) under the Personal Data Act 2000. The online survey included an informed consent for participation that respondents had to accept before completing the survey, where we informed participants about the purpose of the study and explained that data would be treated confidentially. Also, participants were informed that the study was voluntary, and that they could withdraw from it at any time or contact us through the provided email in case of any concerns regarding the study. For additional details about the survey, see Muñoz et al. (2019).

From the 12 values included in the mapping activity, four were comparable to the categories obtained by coding Flickr images: biological diversity, scenic landscapes, social value, and recreation (values 1-4 in List 2). We used all values mapped in Flickr and PPGIS to identify the potential differences between international and domestic visitors for each platform (i.e., difference in clustering and ranking between user groups). We used the subset of 4 values that were comparable for PPGIS and the Flickr coding (see above) to compare the difference in spatial information obtained from these two platforms . When discussing results, we refer to either “all values” (8 values in Flickr and 12 values in PPGIS) or “four common values” (i.e., the ones that are comparable between the two data sets).

List 2. The values used in the PPGIS survey adapted from Gregory Brown and Reed (2000) to the Norwegian context (Hausner, Brown, and Lægreid 2015)*. Only values 1-4 were used in direct comparisons with Flickr values.*

(1) **Biological diversity**: Areas that are important because they provide a variety of plants, wildlife and habitat

(2) **Recreation**: Areas that are important for outdoor recreation activities (e.g., camping, walking, skiing, alpine snowmobiling, cycling, horse riding)

(3) **Scenic landscapes**: Areas that are important because they include beautiful nature and/or landscapes

(4) **Social value**: Areas that are important because they provide opportunities for social activities (e.g., associated with fireplaces, picnic tables, ski- or alpine arrangements, shelters, shared cabins, cabin complexes)

(5) **Clean water/air**: Areas that are important because they provide clean water/air

(6) **Cultural value (including cultural identity):** Areas that are important because of their historical value, or for passing down the stories, myths, knowledge and traditions, and/or to increase understanding of the way of life of our ancestors

(7) **Gathering**: Areas that are important for berries, mushroom or collecting herbs/plants

(8) **Hunting/fishing**: Areas that are important because of hunting and/or fishing

(9) **Spiritual value**: Areas that are important because they are valuable in their own right or have a deeper meaning; emotionally, spiritually, or religious

(10) **Therapeutic**: Areas that are valuable because they make me feel better, either because they provide opportunities for physically activities important for my health and/or they give me peace, harmony and therapy

(11) **Wilderness and undisturbed nature**: Areas that are relatively untouched, providing for peace and quiet without too many disturbances

(12)**Special place**: Please describe why these places are special to you

iii. Statistical analyses

i. Density-based clustering for hotspot mapping

We conducted a density-based cluster analysis of all the values mapped to compare the areas with highest density of values (hotspots) in each dataset and to quantify the number of hotspots. To accomplish this, we used the “Density-based Spatial Clustering of Applications with Noise” (DBSCAN) algorithm (Ester et al. 1996) with a minimum of 10 neighboring points within a 1000 m search radius. In DBSCAN, points represent the geographical location of each Flickr photo or the mapped value location in PPGIS. This algorithm detects points that form clusters with irregular shapes and discards sparse points (Ester et al. 1996). The search radius was determined by visual inspection of the threshold of the k-nearest neighbor distances plot. DBSCAN forms clusters with core and border points. Core points are those that are surrounded by 10 points within the search radius. Ten points was selected as the minimum number of points in order to capture a diversity of values inside each cluster. Border points are those points that belong to a cluster because they are located inside the search radius of a core point, but do not have the requirements to be classified as a core point (i.e., they do not meet the requirement of a minimum 10 points in a 1000 m search radius). The points that are not classified as either core or border points are discarded from the clusters. The resulting clusters are point clouds containing core and border points.

ii. Maximum entropy modelling for environmental and infrastructure variables

The purpose of the modeling was to test whether Flickr and PPGIS data are correlated with the same environmental and infrastructure characteristics. We developed the following 18 models to analyse the distribution of values: two overall models for all values in each dataset separately (i.e., Flickr and PPGIS), and 16 models for each unique combination of the four common values (the first 4 values in List 1 and List 2, we compared each domestic and international user group (n=2), developed for each dataset). We selected the covariates based on previous research demonstrating how nature tourism is related to human infrastructure and environmental characteristics (Richards and Tunçer 2018; Bagstad et al. 2016; Walden-Schreiner, Leung, and Tateosian 2018). Values were modelled against nine environmental and infrastructure variables (hereafter referred to as covariates); 8 continuous variables: distance from trails, roads, touristic cabins, buildings (other infrastructures, e.g. houses, bridges), rivers, lakes, and mountain tops and glaciers; and vegetation cover percentage), and one categorical variable (altitude divided in 500 m elevation intervals) (see SI 1). We extracted covariates from the N500 database developed by the Norwegian Mapping Authority (Kartverket), which contains among other things landscape characteristics and infrastructure (Kartverket 2015). Mountain tops were manually georeferenced based on the protected area brochures published by the Norwegian Environmental Agency. Vegetation cover percentage, was produced from CORINE2006 data (European Environmental Agency 2015) and transformed to vegetation cover percentage. We reclassified the CORINE map by assigning 100 % cover to vegetated areas, 50 % cover to areas sparsely vegetated and 0 % cover to areas artificial surfaces, rocks, non-vegetated areas and water bodies. The values for each pixel were interpolated using the nearest neighbor approach using a 3x3 kernel. We rasterized covariates in a 1 210 000 pixel raster with a 116.1 m pixel size. The raster layers provided distances to natural and human-made features and these were square root transformed to avoid skewedness towards the right end (long distances). We tested for correlation between covariates and found no indication to discard any of the covariates (SI 2).

We developed the 18 maximum entropy models using MaxEnt software version 3.4.0 (Phillips, Dudík, and Schapire [Internet]). Briefly, maximum entropy modelling compares the distribution of presences in environmental space (the set of covariates) against the background distribution of those covariates (Elith et al. 2011). The model compares the presence of points (i.e., values) against a set of randomly distributed background points to estimate the influence of environmental characteristics on the value distribution. Therefore, we removed duplicates from the model as MaxEnt works with presence data and 25% of the presence points were randomly selected as a test set during the internal validation of the model. We selected a random subset of 10 000 background points from the 1 210 000 grid cells in our study region. MaxEnt selected the regularization values and feature types, that is, hinge, product, linear and quadratic, that was best fit to the model. The output is a model that can predict the suitability of other areas for the values mapped by users. To identify those covariates that best explain the distribution of each value, we examined the permutation importance, which is a measure calculated by randomly selecting values for each of the covariates for each permutation during the training of the model, independent of the model path followed. The permutation importance measures how much the model relies on the given variable, normalized to percentages. In other words, the permutation importance is a measure of the contribution of a variable to the predictive ability of the model. We used these models to predict the suitability of the study area to contain the four common values. In order to assess how alike the predictions were for values mapped in different platforms (i.e., Flickr and PPGIS), we used the suitability maps for each value to calculate the niche overlap between the two datasets. MaxEnt is suitable for use with presence-only data such as that generated by Flickr or PPGIS, where the photo or PPGIS locations indicate the ‘presence’ of a value, but unmapped areas cannot be assumed to indicate the ‘absence’ of a value. Maximum entropy modelling has previously been used to model species distribution (Phillips and Dudík 2008) but it is increasingly used for modelling ecosystem services and visitor distribution (Bagstad et al. 2016; Walden-Schreiner, Leung, and Tateosian 2018).

All analyses were conducted using the R Software version 3.4.1 (R Core Team 2019) using “dismo” package for the Maxent model (Hijmans et al. 2017) and “dbscan” package for the DBSCAN algorithm (Hahsler et al. 2018).

iii. Comparing domestic and international visitors

We used exploratory analyses to describe and summarize differences in the mapped values by different user groups for each citizen-generated dataset. First, we identified differences between the values mapped by domestic and international visitors within each dataset using Chi-square tests and then Spearman rank correlation tests. For each mapped common value, we compared standardized chi-square residuals of the proportion of values mapped compared to the total amount of values for domestic and international visitors, identifying those values that were outside the range -2 to 2 as being mapped significantly less or more often than the other group. We used the Spearman rank correlation to show the degree to which the two user groups (i.e., domestic- and international visitors) are similar in their perception of value importance based on the ranks of mapped value frequencies (based on 8 data points in Flickr and 12 data points in PPGIS).

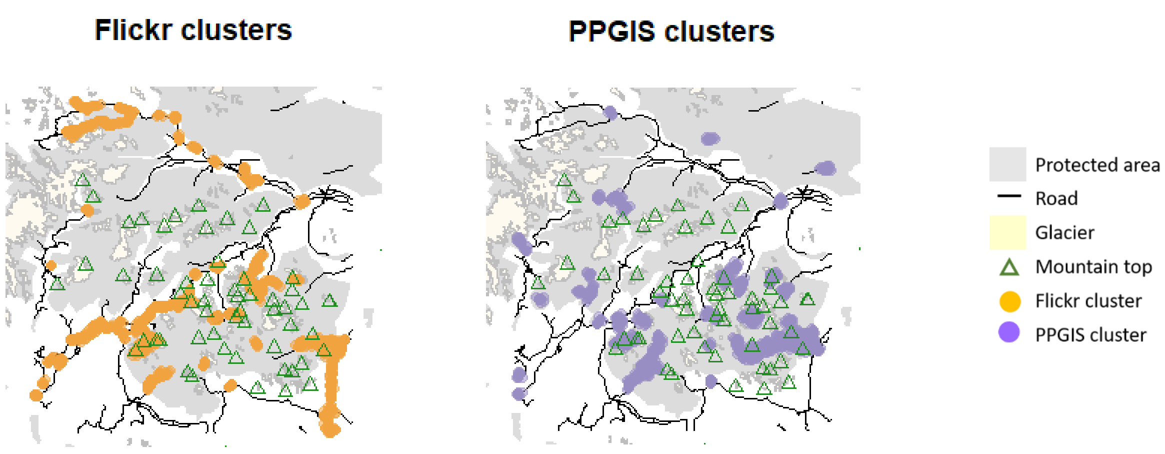
Results

In the Flickr dataset, 479 users geotagged a picture related to nature qualities inside the study area, from which 177 were domestic (Norwegians), 284 were international visitors and 18 had an unknown origin. Of the 479 users, 268 users did not report their origin. Using the median distance of all the photos that each of these individuals uploaded, we concluded that 100 were domestic visitors, 150 international visitors, and 18 remained with no clear origin. From the 4038 uploaded images, photos related to nature qualities primarily showed scenic landscapes (3008 photos) and recreation (601).

The median number of nature related photos uploaded by each user was 2, and 16 users uploaded more than 50 pictures inside the study area (3.3 % of users) (SI 3). In the PPGIS dataset 468 respondents were recruited, split between 332 domestic (Norwegians) and 136 international visitors. From 3873 mapped values, the most commonly mapped value was recreation (1176 markers) followed by scenic landscapes (1070). The median number of mapped values by each user was 5, and 5 users (1 %) were identified as "supermappers" (those who mapped more than 50 values) (SI 3).

We tested differences in the spatial distribution of all values for the two datasets by creating density-based clusters to identify hotspots of values. The density cluster analysis resulted in 51 hotspots for the Flickr database and 36 hotspots for the PPGIS database (Figure 2) with 19.7 % and 35.9 % of the points remaining outside clusters. Figure 2 shows that places attractive to visitors are located along roads in the Flickr dataset, but are predominantly located inside protected areas in the PPGIS dataset (values inside PAs: 32.3 % in Flickr and 77.4 % in PPGIS).

Figure 2. Clusters from the density-based clustering for Flickr (orange, left) and PPGIS (blue, right).



We compared 18 MaxEnt models to determine differences in the two datasets concerning the environmental and infrastructure covariates that explain the distribution of values. We used the permutation importance metric to understand the contribution of each covariate to the MaxEnt model, which contrary to the percent contribution, does not depend on the order in which the covariates are entered into the model (Kalle et al. 2013). The MaxEnt models for all values in each dataset indicate that the location of values in Flickr was mainly explained by distance to motorized access, while the location of values in the PPGIS dataset was determined primarily by distance to mountain tops, glaciers and trails (Table 1). We further examined Maxent models for each comparable value, which confirmed that the values are explained by different environmental and infrastructure covariates in each dataset. It also showed that domestic and international visitors correlate differently to covariates in the PPGIS dataset. According to the permutation importance metric (Table 1) the location of values found in the Flickr dataset were heavily influenced by distance to motorized access, with three exceptions: domestic visitors related recreation and social values to mountain tops and glaciers, and international visitors related social values to trails. Values in the PPGIS dataset differed from these results as they were less influenced by infrastructure and more by proximity to mountain tops, glaciers, and trails. Domestic visitors mapped values closer to mountain tops and glaciers, with the exception of social values which were mostly related to trails. Most values mapped by international visitors were related to distance from trails.

Table 1. Permutation importance expressed in percentage on how much each model relies on each variable. Shaded numbers indicate the landscape or infrastructure covariates with the highest permutation importance percentage. We calculated the permutation importance (percentage of how much each variable contributes to the model) for all values in each dataset, and for the four comparable values for domestic and international visitors.

		motorized access distance	building distance	cabin distance	lake distance	river distance	topography	mountain top/glacier distance	trail distance	vegetation
Flickr	Overall	49.4	0.3	2.9	3.2	0.8	1.4	20.3	19.6	2.3
	Domestic	66.1	2.3	1.7	2.9	1.4	0.4	4.9	13.4	6.9

	Biological diversity	International	55.5	2.1	8.5	0.0	0.1	3.0	6.6	12.3	11.9
	Recreation value	Domestic	26.4	0.3	2.8	4.0	3.7	0.1	43.6	17.7	1.4
		International	47.9	2.7	1.7	1.4	2.1	2.3	15.5	20.6	5.9
	Scenic value	Domestic	36.2	0.9	2.5	7.3	1.4	2.6	27.5	19.5	2.0
		International	56.9	0.3	3.0	1.3	0.6	0.2	14.2	21.0	2.4
	Social value	Domestic	0.0	0.0	36.2	6.7	0.0	0.7	51.4	4.7	0.3
		International	17.0	1.5	4.8	8.0	0.1	7.3	22.5	38.3	0.5
PPGIS		Overall	6.5	2.2	4.0	10.6	5.2	1.6	34.3	33.7	1.7
	Biological diversity	Domestic	4.1	6.6	17.6	1.1	7.2	3.7	42.1	9.9	7.8
		International	0.0	1.8	10.3	0.7	3.2	1.6	35.3	44.1	3.0
	Recreation value	Domestic	7.0	1.9	6.5	11.5	5.6	0.3	38.0	28.9	0.3
		International	7.9	5.9	7.5	4.4	4.3	4.0	26.4	38.5	1.1
	Scenic value	Domestic	8.6	2.1	2.5	7.7	6.1	2.3	34.3	33.7	2.7
		International	11.7	1.4	8.9	3.5	5.5	1.5	22.4	41.9	3.1
	Social value	Domestic	14.3	2.5	4.8	4.9	1.7	11.5	20.5	25.8	13.9
		International	0.0	0.7	22.6	0.0	0.1	0.4	4.6	71.5	0.0

Most of the Flickr values (60 %) were within the first 500 meters from roads, compared with 23 % in the PPGIS dataset. For trails, only 34 % of values from the Flickr data were within 500 meters from trails compared to 50 % of the PPGIS data.

We measured the percentage overlap of the predicted spatial distribution probability of values based on MaxEnt analysis of Flickr versus PPGIS data (Table 2; see maps in SI 4). Whereas different environmental and infrastructure characteristics have a stronger influence on value distribution in the two datasets, it appears that the spatial overlap between Flickr and PPGIS is relatively good, at least for recreation-and scenic values (Table 2).

Table 2. Results for the overlap of predictions for Flickr and PPGIS datasets resulting from MaxEnt models. Values range from 0 (no overlap) to 1 (identical distribution). The last row contains the overlap between the MaxEnt habitat suitability prediction for all values in Flickr and PPGIS for all users together.

	Domestic	**International**
Biological	0.68	0.80
Recreation	0.89	0.83
Scenic	0.94	0.83
Social	0.83	0.64
Flickr vs. PPGIS (model for all values and users together)	0.94	

We used Chi-square tests to assess differences in values between domestic and international visitors within the two datasets (Table 3). In the Flickr dataset, domestic visitors uploaded more images representing social values (127 photos vs 31 respectively) and recreational values, while international visitors took significantly more photos of scenic landscapes (1695 photos by internationals vs. 1238 by domestic). PPGIS data revealed that domestic visitors mapped significantly more values representing cultural, gathering, hunting and fishing, and therapeutic values than international visitors who mapped more clean water, recreation and wilderness values.

Table 3. Standardized residuals for Chi-square tests. Numbers below -2 or above 2 indicate that the value of domestic- and international visitors has been mapped significantly less or more than would be expected within those two datasets (shaded). In brackets, the percentage a value was photographed/mapped by domestic- and international visitors for each dataset.

Flickr				**PPGIS**			
	Domestic	*International*	*Pooled frequency (rank)*		*Domestic*	*International*	*Pooled frequency (rank)*
Biological	-0.82 (3.7)	0.82 (4.2)	4	Biological	-0.21 (4.6)	0.21 (4.8)	6
Recreation	8.59 (19.9)	-8.59 (10.1)	2	Recreation	-3.27 (28.9)	3.27 (34.3)	1
Scenic	-10.52 (66.8)	10.52 (81.5)	1	Scenic	-0.73 (27.3)	0.73 (28.5)	2
Social	8.55 (6.9)	-8.55 (1.5)	3	Social	1.78 (3.7)	-1.78 (2.5)	8

Extraction	1.29 (0.4)	-1.29 (0.1)	8	Clean water	-5.42 (6.6)	5.42 (11.9)	3
Harvest	0.48 (0.5)	-0.48 (0.4)	7	Cultural	4.94 (4.7)	-4.94 (1.3)	7
Heritage	-0.28 (0.6)	0.28 (0.7)	6	Gathering	2.96 (2.0)	-2.96 (0.7)	12
Livelihood	-0.37 (1.3)	0.37 (1.5)	5	Hunt/fish	8.08 (8.1)	-8.08 (1.1)	5
				Special place	0.92 (3.3)	-0.92 (2.7)	9
				Spiritual	-1.32 (1.5)	1.32 (2.1)	11
				Therapeutic	3.33 (3.4)	-3.33 (1.4)	10
				Wilderness	-3.08 (6.0)	3.08 (8.8)	4

The Spearman rank correlation confirmed the differences between domestic and international visitors within each dataset. The Spearman correlation test showed that domestic- and international visitors in the Flickr database were highly positively correlated (rho = 0.96, p = 0.0002) in the ranked themes of contributed photos. The types of mapped values in PPGIS for domestic and international visitors were not as highly correlated (rho = 0.58, p = 0.05) based on frequency rankings.

Discussion

We found large differences in the spatial data generated by passive versus active crowdsourcing methods. Flickr and PPGIS datasets differ substantially in both the types and locations of values mapped. Values represented in Flickr photos were located closer to roads than those mapped in the PPGIS dataset, which were predominantly located inside PAs and often associated with trails, mountain tops and glaciers. Despite these differences, the predicted spatial distribution of values generated by models applied to these two datasets showed substantial overlap, especially for scenic- and recreational values, indicating that both datasets capture similar environmental and landscape characteristics. However, the overlap in value distribution suitability is lower when comparing domestic visitors in Flickr against domestic visitors in PPGIS (the same applies for international visitors). These differences, and the differences in the infrastructure and environmental variables that relate most to the distribution of values, may indicate that each crowdsourcing method gathers different information that is suitable at different scales (fine scale for PPGIS and regional scale for Flickr).

Our study results, consistent with Sonter et al. (2016), demonstrate that the value distribution can differ, or even be contradictory, depending on the data source, type of values mapped, and the local contexts. As values mapped using the Flickr dataset are drawn from photographs, they can only represent visited places. In contrast, PPGIS allows the placement of a wider diversity of values, including areas that have not been visited, but that are important for the respondent (e.g., existence values). This may be one of the reasons why the clusters of values mapped using Flickr data are located in different places than those mapped using PPGIS. Moreover, images uploaded in Flickr might not be georeferenced according to the coordinates of the nature quality (e.g., the mountain photographed), but rather be placed where the picture was taken (Zielstra and Hochmair 2013) (e.g., the road from which the mountain was photographed). While tools that use elevation models or Google imagery to identify the location of scenic values from photographs are available (e.g,. the Scenic Quality Package in InVEST (The Natural Capital Project 2019)), such tools are yet to be developed for more intangible values such as ‘social’ or ‘special place’.

We found visitor infrastructure to be the most important factor explaining the spatial distribution of values in Flickr. Flickr tends to emphasize the importance of roads, and about 60 % of the pictures were located within 500 m of a road. The fact that there is a high proportion of values found near roads does not mean that roads increase nature values. As shown by Kulczyk, Woźniak, and Derek (2018), the distribution of values can be locally affected by infrastructure despite nature being the true attraction in the region. Such data will not fully capture the fine-scale distribution of nature qualities that are appreciated in landscapes more distant from roads. Despite the strong bias towards roads, passive crowdsourced data can be valuable for identifying tourism hotspots and scenic routes on a regional and sub-regional scale and for informing management actions (e.g., Alivand and Hochmair (2017)). Contrary to our Flickr dataset, van Zanten et al. (2016) found hills and mountains to be the strongest predictors of scenic-and recreation values using social media data. They controlled for accessibility using distance to big cities and travel time. Similarly, Kim et al. (2019) found nature attractions such as beaches and waterfalls explained the distribution of Flickr data more than cultural sites and tourist facilities (i.e., accommodation venues and restaurants). These results indicate that the importance of infrastructure can differ depending on the local context. In our case, mountain tops and glaciers were the main predictor of recreational value for domestic visitors in the Flickr dataset, and for multiple values mapped by domestic visitors in the PPGIS dataset. Thus, both datasets can provide valuable information about NCP, confirmed by the high overlap between Flickr and PPGIS in the spatial MaxEnt models.

Differences among domestic-and international visitors with respect to the use and appreciation of nature qualities within protected areas has previously been documented (Tyrväinen, Mäntymaa, and Ovaskainen 2014; Shultis 1989), but few studies have compared the spatial distribution of values among these two visitor groups. Spatially explicit analyses are important for detecting potential overlap of conflicting values of relevance to protected area management. Increasing tourism may have a low impact on local recreation if visitors and locals use different areas and value different nature qualities (Muñoz et al. 2019; Sonter et al. 2016). We found domestic visitors to upload more photos of recreation and social values and less scenic landscapes compared with international visitors Similar results have been reported by Walden-Schreiner, Leung, and Tateosian (2018) and Fagerholm et al. (2019). Data from PPGIS captured a higher diversity of values compared to Flickr, with domestic visitors appreciating cultural, hunting and fishing, and gathering values more than international visitors, who mapped more values related to recreation, wilderness and clean water. The attachment of different groups of people to a place can be key to understand nature qualities that need to be managed, and to discern management actions to avoid conflicts among users (Gundersen et al. 2015; Fagerholm et al. 2019). The difference in mapped NCP can also be indicative of more deeply rooted cultural differences, as determined for example by the country one resides in (Brown et al. 2015). Our study shows that PPGIS captures better the differences between domestic- and international visitors than Flickr does, and will likely be more useful when developing strategies for tourism development and management.

Additional advantages and limitations of Flickr and PPGIS

As previous studies have concluded, crowdsourced data is a valuable source for assessing NCP. However, each method has their advantages and limitations that need to be carefully considered depending on the research questions to be addressed.

The first difference between the two platforms relies on the type of values that can be mapped. In PPGIS, values are generally pre-defined and the definition is available for the respondents, who decide which listed value they ascribe to a given place. However, for social media data, a code is assigned by experts based on the photographs or keywords (see e.g., Oteros-Rozas et al. (2016)). While defining values in a PPGIS platform is flexible and can include a wide range of values because the process is deductive, the coding of social media pictures is an inductive process where themes are limited to those that can be identified visually. While this is likely to be reasonably accurate for values such as recreation (as represented by a photo of a person in skis for instance) some judgment on the part of the expert is involved for other values such as ‘social’ and ‘spiritual’ that are difficult to identify in this way. A limitation of this study lies in the fact that the PPGIS platform was used to map values that are not comparable to the values obtained in the Flickr photographs. The optimal would have been to include only the four comparable values to test for differences in the spatial distribution between the two datasets. On the other hand, by utilizing the full potential for mapping a diversity of values in PPGIS surveys, we could assess the potential of each platform to identify differences between visitors. We found passive crowdsourced data such as Flickr to be unreliable for capturing the full range of values and the importance of protected areas, including typical conservation values (biodiversity, wilderness and clean nature) and those important to local culture (cultural heritage, harvesting and social values) (see also Levin, Lechner, and Brown 2017).

Second, the accuracy and precision of these methods can be difficult to assess. The spatial accuracy of photo-sharing platforms can be assessed through the positional error between the geotagged photo and the actual location of the picture. By visually matching photographs with ArcMap aerial imagery to estimate the camera position of the image, Zielstra and Hochmair (2013) found median errors in geospatial accuracy of Flickr images ranging from 46 to 1606 m in different locations. For PPGIS, the accuracy of attributes that represent subjective judgements cannot be directly assessed against authoritative data (Brown and Kyttä 2014). For spatial variables where accuracy could be evaluated, Brown (2012) and Cox et al. (2014) concluded that PPGIS respondents were able to accurately identify areas of native vegetation and suitable habitat for threatened species . In addition to the accuracy, the resolution of the data also affects the method. For example, Flickr has been shown to capture visitor distribution at coarse resolutions (several kilometers) (van Zanten et al. 2016; Mancini, Coghill, and Lusseau 2018; Graham and Eigenbrod 2019), while PPGIS performs well at fine resolutions (Munro et al. 2017).

Third, researchers need to make choices between the number of participants, representativeness, and timeframe available when using these different crowdsourced data. Crowdsourced data might be biased towards different users depending on the type of social media platform, knowledge about an area, or place of residence (Bubalo, van Zanten, and Verburg 2019; Ruths and Pfeffer 2014; Brown and Kyttä 2014). Demographic data are often not reported by the social media platforms. Also, there are studies showing that social media users are not representative of the general population, with educated people over-represented and gender bias shifting over time on different platforms (Mellon and Prosser 2017; Li, Goodchild, and Xu 2013; Mislove et al. 2011). The social media platform used can provide different results. For example, Hausmann et al. (2018) found that Flickr users post more pictures related to biodiversity than Instagram users, who post more photos of people. However, Instagram performs better at estimating visitor rates than Flickr and Twitter (Tenkanen et al. 2017).

In our case, there was no visitor data available to assess whether the PPGIS data were biased towards mid-aged males and educated participants as shown in similar studies (Bubalo, van Zanten, and Verburg 2019; Brown et al. 2015). Sampling design plays a crucial role in capturing a representative sample of the population or a targeted population segment (Brown and Kyttä 2014; Brown 2017; Brown et al. 2019). However, although data on visitation and visitor distribution provided by social media has previously been validated against local knowledge and field surveys (Kim et al. 2019), there is no available true representation of the spatial distribution of values with which Flickr and PPGIS data can be assessed.

Conclusion

Crowdsourced data from passive and active sources can be a useful tool to inform managers about the spatial distribution of NCP in protected areas. Our results show that crowdsourced data provides fine scale information on a diversity of values that people associate to protected areas, and the differences between user groups that are relevant for management. The methods differ in the distribution of values people ascribe to nature, for example in PPGIS a high proportion of values is located inside protected areas, whereas in Flickr they are more clustered and closer to roads. Although both methods are good at capturing scenic and recreation values, Flickr is more limited on the values that can be interpreted from pictures, whereas in PPGIS the values that are difficult to show in a picture can be captured (e.g., spiritual or inspirational values). We recommend a careful consideration of the type of data needed (in terms of values, explanatory variables, and type of respondents) and logistical constraints (required quantity of data, scale and accuracy). To overcome some of the limitations of crowdsourcing data, combining these tools with field surveys could combine the benefits of both approaches, delivering large-scale datasets from a broad user sample along with more detailed and specific information on NCP and the nature qualities that are valued by different groups of people.

Data archiving

The data will be publicly available at: Muñoz, Lorena; Vera Helene; Runge, Claire; Brown, Greg; Daigle, Remi 2020, "Replication Data for: Using crowdsourced spatial data from Flickr vs. PPGIS for understanding nature's contribution to people in Southern Norway", https://doi.org/10.18710/VQLTM8, DataverseNO.

Conflict of interest

Nothing to declare.

Author contributions

LM and VHH conceived the ideas of the paper. All authors contributed to data gathering design of Flickr and/or through a dedicated PPGIS platform; RD, VHH and LM collected the data for Flickr using an API, and for PPGIS through a household survey and through volunteer recruitment on media and *in situ*. LM coded Flickr data and prepared environmental and infrastructure data, and LM, VHH and CR analysed the data; LM and VHH led the writing of the manuscript. All authors contributed critically to the drafts and gave final approval for publication.

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Supplementary material

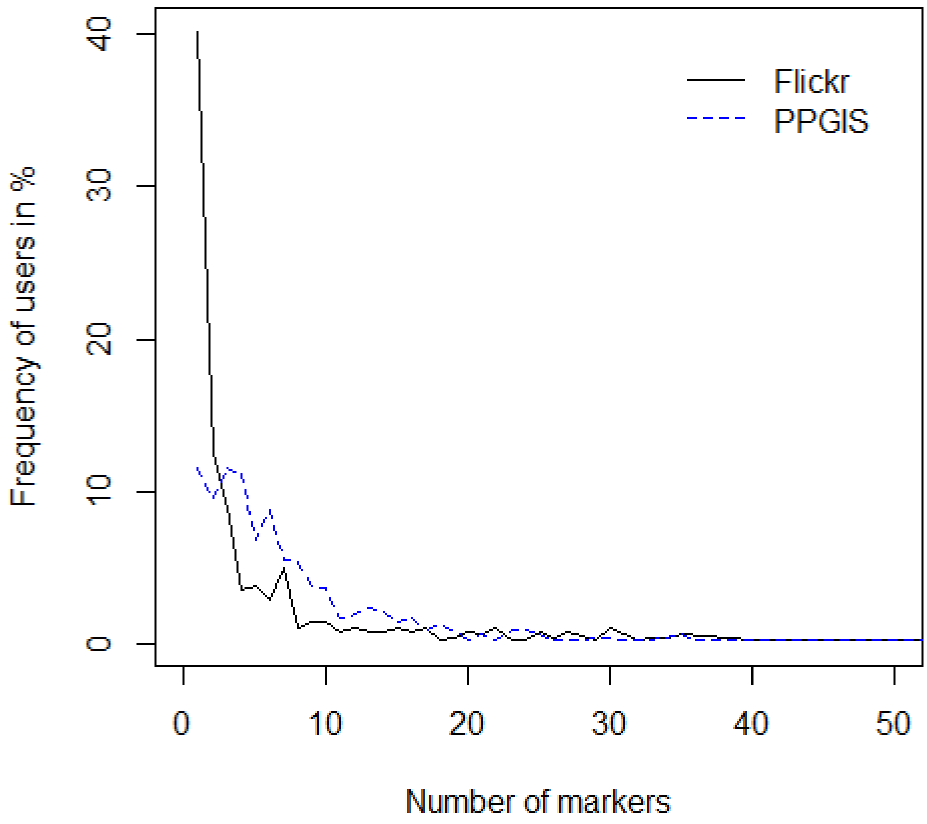
SI 1. Table with the source, scale and reference to each covariate layer used in the study.

Covariate layer	Source	Scale	Reference
Trails	N500 database	1 : 50 000	(Kartverket 2015)
Roads	N500 database	1 : 50 000	(Kartverket 2015)
Touristic cabins	N500 database	1 : 50 000	(Kartverket 2015)
Buildings	N500 database	1 : 50 000	(Kartverket 2015)
Rivers	N500 database	1 : 50 000	(Kartverket 2015)
Lakes	N500 database	1 : 50 000	(Kartverket 2015)
Mountain tops and glaciers	Manual mapping for mountain tops and N500 database for glaciers	1 : 50 000	(Kartverket 2015; The Norwegian Directorate for Nature Management 2019)
Vegetation cover	CORINE 2006	1 : 100 000	(European Environmental Agency 2015)
Elevation	N500 database	1 : 50 000	(Kartverket 2015)

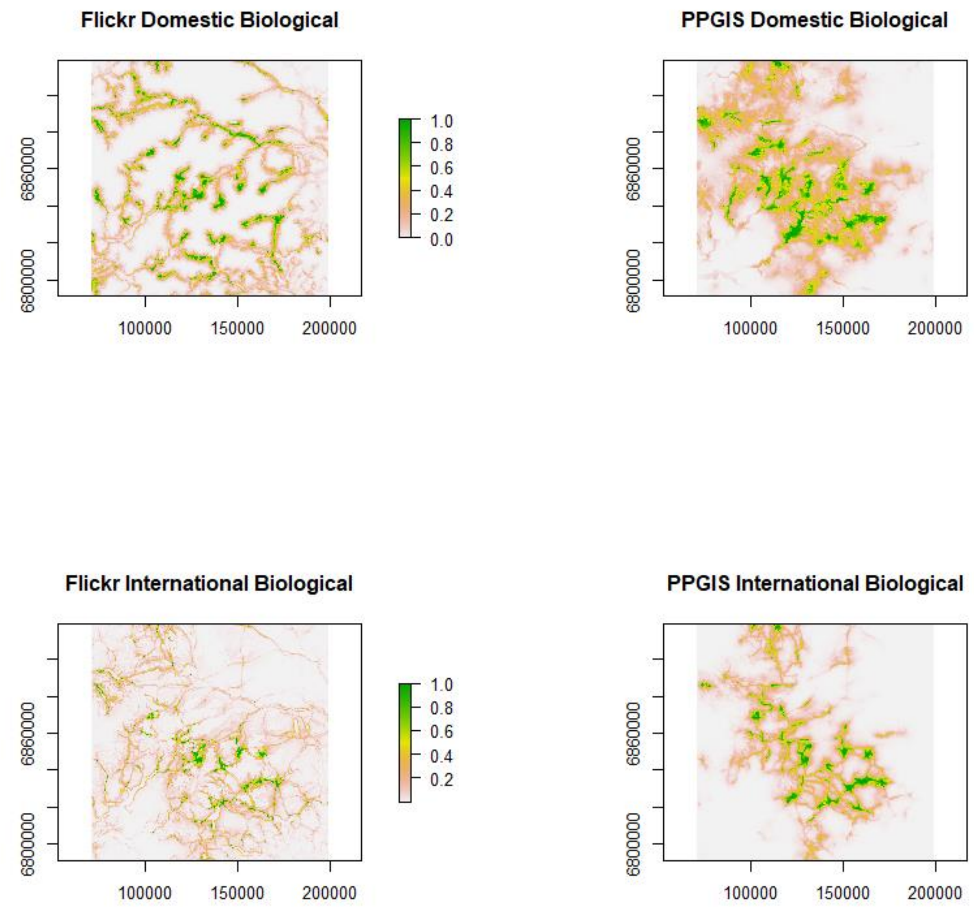
SI 2. Correlation table for the infrastructure and environmental covariates used in the MaxEnt models. "dist" refers to distance

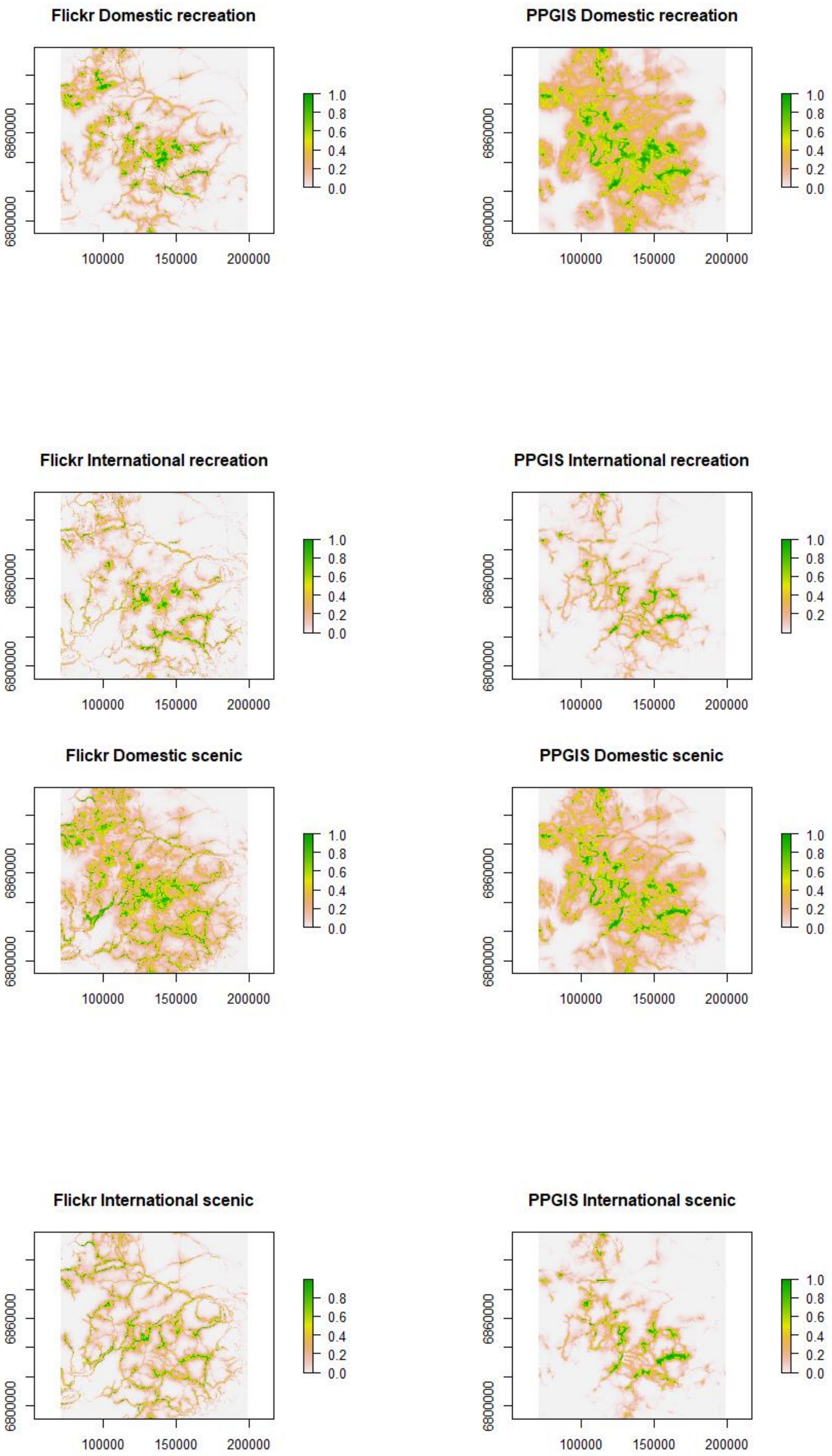
	vegetation	***topography***	***dist to lake***	***dist to river***	***dist to motorized access***	***dist to trail***	***dist to touristic cabin***	***dist to buildings***	***dist to nature mountain tops and glaciers***
vegetation	1								
topography	-0,45	1							
dist to lake	0,05	-0,05	1						
dist to river	-0,3	0,15	0,01	1					
dist to motorized access	-0,5	0,51	0,02	0,27	1				
dist to trail	0,1	-0,24	0,21	0,17	-0,11	1			
dist to cabin	0,17	-0,24	0,36	0,12	-0,17	0,47	1		
dist to buildings	-0,58	0,51	0,02	0,32	0,58	-0,09	-0,18	1	
dist to nature mountain tops and glaciers	0,41	-0,26	0,33	-0,11	-0,31	0,12	0,29	-0,37	1

SI 3. Frequency of users (in %) for each amount of values mapped for Flickr (black line) and PPGIS (blue dotted line) datasets. The x-axis was truncated at 50 due to the asymptotic nature of the data.



SI 4. Predicted distribution probability of values from 16 Maxent models for the four comparable values for each dataset divided into domestic and international visitors. The legend on the right indicates the probability of finding the value present in that location.




Flickr Domestic recreation
PPGIS Domestic recreation
Flickr International recreation
PPGIS International recreation
Flickr Domestic scenic
PPGIS Domestic scenic
Flickr International scenic
PPGIS International scenic
6800000
6860000
100000
150000
200000
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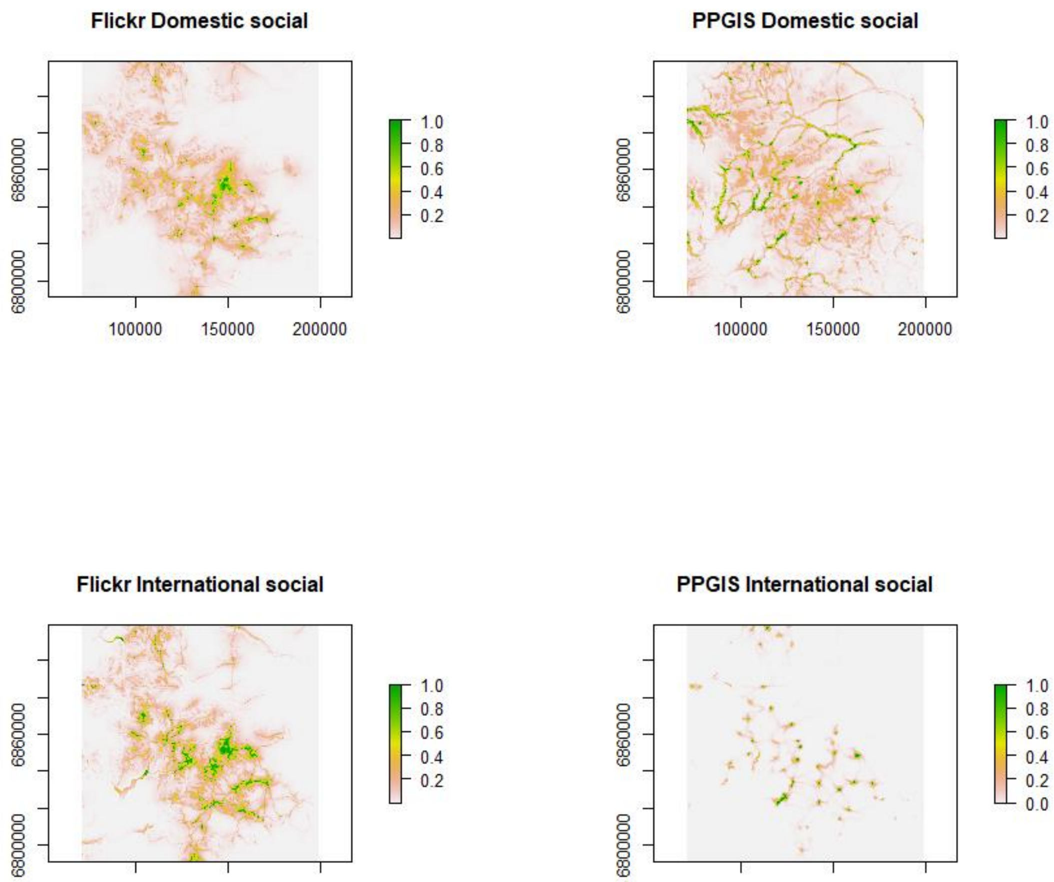
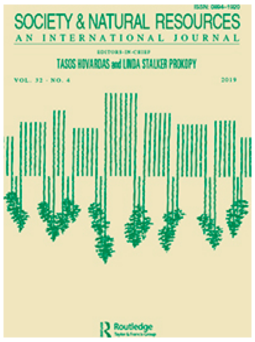
0.2
0.4
0.6
0.8
1.0


Flickr Domestic social
PPGIS Domestic social
Flickr International social
PPGIS International social
6800000
6860000
100000
150000
200000
1.0
0.8
0.6
0.4
0.2
0.0



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Advantages and Limitations of Using Mobile Apps for Protected Area Monitoring and Management

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ABSTRACT

Digital technologies, including participatory Internet mapping, social media and smartphones, provide new avenues for research in outdoor recreation and tourism. The potential to reach a greater audience and collect visitation data on a broader scale, with less costs than traditional paper surveys, are key advantages that have increased the use of these novel technologies. Using of mobile apps for data collection is still at the experimental stage. We evaluate previous attempts to use apps for monitoring recreation and tourism in protected areas, as an alternative to other in situ or online methods. We present a pilot study implemented in Jotunheimen National Park (Norway), where we developed a mobile app for visitor monitoring and real-time mapping of values and experiences. We present the lessons learned, give suggestions on how and for what apps can be used, and discuss the advantages and limitations of using smartphones for visitor monitoring in protected areas.

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Ecosystem services; geotag; mobile application; recreation; spatial; value mapping; visitors to protected area

Introduction

Protected areas (PA) are the main destination for a growing number of nature-based tourists worldwide (Balmford et al. 2009). Tourism can generate public support and provide revenues for conservation and local development, but it also requires careful planning to avoid issues of crowding and ecological impact in PAs (Manning 2011; Newsome, Moore, and Dowling 2013). Understanding the spatial and temporal distribution of visitors, their values, motivation, experience, and impacts, is therefore critical for managing PAs (Hadwen, Hill, and Pickering 2007; Beeco et al. 2013; Hammitt, Cole, and Monz 2015).

Visitors to PAs engage in a range of activities, each with associated spatial behaviors. For example, they are frequently attracted to specific locations of the park (Hallo et al. 2012), they may walk off trails (D'Antonio et al. 2010), they prefer a diverse set of activities and experiences (Ridding et al. 2018), and have different motives for selecting specific locations in the parks (Gundersen et al. 2015). With increased use and a broader range of people and associated activities in PAs, the shift in spatial distribution of use

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Supplemental data for this article can be accessed on the publisher's website at http://dx.doi.org/10.1080/08941920.2018.1544680 may challenge park resource management or increase the tensions with other park users.

Traditional methods for monitoring visitors such as self-report travel diaries, interviews and surveys, are time consuming for respondents. It could be difficult to recruit people *in situ* when they have just completed a recreational activity and prefer to have a rest, and the methods require a large number of field staff for recruiting participants and for managing and analyzing data after data collection (Wolf 2000; Shoval, Isaacson, and Chhetri 2014). The reporting of the spatial dimension of visitors' use depends on the respondents reporting their travel locations on paper maps usually upon trip completion. This increases the chance of imprecise and erroneous reporting because they are highly dependent on the respondents' memory and willingness to participate (Stopher and Greaves 2007). Moreover, paper maps would need to be digitalized, unlike other platforms which can be directly imported into spatial analysis software (Pocewicz et al. 2012).

Tracking visitors by GPS (Global Positioning System) devices, provides higher spatial quality of the data by recording the accurate time and spatial location of the visitors, departure and arrival time, attractions visited and walking speed (Orellana et al. 2012; Grinberger, Shoval, and McKercher 2014; Shoval, Isaacson, and Chhetri 2014). Visitors that enter a PA could be given a GPS device that they carry during their visit which could be followed by a survey collecting their experiences and satisfaction (Birenboim et al. 2015). Data obtained from the GPS devices are accurate and in real time and provide data on the spatial and temporal behavior of visitors (Shoval, Isaacson, and Chhetri 2014). This method also allows identifying off-trail use and important visitation hotspots (D'Antonio et al. 2010). Although the accuracy of GPS devices has been shown to be better than other methods (Raun, Ahas, and Tiru 2016), studies carried out using GPS devices have usually been applied in confined and limited areas, as it requires specific devices to be carried by participants and returned so data can be retrieved (Shoval and Ahas 2016).

While using GPS devices for visitor tracking offers accurate and precise mapping of visitor use patterns with high-resolution, crowdsourced data could be used to assess a large number of users at a broader scale (Shoval and Ahas 2016; van Zanten et al. 2016). Crowdsourcing involves a large number of people collaborating to solve a problem (Doan, Ramakrishnan, and Halevy 2011), or contributing with ideas or content, particularly by use of Internet, social media or smartphone apps (Levin, Lechner, and Brown 2017). According to Doan, Ramakrishnan, and Halevy (2011), crowdsourced data systems can be developed by explicit or implicit participation of users. For example, crowdsourced data can provide the locations visited in PAs on online platforms (explicit participation) where visitors would manually enter their location. This is defined as Volunteer Geographic Information (VGI), which is based on volunteers registering geospatial information of a certain issue, as for example Wikimapia, which is a platform where users can geolocate places and add descriptions of the place (Goodchild 2007). Crowdsourced data can also be obtained through passive positioning of mobile phones, such as data collected from phone companies which store the location of mobile phones (implicit participation (Birenboim and Shoval 2016; Brown and Weber 2013)). Crowdsourced data from georeferenced social media, such as Flickr, Twitter, Panoramio and Instagram, has been used to estimate the number of visitors in PAs (Wood et al. 2013) and to evaluate what attracts tourists to a site by content analysis of the pictures (Gliozzo, Pettorelli, and Haklay 2016; Martínez-Pastur et al. 2016; Walden-Schreiner, Leung, and Tateosian 2018). In addition, passive positioning of mobile phones has been used to study the geographical distribution of international visitors (Ahas et al. 2008).

Disadvantages of using secondary crowdsourced data such as social media and call activity include the lack of other variables that are not recorded by the platform, such as demographics, satisfaction and travel motives (van Zanten et al. 2016). Moreover, manual geotagging can be imprecise (Walden-Schreiner, Leung, and Tateosian 2018) due to unfamiliarity with the area, or lack of memory due to *a posteriori* tagging. Social media and call activity could also be biased toward certain user groups of the PAs. People cannot be recruited by face-to-face contact or mail to participate, and it is therefore challenging to evaluate which of the user groups are over- or underrepresented in the resulting maps.

Public Participation Geographic Information System (PPGIS) collects primary crowdsourced data on an online participatory platform where visitors can drag and drop markers on a map. Web-PPGIS has been used to map values, management preferences, visitor experience and satisfaction, and can be combined with online surveys to collect data on demographics, travel motives, value-orientations and environmental attitudes (van Riper et al. 2012; Brown and Weber 2013). The web-PPGIS can ease the recruitment of respondents in areas with low density of visitors and increases the time people can devote to answering the survey, by participating *a posteriori* at home. An additional advantage is that the recruitment is not affected by meteorological conditions, as is the case of *in situ* questionnaires and GPS tracking. However, web-PPGIS carries some of the challenges of completing a survey after the event/activity is over, which include imprecision and memory dependency, as in the case of locating the markers on the exact location or remembering past feelings and values. Online mapping may also capture only those respondents that are drawn toward using such technologies, such as those with higher education (Pocewicz et al. 2012; Brown et al. 2015). Until recently web-PPGIS required computational skills which acted as barriers for using online mapping, but recently commercial software have eased the process of setting up such platforms (see International Society for Participatory Mapping (2018) for an overview of software and tools).

Smartphones have been proposed to overcome some of the challenges held by the methodologies listed above (Birenboim and Shoval 2016; Shoval and Ahas 2016). Modern smartphones include a set of sensors and features that allow collecting spatial data in real time, are often carried by visitors during their trips and do not depend on face-to-face recruitment. There are many mobile apps dedicated to tourism, mainly providing information for tourists, giving personalized feedback and allowing tourists to give their feedback so other tourists can receive updated information (Dickinson et al. 2014). These mobile apps are assumed to influence travel decisions (Wang, Park, and Fesenmaier 2011) and may contribute to tourism research by solving many of the shortcomings faced by other tracking methodologies (Shoval and Ahas 2016).

The use of dedicated mobile apps for tourism tracking and monitoring is an emerging field (Pickering et al. 2018), and most pioneer studies have made use of already existing platforms to collect spatial data on visitors. Norman and Pickering (2017) compared three tracking apps to collect data on visitors' spatial distribution and to assess the usefulness of such tools for three areas of varying degree of remoteness. They found these apps to be useful for visitor distribution monitoring and off-trail use, but number of visitors on formal trails was more accurately measured by automated counters. Montini et al. (2015) developed the PEACOX journey travel mobile app as an alternative to traditional paper-based travel diaries. They concluded that data collected by dedicated GPS devices have a higher accuracy and gather a greater amount of trips than smartphones, but both tools could replace traditional paper diaries in terms of mapping travel behavior. Kangas et al. (2015) developed a mobile app called Tienoo as a tool for participatory forest planning. The app has three functions, which are (i) practical information for visitors (e.g. trails, ecology, history), (ii) georeferenced opinions of visitors at any time and place, and (iii) a geocaching game that directs visitors to certain locations in the forest and asks them about those particular areas. They argued that mobile apps can increase the accuracy of georeferenced feedback and provide real-time data. The main advantage of using mobile apps compared to other methods, is that a set of different data collection methods can be combined in a single interface, both spatial and nonspatial, thanks to built-in smartphone functionalities. Also, participants can be asked to consent to using their data for a research study or monitoring program unlike, for example, passive data gathering methods. There are, however, several challenges to solve before smartphone-based visitor monitoring becomes a standard method for protected area management.

The purpose of this paper is to explore the potential of using a dedicated smartphone application to combine GPS tracking (real-time data on travel routes and time spent on location in the park), participatory mapping of visitor experiences and values (real-time mapping of what visitor like and dislike, a.k.a. real-time PPGIS) and short surveys (including sociodemographic data, travel motives and satisfaction). We first present the lessons learned from our pilot study in Jotunheimen National Park and Utladalen Protected Landscape and thereafter we discuss how mobile apps can be implemented for visitor monitoring and research in PAs.

Jotunheimen Tracking mobile app: a pilot study

We developed a dedicated mobile app (called *Jotunheimen Tracking*) for visitor monitoring as a proof of concept to show the utility of using such a technology for visitor monitoring in protected areas and social spatial data gathering in an integrated interface. While mobile apps have been developed previously for location-specific preferences in forest management (Kangas et al. 2015), we are not aware of any mobile apps monitoring visitors to PAs using questionnaires and real-time PPGIS mapping of landscape values in a single interface. The goal of the app was to identify the spatial distribution of visitors, locate value hotspots and the type of activity conducted during the trip to a PA. In addition to questionnaires, the app included a functionality to tag places of interest *in situ* while visitors were on tour. This functionality resembles real-time PPGIS and can emulate trail use.

Table 1. Demographic variables included in the first questionnaire of the mobile app Jotunheimen Tracking.

Q1. What is your country of residence?	Norway (postal code)	Other (country)
Q2. What is your gender?	Male	Female
Q3. What is your age?		
Q4. What it the highest education level you have completed?		
Primary school	Secondary school	High education
Q5. What was the approximate total after-tax income of your household for year 2016? (optional question)		
Q6. How many times in the past have you visited this areas?		

Study area

We tested the app in two PAs in southern Norway: Jotunheimen National Park and Utladalen Protected Landscape. They were designated in 1980 for the purpose of protecting wilderness and cultural landscapes in alpine environments. These are among the most visited PAs in Norway as Jotunheimen National Park contains the highest peaks in Scandinavia, several lakes and glaciers that attract many visitors. There is about 300 km of trails offering cabin-to-cabin hikes that run across the national park. In Scandinavia, PA management is challenging as visitors do not necessarily enter through major gateways in the parks. The Right of Open Access ("allemannsretten") allows visitors access to nonintrusive outdoor recreation, including hiking and camping almost anywhere in PAs, unless special restrictions have been set (Tolvanen et al. 2005; Kaltenborn et al. 2001). The reason behind using a mobile app instead of other methods for visitor monitoring, is the challenges of recruiting participants due to low density of visitors, dispersed hiking off trails, and undefined entrances to protected areas (Kuba et al. 2018). We reasoned that a mobile app would be appropriate for our study because it requires the least face-to-face contact, whilst actively involving visitors to provide data on spatial information on values and experiences from the locations they visited in the park.

App description

The mobile app can be downloaded at jotunheimen-tracking.no, where we also include instructions for its use. The app was designed in collaboration with users to enhance usability and clarity for the users. The interface was divided into four individual screens (screen 2, 3 and 4 were developed with input from park managers and accommodation venues). First, the study aim and the instructions were presented to the participants. Informing the participant about the study is crucial for motivating visitors to participate, to provide clear instructions for how to use the app, and to inform about confidentiality, free consent and their rights to withdraw from the study. At this stage, a confidentiality consent was signed by the participant following the Norwegian Personal Data Act 2000. In the second stage, participants were asked to provide demographic variables (Table 1), which were answered only once, independently of the amount of times the mobile app was used for tracking activities. Demographic variables have been shown to influence travel behavior, and they are therefore important to include in the app (Gundersen et al. 2015; Korpilo et al. 2018).

Third, visitors were encouraged to map their values in real-time inside the study area (also referred to as real-time PPGIS). The GPS functionality was activated by clicking

Figure 1. Buttons displaying reasons for liking/disliking a location (Values). The list on the left corresponds to the buttons that appear when "I like this area" is pressed. The list on the right corresponds to the buttons that appear when "I dislike this area" is pressed.

on "Start" to activate the tracking. During the trip, visitors could push the buttons "I like this area" or "I dislike this area", each of which opened a list of reasons for why they liked/disliked the area (Figure 1). The list aimed at capturing the values that people ascribe to nature and was inspired by The Common International Classification of Ecosystem Services (European Environmental Agency 2018) and studies on disservices emphasizing negative values that people may assign to nature and impacts caused by other humans (hereafter refer to as disservices) (Mackay and Campbell 2004; Plieninger et al. 2013; Hammitt et al. 2015). The time, day and location was recorded for these values at the moment the like/dislike button was pressed. When the activity was finalized, the visitor pushed the finish button which directed respondents to the next survey. Thus, the variables registered were: start and end locations of the trip, and the location of landscape values and disservices. We assessed the possibility of including a tracking functionality to the mobile application in order to track the route of participants, but this was eliminated to avoid battery drainage.

Fourth, once the activity was finished, the respondents were directed to a final questionnaire about the trip just tracked. Respondents could select all the activities conducted during their last trip from a list. We allowed respondents to select multiple activities since one trip in nature often combines activities (Manning 2011), such as hiking, photography and camping. In order to classify how visitors travel, we asked whether the respondents were accompanied by others during the trip, such as family, friends, partners, were participating on an organized trip, or whether the respondents were traveling alone. We asked three questions regarding the recreational experience of the trip which included values that were difficult to assign to a particular location but that could influence the experience of the trip (rated on a Likert scale from 1 to 5),

Table 2. Final questions relating to the recreational experience for the whole trip inside the protected area.

Q9. The visit today has been important for … (from 1 strongly disagree to 5 strongly agree)
1. Learning about the nature
2. Being together with my family/friends
3. My physical/mental health
4. Inspiring me to create crafts, stories or other artistic work
5. Nurturing a deeper meaning of nature; emotionally or spiritually
Q10. My experience today was negatively impacted by … (choose)
1. Crowdedness
2. Lack of facilities
3. Motorized vehicles
4. Vehicle roads/tracks
5. Trail condition
6. Other:
Q11. How would you rate your overall experience today? (from 1 disappointing to 5 very good)

impacts encountered during the trip which could affect visitors' experiences, and the overall experience (Table 2). A description of the recruitment campaign and the results from our pilot study can be found in the Supplementary material.

Results

Here, we summarize some of the results obtained from our pilot study (see also supplementary material). While 123 visitors completed the first survey, only 25 completed the last step. This could be due to a variety of reasons, including past visitors answering the first survey, difficulties to understand the mapping exercise, or lack of time or interest to complete all the steps. The average age of respondents was 41.7 years, the majority were males and had colleague or university education. Almost half of the participants were Norwegians, and the same proportion was first time visitors. Most frequently conducted activities were hiking and photography, most commonly together with their partners or family members. "Undisturbed nature" and "aesthetic/scenic" were the most frequently mapped values. Spending time with family and/or friends and contributing to physical and/or mental health were valued highest in the questionnaire addressing nonspatial values. The overall experience was rated as good by the respondents.

The spatial analyses of place values demonstrated that the mapping functionality was not properly understood, nor used for long trips, as 90% of the values were placed within 1 km from roads and the median distance between start/end locations and values was 13.8 m. Most of the participants only used less than 15 minutes for a tracked trip, which could be explained by the functionality, battery capacity or a lack of motivation for the mapping exercise. Few left their email address for further evaluation of the app, so we were not able to get feedback directly from the users.

Lessons learned from using mobile apps for visitor monitoring in protected areas

A primary goal of this pilot study was to understand the challenges and opportunities of using a mobile app-based approach for visitor monitoring. The principal question researchers (and practitioners) need to ask before embarking on a monitoring program using crowdsourced data is whether it is the right tool to undertake a mobile app study for visitor monitoring (Why use mobile apps for visitor monitoring?). It is also important to consider the feasibility_ of visitor monitoring using mobile apps by asking: what population of visitors are we targeting? How, when and where do we recruit people? What kind of data can be collected? What kind of technical support is needed? We also discuss some of the challenges of implementing the mobile app.

Why monitor visitors using mobile apps

Most protected areas lack the spatial and temporal data of visitor use necessary for managing the increasing number and diversity of nature-based tourists (Newsome, Moore, and Dowling 2013; Hammitt et al. 2015; Schägner et al. 2017). Visitor monitoring is limited by the costs and logistical constraints for collecting data on the park level, and lack of data with sufficient accuracy for site-specific management within park boundaries. Previous studies have shown that crowdsourced data could provide the "volume, velocity and variety" for monitoring visitor numbers on park level (Wood et al. 2013; Levin, Lechner, and Brown 2017), and for early detection of new activities and trends in visitors' uses of the parks (Heikinheimo et al. 2017). PPGIS has the potential to account for the wider spectrum of values appreciated by visitors to PAs which can be defined by the researcher, whereas other VGI methods are limited with regard to mapping indirect-use and nonuse values (Levin, Lechner, and Brown 2017). The mobile app approach could therefore be used when there is a need for site-specific information about values, preferences or experiences associated with different user groups. The "Jotunheimen Tracking" app was specifically designed for capturing spatial explicit information about visitors' values and experiences in PAs for evaluating spatial behavior, crowding and ecological impact on PAs. Mobile apps are unique compared to other methods in terms of its ability to couple broad scale data on sociodemographic profiles, with the spatial and temporal pattern of visitor use to site-specific preferences, values, and experiences mapped in real-time.

Who is the mobile app targeting

Protected areas are often large with a low number of staff which makes recruitment by face-to-face contact at park gateways time-consuming. In our pilot, and in many remote PAs, visitors could enter PAs from different trailheads, walk off trail and disperse over large areas, which makes indirect recruitment necessary. Traditional media (such as TV, newspapers, radio, posters), social media (blogs, webpages, Facebook, Twitter and Instagram among others), and tourism information and accommodation venues close to PAs are more appropriate means for collecting data from a large number of visitors reducing the need for field assistance during the sampling campaign. Venturelli, Kieran, and Christian (2016) found recruitment (and retention) to be among the main barriers for using apps to monitoring recreational fishing. According to them, apps need to be easy-to-use, have appealing interfaces, be fun to use, and/or provide some incentives to increase participation. Logging your trips, sharing information with other users and location-specific information about destinations in the app are functionalities that can increase the use of mobile apps. Collaboration with the tourist offices, restaurants and accommodation venues surrounding the PAs tourist could provide small rewards (e.g. beverages), and the use of gaming or geocaching functions as in the Tienoo mobile app are more advanced functions which could increase the motivation to participate (Kangas et al. 2015). Finally, informing about how data will be used and reporting of end-results for those who are interested are also considered best practices in research. Brovelli, Minghini, and Zamboni (2016) also concluded from three mobile app studies that the users' awareness of their contribution, the use of the data by decision makers, and monetary or nonmonetary incentives are key factors for increasing response rates.

In our pilot study, we used direct and indirect contact through traditional media, social media, posters and leaflets at accommodation venues and tourism offices (for details see Supplementary material). An article published in the local newspaper and direct contact through social media increased downloads of the mobile application and visits to our website. However, the lack of collaboration from the main tourist cabin network limited the spread of the application. The use of other methods than face-to-face contact require a prior-to-study campaign where social media content is created and bonds with local media and accommodation venues are established. We adopted the recommendations by Brovelli, Minghini, and Zamboni (2016) to make our mobile application code publicly available in order to ease future studies, and to conduct a short recruitment campaign focusing on groups of interest (see supplementary material for more details on the recruitment strategy), but our pilot study did not include incentives, which could potentially have increased participation.

What type of data could be collected from mobile apps

Managers often lack spatial data for effective planning of tourism in protected areas. The potential of Web-PPGIS to provide spatial explicit data on visitor values, experiences and preferences for different user groups has previously been demonstrated (Brown and Weber 2013; Wolf et al. 2015; Levin, Lechner, and Brown 2017; Muñoz et al. 2019). The "Jotunheimen Tracking" app was designed to provide the same kind of data, but with higher spatial accuracy compared with *a posteriori* mapping. However, some visitors might be reluctant to use mobiles for real-time PPGIS mapping as it would impact their enjoyment of the recreation activity. Some authors have raised questions regarding the battery capacity when implementing such a mobile application (Shoval, Isaacson, and Chhetri 2014; Montini et al. 2015). For studies that only require tracking a route, smartwatches with built-in-GPS functionality can overcome this limitation. Also, in our pilot people mapped values and experiences close to cabins and roads, which may indicate a biased mapping. Further improvements of our mobile app should include a clear instruction on how to use the app and provide participants with a summary of the maps they create to increase their motivation to participate.

An additional potential of mobile apps is to collect data on spatial behavior by use of GPS tracking such as time spent in different locations, travel speed, tracks and destination chosen, and off-trail hiking (Viswanath, Yuen, Ku, and Liu 2015), data commonly gathered in studies using dedicated GPS devices (D'Antonio et al. 2010). Several mobility studies have shown the applicability of mobile apps for transport mode and travel behavior analyses based on travel distance and speed (Jariyasunant et al. 2011; Nitsche et al. 2014). The advantage of using smartphone built-in GPS functionalities over passive positioning is that it allows continuous tracking, also in remote areas where phone coverage is poor or nonexistent. Built-in GPS functionality can be combined with other smartphone features so mobile apps could be used to record unique data that could explain spatial visitor use. Thus, behavioral data could be directly combined with how visitors perceive the quality of their destination (i.e. real-time mapping of values, experiences and satisfaction), and the motivation of different user groups to select the different destinations (i.e. brief survey recording motivation and sociodemographic data).

Another functionality which could be incorporated includes geotagged photos or voice recordings. These can illustrate the real-time experience the visitor has during the trip. For example, Birenboim et al. (2015) used a GPS device to track visitors in a zoo and phone messages to report real-time experiences, which could be integrated in a mobile app for visitor monitoring. Regarding the use of geotagged photographs, the advantage of mobile apps over other crowdsourcing methods (such as social media) is the possibility to sign a consent for data usage and collect other data than the picture or its metadata. Also, participatory mapping could capture visitor impacts or disservices to a larger extent than geotagged photographs in social media would do, as social media posts are generally more positive although negative posts show a higher impact (Stieglitz and Dang-Xuan 2013).

Challenges

There are several limitations of using mobile applications for visitor monitoring in protected areas. The use of novel technologies for participatory mapping may be limited to certain groups of respondents which are more familiar with the technologies used. Using digital technologies for collecting data on values, preferences and experiences are likely to be biased toward specific user groups. Brovelli, Minghini, and Zamboni (2016) found that the majority of the participants in a mobile app mapping studies were under 30 years old. Web-PPGIS studies with random household sampling have shown a tendency for overrepresenting mid-aged men with higher education (Brown and Kyttä 2014). Due to lack of knowledge on actual visitor statistics in our study area, we are unable to assess the representativeness of the sample. In general, our pilot corresponded to previous visitor surveys showing that the majority visiting Jotunheimen are Norwegians, first time visitors, and people in their mid-ages, but there was most likely a large overrepresentation of males (2/3) and highly educated respondents (70.3%). Shoval, Isaacson, and Chhetri (2014) found that tourists are more willing to participate in GPS tracking than other groups, but we had no possibilities to evaluate whether international or domestic visitors were more willing to participate than others.

Unlike a GPS device, people are generally used to carrying their smartphones (Birenboim and Shoval 2016), but activating and using the mobile app during a trip is easy to forget (Montini et al. 2015). This poses a challenge in real-time PPGIS, which required active mapping during the whole trip. *A posteriori* mapping could overcome this limitation; however, the precision of mapped values would be dependent on the respondent's memory, which is the main reason to implement a real-time PPGIS rather than *a posteriori* PPGIS.

The accuracy of smartphone built-in GPS varies from device to device which can be corrected and averaged depending on the question at hand (Korpilo, Virtanen, and Lehvävirta 2017). This can be challenging for studies that require a given accuracy of coordinates, which may favor the use of dedicated GPS devices.

Developing and implementing mobile apps for visitor monitoring carry a set of technical challenges similar to those often encountered in other mobile apps. Mobile applications designed with relevance and needs of the end user in mind, with clear and easy navigation are more successful and are able to recruit more users (Luna et al. 2018; Sturm et al. 2018). Furthermore, allowing direct feedback and making data publicly available are important principles when involving citizens in data collection (European Citizen Science Association 2015; Ahmad, Rextin, and Kulsoom 2018). Open source, code increases the usability and reuse of such a technology thereby reducing the costs of designing and developing a new app (Luna et al. 2018; Sturm et al. 2018). This allows more investment in time and resources for improving the design and functionality of the new mobile app.

Conclusion: advantages and limitation of using mobile apps for visitor monitoring

The advantage of using mobile apps for PA monitoring is the potential of simultaneously collecting different types of data: visitor behavior through GPS tracking, spatial information of values and experiences mapped by visitors themselves, and questionnaire responses. Similar to other crowdsourced data (VGI and PPGIS) a large number of visitors can be recruited using indirect contact methods, which increases the chance to capture those visitors that enter PAs from other entrances than major gateways. However, contrary to *a posteriori* mapping by web-PPGIS, real-time mapping of values and experiences reduces accuracy problems and dependency of memory and knowledge about the location visited. In addition, the use of smartphones with built-in GPS functionality reduces logistic challenges of delivering and collecting GPS devices in visitor tracking studies. Compared to passive positioning methods in PAs, which depend on phone coverage, GPS tracking through smartphones could also provide data on spatial behavior in remote areas (although depending on battery capacity for long-distance trips). Unlike passive positioning and social media, real-time PPGIS can better capture negative experiences. Also, the mobile app allows implementing an adaptive monitoring strategy by adapting the app to collect new information as needed in the monitoring program. This could be done by either adjusting survey questions or using other built-in functionalities.

Despite the advantages, mobile apps also carry some shortcomings. First, the use of novel technologies, such as mobile apps, can bias the data to visitors that are more accustomed to digital tools. Shoval, Isaacson, and Chhetri (2014) found that tourists are more willing to participate in GPS tracking studies, and mobile apps are perhaps most appropriate for monitoring the emerging trends in tourism and new user groups in the PAs. However, it is not necessarily the right tool for capturing the use of visitors living in the vicinity of the parks. Second, visitors' behavior could change when they know that they are tracked. There are no published studies that evaluate behavioral change as a result of tracking (Shoval and Ahas 2016), which is a limitation for understanding the efficiency of mobile apps for monitoring. Third, the high battery capacity needed to track an activity for several hours or days on the smartphone is a limitation for collecting visitor use patterns and time spent at different sites. It is possible to use an external power bank, or as we did, limiting the functionalities of the app by prioritizing real-time PPGIS instead of continuous GPS tracking. Finally, collecting data about users through mobile apps involves privacy concerns, albeit mobile applications allow to ask for consent to use data in research, unlike passive tracking technologies. As for all online surveys, and particularly for those including the location of individuals, tracking visitors' behavior through mobile apps carries the responsibility of a careful data treatment and a comprehensive ethical review before implementation (Fisher and Dobson 2003; Shoval and Ahas 2016),

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