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# Effects of land tenure and protected areas on ecosystem services and land use preferences in Norway

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ABSTRACT

Prior research has examined the relationship between physical landscapes and ecosystem services, but the distribution of ecosystem services by land tenure and protected areas is less developed. We analyze the spatial distribution of participatory mapped ecosystem values, as indicators of ecosystem services, to determine their relationship with land tenure in southern Norway, a region characterized by private, village, and state commons lands overlaid with designated protected areas managed by local governments. We found land tenure to be a significantly stronger predictor of the distribution of ecosystem values and land use preferences than protected area status. Protected area designations layered on older land tenures exert relatively little influence on how Norwegians perceive ecosystem values and land use preferences. The exception is a few iconic parks located on state commons where participants mapped a higher proportion of biological diversity and undisturbed, natural qualities. Hunting and fishing opportunities were especially important in village commons, whereas social interactions, gathering, and cultural identity clustered near settlements on private lands. The cultural ecosystem values of recreation and scenery were most frequently identified, but were unrelated to both land tenure and protected areas. Cabins, tourism development, and snowmobile use were important land uses to regional residents and most controversial in the commons and protected areas, but the overall potential for land use conflict appears highest on private land. Participants mapped preferences to increase predator control across all tenures reflecting the strong interest in large game hunting and livestock grazing in the region. Overlapping tenures that were in place before the designation of protected areas are important for understanding conservation effectiveness and the potential for land use conflict.

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## 1. Introduction

Ecosystem services describe the contribution and capacity of ecosystems to provide goods and services to satisfy human needs and promote human well-being (De Groot et al., 2010; Burkhard et al., 2012). To date, much research effort has focused on identifying the value of ecosystem functions, goods, and services (De Groot et al., 2002) provided by natural or semi-natural systems (Costanza et al., 2006) for the purpose of integration with landscape planning, management and decision making (De Groot et al., 2010). The spatially explicit mapping or assessment of ecosystem services appears essential for the development of strategies that will ensure their future supply (Martínez-Harms and Balvanera, 2012). But the scientific underpinning to assess and manage ecosystem services has been limited by a focus on discipline-bound sectors of the full social–ecological system (Carpenter et al., 2009) with greater research emphasis on the ecological and economic components of ecosystem services over the social systems that may enhance or constrain the provision of services.

There is a growing awareness of the importance of institutions for understanding the spatial distribution of ecosystem services. In the recently published conceptual framework of the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES), institutions take a central role in explaining all aspects of how people and society organize and interact with nature (Díaz et al., 2015). Institutions are defined by IPBES as “all formal and informal interactions among stakeholders and social structures that determine how decisions are taken and implemented, how power is exercised and how responsibilities are distributed” (p. 13). They are perceived as the underlying causes explaining land use and land

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degradation. Protected areas are an example of institutions that aim to protect the supply of global benefits such as biodiversity, but the evidence for the effectiveness of protected areas to supply some ecosystem services is equivocal. For example, sustainable use areas and community-based conservation are, in some cases, more effective in halting deforestation than strict protection (Nelson and Chomitz, 2011; Nolte et al., 2013; Lambin et al., 2014). These results echo decades of research on institutions suggesting that private, public, or common lands alone cannot ensure sustainability over time (Ostrom et al., 2007).

More empirical research on land tenure, defined as the "set of institutions and policies that determine how land and its resulting resources are accessed, who can benefit from these resources, for how long and under what conditions" (Robinson et al., 2014, p. 282), is needed to increase our understanding of how the spatial distribution of ecosystem services may be influenced by land tenure. Institutions influence the supply and distribution of ecosystem services, but they also reflect historical demand for resources. Comparing private, communal, and state land may underestimate the importance of complex land tenure systems with overlapping bundles of historically derived property rights (Holland et al., 2014). Many of these studies try to explain deforestation by land tenure and protected areas, but lack the empirical data to investigate or control for local values and preferences that have evolved in these socio-ecological systems over time. Landscapes shaped by humans over long time periods appear particularly important in the evolution of landscapes in Europe (Netting, 1981; Antrop, 2005; van Gils et al., 2014). Institutions built around shared rights to pastures and other resources traditionally used for subsistence are highly valued today as cultural landscapes (Daugstad et al., 2006a; Soliva and Hunziker, 2009; Rodríguez-Ortega et al., 2014; Plieninger et al., 2015). While pastoral commons in the European lowland was dissolved in the 18th and 19th century, there are still upland agro-pastoral commons in which owners of ancestral farms have a use-share in collectively held land (van Gils et al., 2014). Transhumance is still practiced in some of these agro-pastoral commons, where livestock is moved between the permanent farms and up along altitudinal gradients to summer farms (Daugstad et al., 2014).

In the mountainous region in Norway, land tenure deriving from shared subsistence uses such as grazing, hunting, fishing and gathering has survived since the pre-medieval times. In the last half century, protected areas have been designated that promote different values compared to historical use. In this paper we seek to understand how these land tenure regimes overlaid by protected areas influence the ecosystem values held by local people and the preferences for land uses. Protected areas emphasizing public goods and non-consumptive values could be in conflict with the traditional land tenure systems that have evolved primarily to regulate consumptive uses (Berge, 2006; Kitamura and Clapp, 2013). There has been limited research on the interplay between land tenure and protected areas and their effects on ecosystem values and land use preferences. The context for this investigation is the country of Norway with a historic system of both village and state commons based on use rights that have been overlaid with contemporary protected area designations managed by a local board following governmental reform in 2009 (Fauchald and Gulbrandsen, 2012). We posit that different ecosystem values and land use preferences may be associated with agro-pastoral systems in Norway that have been managed as commons since pre-mediaeval times compared to landscapes that are dominated by smaller, private properties.

### *1.1. Using PPGIS to identify spatially explicit ecosystem services*

Public participation GIS (PPGIS) is a term that describes a range of participatory methods and processes that generate spatial information for urban, regional, and environmental planning applications (see Brown and Kyttä, 2014; Brown, 2005) with increasing use to spatially identify ecosystem values. In their review of PPGIS to identify ecosystem services, Brown and Fagerholm (2015) identified more than 30 empirical studies characterized by case study approaches and methodological pluralism. The mapping of ecosystem services has been operationalized using three typologies—the millennium ecosystem assessment typology (MEA, 2005), a *landscape values* typology (Brown and Reed, 2000), and a *landscape services* typology (Fagerholm et al., 2012). The most frequently used typology in PPGIS to identify ecosystem services has been the landscape values typology consisting of 10–13 common values that are adapted to fit the local, regional, or national context of a particular PPGIS study. The landscape values typology is also called the "social values for ecosystem services" typology (Sherrouse et al., 2011) and has been used in more than 15 published PPGIS studies (Brown and Kyttä, 2014). The topology contains cultural ecosystem values such as recreation, aesthetics, history/culture, and spiritual values, but also includes perceived values for provisioning ecosystem services (economic/subsistence value), and supporting/regulating ecosystem services (biological and life sustaining values). For purposes of consistency, we use the term *ecosystem value*s to refer to participatory mapped attributes in this study. These ecosystem value locations are indicators of the ecosystem services ("benefits") received by study participants.

Of particular relevance to this research are PPGIS studies that have examined the spatial distribution of ecosystem values by land use and protected area designation. For example, Brown and Alessa (2005) found that legal "wilderness" areas in Alaska contained disproportionately more ecosystem values associated with indirect and intangible uses such as life-sustaining, spiritual, and intrinsic values while on multiple-use, national forest lands, recreation and aesthetic values were consistently the most frequently mapped values (Brown and Reed, 2009; Beverly et al., 2008; Clement-Potter, 2006). A recent PPGIS study by Brown et al. (2014) examined the spatial distribution of ecosystem values on public lands in Victoria, Australia. The study determined that the general public associated certain classes of public lands with specific types of ecosystem values, e.g., the public disproportionately associated biological values with strict nature preserves, recreation values with community and regional parks, and wilderness values with national parks.

These previous studies, however, were situated in Western countries such as the U.S., Canada, and Australia with reasonably well-defined property rights and governance structure for public lands. This situation is not the case for Norway which has an older land tenure system and decentralized management of protected areas to a local level of governance.

### *1.2. Overview of land tenure system in Norway*

The uplands in Norway have functioned as subsistence agroecosystems since 4000–3.500 BP (Olsson et al., 2000) and have been perceived as shared pastures since pre-medieval times (Berge, 2006). The village commons that were first described in the old landscape laws from the 9th and 10th century, the *Gulating* and *Frostating*, were formally codified in the "law of the realm" from 1274 (Falkanger, 2009). The usufruct rights allowed farmers shared access to subsistence uses on common land owned by the Crown. The law also allowed farmers to build summer farms and stay there with their livestock throughout the summer. In the 17th century, the King started to sell the land which was bought by private interests or the farms sharing the grazing lands. The remaining land was later designated as state commons in the forestry legislation from 1857 and was distinguished from the village commons (*Bygdeallmenning*; Crown land bought by the village) and village commons (Crown land bought by private owner, but included usufruct rights to common lands) (Falkanger, 2009). In all the commons, the usufruct rights remained roughly the same and encompassed collective rights to subsistence use of wood, mosses, peat, grazing areas, haymaking, and building summer farms, and personal rights to fish, trap, and hunt. The regulations established local boards responsible for the management of forests (*Allmenningsstyre*). In 1920, upland boards were established in the state commons in southern Norway to manage and regulate summer farms, grazing, fishing and hunting rights in the common lands (*Fjellstyre*).

The village commons are owned by at least half of the farmers that once had usufruct rights in the villages and are governed by The Act relating to rural common lands (LOV 1992-06-19 No 59). A village board manages the usufruct rights to forestry, grazing, summer farms, hunting, and fishing. A village commons, through the board, can lease property for tourism enterprises or cabins, and collect fees for hunting and fishing. Revenues can be invested in village projects, recreational facilities, savings, or the village board can distribute the funds as revenues to the right holders. The management of the state commons is more complex and rights and duties are governed by two different Acts: the 1975 Mountain Act (LOV-1975-06-06 No 31) and the Act on Forestry in the State Commons (LOV 1992-06-19 No 60). The land is owned by the State and administered by the state-owned forestry company, Statsskog SF, which can lease the land for tourism, cabins, or extractive industries. Statsskog SF also manages forests in the state commons in collaboration with the commons boards which is elected by those who have usufruct rights to timber and firewood in the commons. Finally, the upland boards manage the common grazing lands, summer farms, hunting and fishing activities, and provide recreational facilities for the public. Funds for operating the upland boards are covered by 50% of the leasing income and the fees collected for hunting and fishing on the land. Although not relevant for this paper, it is important to note that these laws do not apply on State land in northern Norway.

The commons evolved on marginal lands that were less suitable for cultivation. In the valleys and along the coast, the land is typically parceled out in smaller properties (as much as 57% of the defined ownership is less than 10 ha). Small-scale farming has traditionally been combined with forestry and fishing to maintain a diversified economy. Today, tenancy is common in the lowlands as a few active farmers rent smaller parcels on private land from non-farmers to grow fodder (Dramstad and Sang, 2010). In the uplands, sheep grazing on common land is the prevailing agricultural land use. Many small private landowners require coordination to manage resources such as wildlife, forestry, migrating fish, and recreational areas which is a challenge for municipalities and land use planning in coastal areas.

### 1.3. Overview of protected areas in Norway

Norwegian protected areas have evolved through a process of devolution of authority to local control. The establishment of the first large protected areas was based on the Nature Preservation Act (1954) and on national park plans developed by the Nature Conservation Council (NOU 2004:28; Hausner, 2005). Management of protected areas was largely top–down and based on "purist values" promoting the absence of human influence as the most important reason for protecting nature (Emmelin and Kleven, 1999; Daugstad et al., 2006b; Falleth and Hovik, 2009). The first national parks were established on state property in remote areas where traditional uses were allowed to continue (NOU 2004:28). Local participation in protected area management was strengthened during the 1980's with an amendment to the Nature Conservation Act (1979) that harmonized protected area planning with existing land use planning legislation. A two-step participation process was implemented that provided for negotiation about the designation, boundaries, and regulations of protected areas before sending the plan for local hearings and municipal review.

The involvement of local people in land use planning has always been important in Norway but was strengthened for protected areas by policy reforms throughout the 1990's. The devolution of control for protected areas culminated in 2009 when the Norwegian Parliament established more than 40 local management boards with extensive decision-making authority over much of Norway's protected areas, an outcome described as a "grand experiment with delegation of authority" (Fauchald and Gulbrandsen, 2012). These protected area boards have management authority over clusters of national parks, protected landscapes, and nature reserves. The Sami Council was further empowered through a consultation agreement that ensures early involvement of Sami representatives in protected area establishment and by participation in local boards. In a few cases, non-political organizations are also represented on local protected area boards, such as the wild reindeer committee in Reinheimen, a member from the Skjåk commons property in Breheimen, and the Swedish reindeer herders in Øvre Dividalen (Lainovouma sameby). In all protected areas, reindeer herders, landowners, and other right holders are to be involved early in the planning process. The responsibility for small protected areas has been delegated to many municipalities.

The devolution of authority to local governments from the late 1980's was inspired by the success of devolving welfare policies in Scandinavia (Falleth and Hovik, 2009). The municipalities were regarded as effective at providing public services adapted to the local context. The environmental policy reforms included a wide range of tasks associated with land uses, wildlife, forests, motor vehicles use, and small protected areas. Gradual transfer of power from the environmental governor to local government has strengthened local influence on the designation as well as in the actual management of national parks (Fauchald and Gulbrandsen, 2012). The second national park plan included significant private land, and negotiations with landowners and local users have resulted in the borders adjustments and changes in designation from national park (IUCN category II) to protected landscapes (IUCN category V) (Hausner, 2005). Today, the objectives for national parks include preservation and restoration of cultural landscapes based on traditional livestock grazing and summer farms (i.e., working landscapes) in addition to purist values (Olsson et al., 2004; Daugstad et al., 2006b). Traditional rural uses, such as grazing, hunting, fishing, gathering, and traditional outdoor recreation on foot and ski, have rarely been restricted in Norwegian national parks, but commercial tourism has been perceived as a threat and strictly regulated (Haukeland et al., 2011). In Saltfjellet/Svartisen, Jotunheimen, and Reisa national parks, commercial tourism was banned until removed by a budgetary decision in 2003 ("the mountain text").

### 1.4. Research questions

The primary purpose of this research is to examine the contribution of different land tenures and protected areas to ecosystem values perceived as important by local residents in Norway. We examine the potential effects of land tenure and protected area designation by seeking answers to the following specific research questions:

- How are participatory mapped ecosystem values and land use preferences distributed by land tenure category?
- Does protected area designation, as regulatory overlay, interact with land tenure to alter ecosystem values and tenure associations?
- What is the spatial distribution of cultural, provisioning, and supporting ecosystem values and how can these be described

using social landscape metrics including dominance, richness, and diversity?
- Do ecosystem values spatially cluster into observable "bundles" of ecosystem services?
- Does the potential for land use conflict differ by tenure and protected area status?

## 2. Methods

### 2.1. Study location and context

The case is unique as different land tenures (private, village, and state commons) are overlaid with different protected areas designations. The study area is Sogn, Norway, a region characterized by fjords stretching 200 km surrounded by glaciers and mountain plateaus and includes more than 10 of the highest peaks in Norway. The area covers 6 municipalities in the counties of Sogn og Fjordane, and Oppland, with a total area of 15,862 km$^2$. Less than 5% of the study area is used for cultivation or forestry with about half of the properties in the region being less than one ha in size (Lågbu et al., 2012). In the valley of Sogn, most of the land is private, while land located on mountain plateaus is almost entirely covered by village or state commons. The Skjåk village commons cover 95% of the municipality and comprise the third largest landowner in Norway. The common property was bought by a group of farmers in 1798 and is today shared by 368 farmers with usufruct rights to pastures, summerhouses, firewood, and building materials, of which 206 are also owners of the land. The owners are the only ones with rights to cash dividends generated from the commons. About 580 households located in the commons do not share collective rights to the land, but share access to hunting and fishing. Only 6% of the land is forests, but forestry has historically been an important industry. Sale of hunting and fishing permits, cabin rentals, and leasing of property for cabins or tourism are major sources of income. The village commons invests in recreational activities with approximately 250 km of trails, alpine skiing facilities, and orienteering activities for children. There are also smaller village commons such as near Sogndal (Haflso, Fjærland, Leikanger and Feios), Nordherad in Vågå, and Stranden in Lom, but these are minor compared with the Skjåk village commons.

There are a total of 12 state commons in the study area. The two upland municipalities with the largest share of state commons are Lom, the most visited area by tourists in Norway with 12 large tourist companies, and Våga, where 70% of the municipal land area is covered by state commons that generate income from tourism, forestry, livestock and hydroelectric power. The lowland areas in the region have a more diversified economy that includes aquaculture, industry, cruise tourism, fruit and berry cultivation, with major service hubs located in Voss and Sogndal with 14,006 and 7623 inhabitants, respectively.

There are four national parks located in the study region (Breheimen, Jotunheimen, Reinheimen, Jostedalsbreen) mostly situated in the uplands, and there are two large protected landscapes, Stølsheimen and Nærøyfjorden, that have world heritage status. There are also smaller protected landscapes close to national park borders that function as buffer zones.

### 2.2. Data collection process

The research team designed, pre-tested, and implemented an internet-based PPGIS website in Norwegian language for data collection. The study website consisted of an opening screen for

**Table 1**
Ecosystem values typology with operational definitions and preferences for increasing or decreasing activity. P = provision, C = cultural, S = supporting.

| Ecosystem Values and Places | Operational definition |
|---|---|
| Cabin(s)/summer farms | Mark the location of cabin(s) or summer farms that are important to you |
| (P) Hunting/fishing | Areas are important because of hunting and/or fishing |
| (P) Pastures/fodder | Areas are important because they are used for haymaking and pastures for reindeer, sheep, cows |
| (P) Gathering | Areas are important for berries, mushroom or collecting herbs/plants here |
| (P) Clean water | Areas are important because they provide clean water |
| (S) Biological diversity | Areas are important because they provide a variety of plants, wildlife, and habitat |
| (C) Recreation | Areas are important for outdoor recreation activities (e.g., camping, walking, skiing, alpine, snowmobiling, cycling, horse riding etc.) |
| (C) Beautiful areas | Areas are important because they include beautiful nature and/or landscapes |
| (C) Culture/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 |
| (C) Income | Areas are important because they provide tourism opportunities, mining, hydroelectric power or other potential sources of income |
| (C) Undisturbed nature | Areas are relatively untouched, providing for peace and quiet without too many disturbances |
| (C) Social | 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) |
| (C) Spiritual | Areas are important because they are valuable in their own right or have a deeper meaning; emotionally, spiritually, or religious |
| (C) Therapeutic/health | Place 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 |
| (C) Special places | Please describe why these places are special to you |
| Preferences (increase/decrease) | Operational definition |
| Development | Increase/decrease development of homes or holiday homes in this area |
| Tourist facilities | Increase/decrease tourist facilities and accommodation in this area |
| Industry/energy | Increase/decrease mining (e.g., minerals, stone, sand, gravel, etc.) or energy development (e.g., windmills, power plants, dams, power lines, etc.) in this area |
| Logging | Increase/decrease logging in this area |
| Helicopter transport | Increase/decrease access to helicopter transportation of tourists in this area |
| Roads/all-terrain vehicles | Increase/decrease access to the area by roads or all-terrain vehicles |
| Snowmobiles | Increase/decrease the use of snowmobiles in this area (including snowmobile trails and/or extended seasons) |
| Boating | Increase/decrease access for use of boats in this area |
| Grazing | Increase/decrease grazing in this area (e.g., sheep, reindeer, cows) |
| Predator control | Increase/decrease in predator control in this area |
| Fishing | Increase/decrease access to fishing in this area |
| Hunting | Increase/decrease hunting in this area |
| Other changes | Describe other changes in use or activities should increase or decrease |

participants to either enter or request an access code, followed by an informed consent screen for participation, and then a Google® maps interface where participants could drag and drop digital markers onto a map of the study area. The interface consisted of three "tab" panels with the first panel containing markers with 14 ecosystem values plus a marker to identify the location(s) of cabins or summer farms. The selection of ecosystem values to be mapped was based on a values typology first developed by Brown and Reed (2000) for participatory mapping in Alaska. The typology was modified and adapted for use in Norway acknowledging there is a limit to how many types of markers a respondent could map. The state and the village commons was originally built around subsistence uses, therefore harvestable ecosystem values (i.e. hunting, fishing, grazing and gathering) are more emphasized in this study. It is important to note that gathering is a part of the right of common access, so it is an activity which could be conducted anywhere. Hunting and fishing cards have to be bought from the owner of the hunting and fishing rights (i.e., private landowner, the village or the state common boards). Grazing, hunting and fishing are usually not restricted in protected areas. The second and third panels on the PPGIS website contained 12 management preferences to identify locations of activities or uses. The second panel identified preferences to increase a specific activity or use such as grazing while the third panel contained similar markers to decrease the same activities or uses (see definitions in Table 1). The third panel also contained a general marker where the participant could locate an activity or use not listed. The typology and the management preferences were presented to protected area managers in the two study areas and modified according to their advice.

The instructions requested the participants to drag and drop the markers onto map locations that are important for the values listed and to indicate how these areas best be managed—by increasing or decreasing particular activities or uses. The different types of markers and their spatial locations were recorded for each participant on the web server in a database, along with other information including a timestamp of when the marker was placed, the Google® map view at time of marker placement, and the Google® map zoom level (scale) at which the marker was placed. Participants could place as few or as many markers as they deemed necessary to express their values and preferences. Following completion of the mapping activity (placing markers), participants were directed to a new screen and provided with a set of text-based survey questions to assess general, non-spatial public land management preferences and to measure respondent socio-demographic characteristics. PPGIS data collection ended with completion of the survey questions.

Based on protected area designation, population density, and property structure, six municipalities were selected (Voss, Sogndal, Luster, Skjåk, Vågå, Aurdal). These municipalities were selected because of the location of the village common in Skjåk municipality. The neighboring municipalities include state commons and private lands. In each municipality 10% of the adult population (>18 years) were randomly drawn, for a potential 3,104 participants. The random draw was based on the tax lists and provided by EVRY (https://www.evry.no/). Selected individuals were sent a letter of invitation and a reminder two weeks after the initial invitation. Parallel to the random sampling recruitment, we contacted a number of regional organizations, either by email or Facebook, to inform them about the study and to encourage volunteer participation. The organizations contacted consisted of groups with interests in local communities (65), agriculture (13), hunting and fishing (29), volunteer work (22), wilderness recreation (11), athletics (66), animal activities (10), motorized vehicle use (9), politics (16), culture (30) and education (3). In total, 274 organizations were contacted.

## 3. Analyses

### 3.1. Participant characteristics

We assessed the representativeness of participants in the study area with Norwegian census data on the variables of age, gender, education, income, and family structure by use of municipal statistics available from the population and housing survey in 2011 (Statistics Norway, 2013). We also examined the geographic distribution of participants within the study area based on postcode provided.

### 3.2. Association of ecosystem values and land use preferences by tenure and protected areas

The point locations of ecosystem values and land use preferences were spatially intersected with the three classes of land tenure in the study area—state commons, village commons ("Skjåk allmenning"), and private/other property. Cross-tabulations (contingency tables) were generated to examine the distribution of mapped values and preferences by land tenure category. We calculated chi-squared statistics and standardized residuals to determine whether the number of mapped points differed significantly from the number of points that would be expected in each tenure category. Expected counts are the projected point frequencies in each table cell if the null hypothesis is true, i.e., if there is no association between a given ecosystem value and land tenure category. In a contingency table, expected counts are calculated for each cell by multiplying the row total (e.g., total scenic points) by the column total (e.g., state commons) and dividing by the total number of points. The chi-square statistic sums the squared differences between the observed number of points and expected number of points for all table cells. The larger the chi-square statistic, the greater the probability that the mapped values and tenure categories are not independent, i.e., there is a significant association. Standardized residuals indicate the importance of a given table cell (value/tenure pair) to the overall chi-square value and are like *z*-scores that show how many standard deviations above or below the expected count the observed cell count is. Standardized residuals identify the cells that contribute most to the overall chi-square statistic. Residuals are calculated for each cell by subtracting the expected value from the observed value and dividing by the square-root of the expected value. This same type of analysis was used to examine the association of values with protected areas and their overlays with commons areas wherein a marker could be located in protected areas only, or in protected areas that intersect with state or village commons land.

We also conducted correspondence analysis between the ecosystem value categories and land tenure to visually plot the associations. Correspondence analysis computes row and column scores and produces a normalized plot based on the scores. In the resulting plot, the distances between points reflect the relative strength of association between the land tenure and ecosystem value categories.

To visualize the spatial distribution of ecosystem services within the study area, we grouped the 14 services into cultural ($n=9$), provisioning ($n=4$), and supporting ($n=1$) categories. We then we generated kernel point densities using a 1 km cell size with a 3 km search radius for each of the three groups of services. Using kernel densities as a probability surface, we created and mapped ecosystem value "hotspots" with isopleths that captured 30, 50, and 70% of the points for each of the groups of values using the Geospatial Modelling Environment (Beyer, 2014). As an alternative to kernel densities which smooth the point distribution, we also used a simple grid approach that divided the study area into 2 km grid cells to plot the frequency distribution of ecosystem services by grid cell.

### 3.3. Quantifying ecosystem values and use preferences with social landscape metrics

We examined the distribution of ecosystem values and land use preferences using social landscape metrics as described by Brown and Reed (2012). The purpose of social landscape metrics is to understand the structure and distribution of values and preferences across land tenure and protected area categories. In addition, metrics provide a means to identify land use conflict potential (Brown and Raymond, 2014) based on the spatial concurrence of mapped values and preferences that may or may not be compatible. The *count* (**P0**) metric counts the number of point locations within the tenure or protected area while the *percent* **(P1)** metric calculates the percent of mapped points in the area compared to the total number of mapped points across all areas. The *dominant value* (***D***) metric is the value or preference marker type with the largest count of points within the tenure or protected area. The *dominance* (**D1**) metric quantifies the dominance relationship between the most frequently mapped attribute and the next most frequently mapped attribute on a scale that ranges from 0 (i.e., the frequencies are the same) to 1.0 (there was only one type of marker mapped in the area). The *density* (**D2**) metric calculates the density of values or preferences per area while the *diversity index* (**D3**) metric calculates the Simpson diversity index commonly used in ecological studies and ranges on a scale from 0 (low diversity of marker types) to 1 (high diversity of marker types). The *richness* metric (**R**) is the number of different value or preference marker types mapped in an area and can range from 0 to 14 for ecosystem values and 0 to 24 for preferences. The *conflict potential* (**C**) metric can be calculated in many ways, but here we follow the methods suggested by Brown and Raymond (2014) where the conflict potential index is derived from a mathematical combination of land use preferences located in the same area where the differences in preference markers to increase/decrease a use/activity are optionally weighted by the number of preferences or the number of values located in the same area. Specifically, we operationalized three variants of the conflict index as follows:

$$C1 = \sum_{1}^{j} \frac{MIN(P_I, P_D)_j}{MAX(P_I P_D)_j}$$

$$C2 = \sum_{1}^{j} \frac{MIN(P_I, P_D)_j}{MAX(P_I P_D)_j} * P_{Tj}$$

$$C3 = \sum_{1}^{j} \frac{MIN(P_I, P_D)_j}{MAX(P_I P_D)_j} * V_T$$

where **C1** is the conflict index based on summed preference differences for increasing/decreasing use across all 12 mapped preferences (higher index values indicate greater conflict potential), $\boldsymbol{P_I}$ is the number of mapped preferences for increasing the use or activity, $\boldsymbol{P_D}$ is the number of mapped preferences for decreasing the use or activity, $\boldsymbol{P_T}$ is the total number of preferences ( $\boldsymbol{P_I + P_D}$) in the area, *j* is a specific preference and ranges from 1 to 12 preferences in this study, and $\boldsymbol{V_T}$ is total number of ecosystem values located in the area. The **C2** index weights the **C1** index by the number of preferences in the area and the **C3** index weights the **C1** index by the number of ecosystem values in the area.

### 3.4. Assessment of spatial "bundles" of ecosystem services

Ecosystem service "bundles" are sets of services that appear together repeatedly (Raudsepp-Hearne et al., 2010). To determine whether the mapped ecosystem services were mapped in spatial "bundles", we overlaid the study area with a two kilometer grid resulting in $n = 4544$ grid cells. The ecosystem values by marker type ($n = 14$) were counted for each grid cell. The marker counts for the 14 values were then factor analyzed (SPSS v.22) using principal components extraction with the number of extracted factors determined by eigenvalues greater than one (Kaiser, 1960). The resulting factors were rotated using varimax rotation to enhance interpretation.

## 4. Results

### 4.1. Response and participant characteristics

A total of 440 participants accessed the study website and placed one or more markers from November 2014 to January 1, 2015. See Table 2. Of these participants, 380 (86%) fully or partially completed the survey questions that followed the mapping activity. The estimated response rate, after accounting for non-deliverable letters of invitation, was 14%. A total of 9,039 markers were mapped during data collection, with 8,560 (95%) of these markers placed inside the designated study area. The number of markers placed per participant ranged from 1 to 276 with the average number of numbers placed being 20.5. Approximately 75% of the markers placed were ecosystem *value* markers with the remaining 25% being land use *preference* markers.

Most participants (91%) learned of the study directly through a recruitment letter from the Arctic University of Norway. Referrals to the study website were encouraged and an estimated

**Table 2**
Participation statistics and respondent characteristics (Sogn) with comparison to 2014 census data.

| Participation Statistics | |
|---|---|
| Number of participants (one or more locations mapped) | 440 |
| Number completing post-mapping survey | 380 |
| Number of locations mapped | 9,039 |
| Range of locations mapped (min, max points) | 1–276 |
| Mean, median of all locations mapped | 20.5, 14 |
| Mean, median of values and places mapped | 14.7, 9 |
| Mean, median of preferences mapped | 5.8, 1.5 |
| How participants learned of study | |
| Mail (UiT) | 91% |
| Other organization/referral | 9% |

| | | Study Participants | Census Data |
|---|---|---|---|
| Age (mean) | | 48.7 | 50.5 |
| Gender | Male | 57% | 50% |
| | Female | 43% | 50% |
| Education (highest level completed) | | | |
| Primary | | 3% | 27% |
| Secondary | | 37% | 49% |
| Higher | | 60% | 24% |
| Household income (annual)[a] | | | |
| 0–200,000 | | 9% | 7% |
| 200,000–300,000 | | 3% | 11% |
| 300,000–400,000 | | 12% | 11% |
| 400,000–500,000 | | 15% | 11% |
| 500,000–600,000 | | 12% | 15% |
| More than 600,000 | | 40% | 47% |
| Not disclosed | | 10% | N/A |
| Families with children | | 50% | 41% |

[a]Census income categories do not align with categories in survey question. Census data was estimated to match survey data. All census data was collected from Statistics Norway (2013).

9% of participants learned of the study indirectly from friends, organizations, or social media.

Table 2 also provides a socio-demographic profile of study participants with comparative Norway census data derived from Statistics Norway (2013). The mean age of participants was 49 years with the majority being males (57%), with higher levels of formal education, and higher self-reported household income than comparable Norwegian census data. About half of the participants were from families with children. The PPGIS participation bias toward more highly educated and higher income males is consistent with other reported PPGIS studies in developed countries (Brown and Kyttä, 2014).

We assessed the geographic distribution of participants by plotting the number of participants by their postcode which is a geographical area representing multiple households See Fig. 1. Participants in the study were geographically distributed throughout the study area with more participants living in the more highly populated communities of Skjåk and Vågå in the north, Sogndal in the central region, and Voss in the south.

### 4.2. Frequency of mapped ecosystem values and preferences in the study area

We generated frequency counts of the PPGIS mapped values and preferences. The most frequently mapped ecosystem values were recreation ($n = 1{,}264$/15% of all markers), scenic beauty (918/11%), hunting/fishing (686/8%), pastures/grazing (407/5%), and undisturbed nature (330/4%). The least frequently mapped values were spiritual (80/1%), therapeutic (135/2%), and biological diversity value (147/2%). Falling in the middle of the distribution were social (206/2%), income (229/3%), clean water (263/3%), and gathering values (295/3%). The relative frequency of mapped

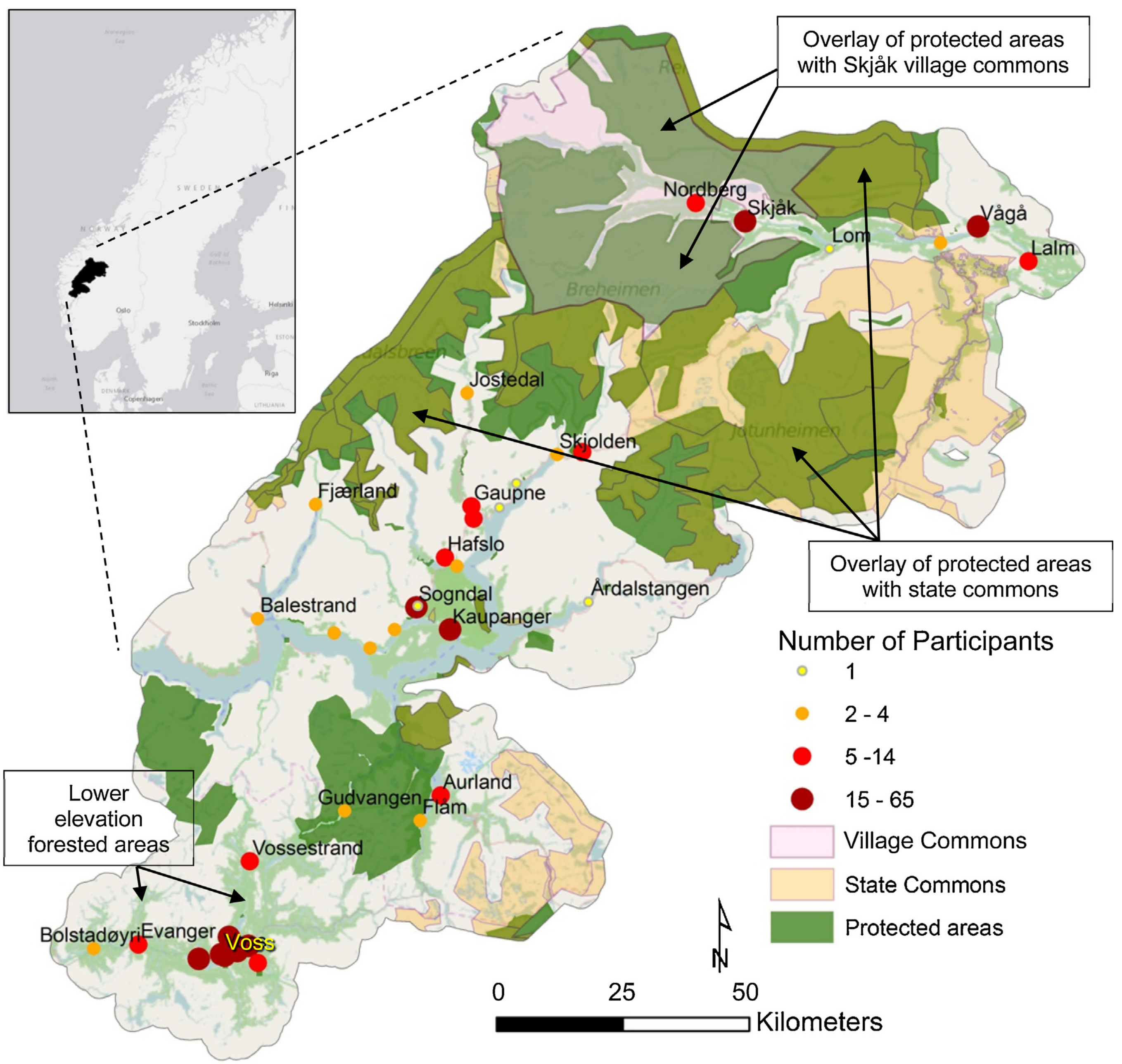


**Fig. 1.** Study area in southern Norway showing land tenure and number of study participants by geographic location. The large Skjåkvillage commons and state commonsoverlap with protected areasin the northern half of the study area.

values was similar to other reported PPGIS studies with recreation and scenic values being the most frequently identified, and spiritual and therapeutic values the least frequently mapped. Cabins and summer farms were also mapped in the study area ($n = 700$) and appear very important to Norwegian cultural identity and lifestyle.

The mapping of land use preferences, in aggregate, totaled 2454 markers in the study area. The most frequently mapped preferences were to increase predator control (218/3%), increase fishing opportunities (178/2%), decrease snowmobile use (174/2%), and increase tourism development (172/2%). The least frequently mapped preferences were to decrease grazing (22/<1%), decrease hunting (27/<1%), decrease logging (29/<1%), and decrease predator control (33/<1%). All but two mapped preferences revealed a clear preference for either increasing or decreasing a particular land use/activity in the study area. The preferences for development of homes/holiday homes (145/147) and industrial/energy development (106/110) were split between increasing and decreasing the activity.

### *4.3. Association of mapped values and use preferences with land tenure*

There was a statistically significant association between land tenure and mapped values ($X^2 = 93.7$, $df = 28$, $p < .001$) with cross-tabulated frequencies appearing in Table 3. Adjusted standardized residuals ≥ +2.0 or ≤ −2.0 indicate the number of observations in the cell is significantly larger or smaller than would be expected. The larger the absolute value of the standardized residual, the greater the deviation from expected marker counts. Especially large standardized residuals command particular attention. For example, more biological diversity values (residual = 2.0) and undisturbed nature values (residual = 2.7) were located on state commons than expected; hunting/fishing (5.4) and therapeutic values (3.0.) were more abundant on village commons; and cultural identity (2.2) and gathering values (3.4) were more abundant on private/other lands. Fewer gathering (−2.4) and grazing/pasture values (−2.1) were identified on state commons than expected; gathering (−2.1) and income values (−2.5) were less abundant on village commons; and

**Table 3**
Association between mapped ecosystem values and land tenure. Overall association is significant ($X^2 = 93.7$, $df = 28$, $p < .001$) with standardized residuals ≤−2.0 (pink) or ≥+2.0 (green) indicating significant over/under representation of the ecosystem value by land tenure category.

| | | State commons | Village commons | Private/other | Totals |
|---|---|---|---|---|---|
| Biological diversity | Count | 36 | 10 | 101 | 147 |
| | % | 3.3% | 1.9% | 2.3% | 2.4% |
| | Residual | 2.0 | −.7 | −1.3 | |
| Clean Water | Count | 48 | 14 | 201 | 263 |
| | % | 4.3% | 2.7% | 4.5% | 4.3% |
| | Residual | .0 | −1.9 | 1.1 | |
| Culture/identity | Count | 47 | 19 | 244 | 310 |
| | % | 4.2% | 3.7% | 5.5% | 5.1% |
| | Residual | −1.4 | −1.5 | 2.2 | |
| Gathering | Count | 38 | 15 | 242 | 295 |
| | % | 3.4% | 2.9% | 5.4% | 4.8% |
| | Residual | −2.4 | −2.1 | 3.4 | |
| Hunting/Fishing | Count | 132 | 95 | 459 | 686 |
| | % | 11.9% | 18.4% | 10.3% | 11.2% |
| | Residual | .8 | 5.4 | −4.1 | |
| Income | Count | 44 | 9 | 176 | 229 |
| | % | 4.0% | 1.7% | 3.9% | 3.8% |
| | Residual | .4 | −2.5 | 1.2 | |
| Grazing/pasture | Count | 58 | 34 | 315 | 407 |
| | % | 5.2% | 6.6% | 7.0% | 6.7% |
| | Residual | −2.1 | −.1 | 1.9 | |
| Recreation | Count | 237 | 92 | 935 | 1264 |
| | % | 21.4% | 17.9% | 20.9% | 20.7% |
| | Residual | .6 | −1.7 | .5 | |
| Scenic/beauty | Count | 184 | 73 | 661 | 918 |
| | % | 16.6% | 14.2% | 14.8% | 15.1% |
| | Residual | 1.6 | −.6 | −1.0 | |
| Social | Count | 29 | 14 | 163 | 206 |
| | % | 2.6% | 2.7% | 3.6% | 3.4% |
| | Residual | −1.5 | −.9 | 1.9 | |
| Spiritual | Count | 12 | 6 | 62 | 80 |
| | % | 1.1% | 1.2% | 1.4% | 1.3% |
| | Residual | −.7 | −.3 | .8 | |
| Therapeutic | Count | 26 | 21 | 88 | 135 |
| | % | 2.3% | 4.1% | 2.0% | 2.2% |
| | Residual | .3 | 3.0 | −2.2 | |
| Undisturbed nature | Count | 78 | 35 | 217 | 330 |
| | % | 7.0% | 6.8% | 4.8% | 5.4% |
| | Residual | 2.7 | 1.5 | −3.2 | |
| Special places | Count | 20 | 9 | 100 | 129 |
| | % | 1.8% | 1.7% | 2.2% | 2.1% |
| | Residual | −.8 | −.6 | 1.1 | |
| Cabin or summer farm | Count | 118 | 69 | 513 | 700 |
| | % | 10.7% | 13.4% | 11.5% | 11.5% |
| | Residual | −.9 | 1.4 | −.1 | |
| Totals | Count | 1107 | 515 | 4477 | 6099 |
| | % | 100.0% | 100.0% | 100.0% | 100.0% |

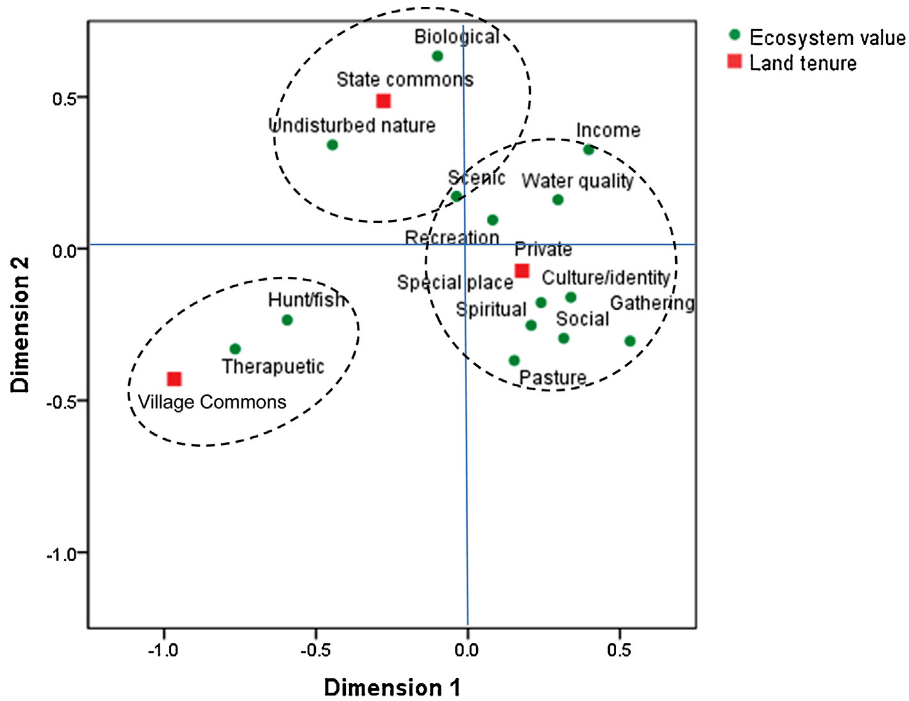


**Fig. 2.** Symmetrical, normalized plot of correspondence analysis results of the association between ecosystem values and land tenure. The dashed ellipses show logical associations based on the proximity of ecosystem value markers to land tenure categories.

hunting/fishing (−4.1), therapeutic (−2.2) and undisturbed nature values (−3.2) were less associated with private/other land.

A normalized plot of the two variables from correspondence analysis appears as Fig. 2. The plot affirms the significant associations found in the chi-square table wherein biological and undisturbed nature values are closest to state commons, hunting/fishing and therapeutic values are closest to village commons, and spiritual, social, cultural, gathering, pasture and special place values are proximate to private/other lands. Recreation, income, and water quality (clean water) do not show strong spatial association with any particular land tenure but have stronger association with state commons and private/other land than with village commons.

The potential interaction of protected area designation with commons land tenure was examined in Table 4. Gathering (residual = 2.5) and pasture/grazing (2.3) values were over-represented in protected areas only while hunting/fishing values were under-represented (−3.5).

Where protected area designation intersects with common land tenure, hunting/fishing (5.8) and therapeutic value (3.7) were over-represented in protected status and village commons, while income value was over-represented in protected status and state commons.

With respect to land use preferences, there were four statistically significant associations (chi-square, $p \leq 0.05$) with land tenure—home/cabin development, roads/ATV access, snowmobile use, and predator control. See Table 5. Participants mapped more preferences than expected to decrease home/cabin development on state commons, to increase roads and snowmobile use on private/other lands while decreasing both of these uses on village commons, and to increase predator control and hunting activity on village commons.

### *4.4. Social landscape metrics by tenure and protected areas*

Social landscape metrics were calculated for both ecosystem values and land use preferences and appear in Table 6. Recreation values were the most frequently mapped in state commons and protected areas and thus were the dominant (*D*) values for those areas. Hunting/fishing values were dominant in village commons and the overlay of village commons with protected areas. The dominance index (D1) indicates the magnitude of dominance compared to the second most frequently mapped value in the area. Recreation value was not especially dominant in either protected areas or state commons (D1 = .18 and .22, respectively) compared to scenic value which was the second most frequently mapped value. On village commons, recreation values were mapped almost as frequently as the dominant hunting/fishing value (D1 = .03). Participants identified the full range of ecosystem values across all tenures and protected areas as indicated by the richness (*R*) index ($n = 14$).

The density metric (D2) controls for the size of the area under the assumption that all else being equal, larger areas should have more mapped values. Private/other land was largest in area of all tenures, but also had the highest density of mapped values per square kilometer (0.32) while state commons had the lowest density (0.21). The diversity metric (D3) measures the number of different value types mapped in the area while also accounting for the evenness of the distribution. All land tenures and protected areas showed a high diversity of mapped attributes with Simpson's index ranging from .86 to .88.

The metrics for land use preferences reveal that the majority of preferences (P1 = 57%) were mapped on private/other land which also had the highest density (D2 = .16). Increased predator control was dominant across all land categories with the exception of private/other land, where increased fishing was dominant and increased predator control was the second most frequently mapped attribute. There were fewer types of preferences mapped on village commons ($R = 20$) and the overlay with protected areas ($R = 18$) than other categories. Similar to mapped values, the diversity of mapped preferences was large across all land categories.

The conflict index metric (*C*) measures the potential for land use conflict. In this study, the conflict index measures the difference between mapped preferences to increase a use/activity with preferences to decrease the same use/activity in the land tenure category area. The differences in the 12 potential uses were aggregated

**Table 4**
Association between mapped ecosystem values and protected area overlays on state and village commons. Overall association is significant ($X^2 = 89.8$, $df = 28$, $p < .001$) with standardized residuals ≤−2.0 (pink) or ≥2.0 (green) indicating significant over/under representation of ecosystem value by land tenure category.

| | | Protected area/ private | Protected area/state commons | Protected area/village commons | Totals |
|---|---|---|---|---|---|
| Biological diversity | Count | 27 | 32 | 10 | 69 |
| | % | 3.0% | 4.2% | 2.8% | 3.4% |
| | Residual | −.9 | 1.5 | −.8 | |
| Clean Water | Count | 45 | 35 | 11 | 91 |
| | % | 5.0% | 4.6% | 3.0% | 4.5% |
| | Residual | 1.0 | .2 | −1.5 | |
| Culture/identity | Count | 56 | 35 | 14 | 105 |
| | % | 6.3% | 4.6% | 3.9% | 5.2% |
| | Residual | 1.9 | −.9 | −1.3 | |
| Gathering | Count | 44 | 22 | 9 | 75 |
| | % | 4.9% | 2.9% | 2.5% | 3.7% |
| | Residual | 2.5 | −1.5 | −1.4 | |
| Hunting/Fishing | Count | 73 | 76 | 71 | 220 |
| | % | 8.2% | 10.0% | 19.6% | 10.9% |
| | Residual | −3.5 | −1.0 | 5.8 | |
| Income | Count | 20 | 29 | 6 | 55 |
| | % | 2.2% | 3.8% | 1.7% | 2.7% |
| | Residual | −1.2 | 2.3 | −1.4 | |
| Grazing/pasture | Count | 63 | 33 | 19 | 115 |
| | % | 7.1% | 4.3% | 5.2% | 5.7% |
| | Residual | 2.3 | −2.0 | −.4 | |
| Recreation | Count | 198 | 176 | 55 | 429 |
| | % | 22.2% | 23.2% | 15.2% | 21.3% |
| | Residual | .9 | 1.6 | −3.2 | |
| Scenic/beauty | Count | 163 | 134 | 55 | 352 |
| | % | 18.3% | 17.7% | 15.2% | 17.5% |
| | Residual | .8 | .2 | −1.3 | |
| Social | Count | 26 | 18 | 11 | 55 |
| | % | 2.9% | 2.4% | 3.0% | 2.7% |
| | Residual | .4 | −.8 | .4 | |
| Spiritual | Count | 7 | 11 | 6 | 24 |
| | % | 0.8% | 1.4% | 1.7% | 1.2% |
| | Residual | −1.5 | .8 | .9 | |
| Therapeutic | Count | 17 | 14 | 19 | 50 |
| | % | 1.9% | 1.8% | 5.2% | 2.5% |
| | Residual | −1.5 | −1.4 | 3.7 | |
| Undisturbed nature | Count | 53 | 63 | 29 | 145 |
| | % | 5.9% | 8.3% | 8.0% | 7.2% |
| | Residual | −2.0 | 1.5 | .6 | |
| Special places | Count | 23 | 15 | 7 | 45 |
| | % | 2.6% | 2.0% | 1.9% | 2.2% |
| | Residual | .9 | −.6 | −.4 | |
| Cabin or summer farm | Count | 78 | 66 | 41 | 185 |
| | % | 8.7% | 8.7% | 11.3% | 9.2% |
| | Residual | −.6 | −.6 | 1.5 | |
| Totals | Count | 893 | 759 | 363 | 2015 |
| | % | 100.0% | 100.0% | 100.0% | 100.0% |

within the area (C1) with larger indices reflecting greater conflict potential, and optionally weighted by the number of mapped preferences (C2) or mapped values (C3). In this study, the private/other tenure had the highest potential for land use conflict (C1 = 5.9) while the overlay of village commons and protected areas had the lowest potential for conflict (C1 = 2.1). The weighting of the conflict index by the number of mapped preferences (C2) or mapped values (C3) did not change the relative potential for conflict as indicated by the ranked conflict index scores.

### *4.5. Assessment of spatial "bundles" of ecosystem services*

To visualize the intensity of ecosystem value distribution in the study area, we grouped the 14 services into cultural ($n = 9$), provisioning ($n = 4$), and supporting ($n = 1$ "biological diversity") categories as per the millennium ecosystem assessment typology (see Table 1). We generated kernel point densities for each group, and plotted these "hotspots" in Fig. 3. The spatial distribution of hotspots affirms the chi-square association results and reveals large hotspots of cultural (Fig. 3a) and provisioning (Fig. 3b) values on private/other lands, particularly in the areas around settlements such as Sogndal (**1**) in the central region and Voss (**2**) in the south. Close to these settlements, people mapped cultural identity, social values, and gathering activities as important place values (Appendices B–D).

The marker counts by grid cell (Fig. 3d) also show that the overall intensity of mapped ecosystem values in the region with greatest intensity on private/other lands relative to commons and protected areas. In contrast, hotspots for biological diversity values (Fig. 3c) were located more on state commons or in protected landscapes. For instance, Gudvangen ("Gods place by the water") in the Nærøyfjorden protected landscape (**3**) is a highly productive area providing rich pastures, berry fields, clean water, recreational opportunities, and cultural history as important for communication and a market place in the Viking era, as well as the royal mail route in the 17th century. The fjords are on UNESCO's world heritage list and attract many tourists. Finndalen (**4**), located on state commons, attracts local recreationists from Skjåk, Lom, and Vågå. It is a biologically rich valley and is important for consumptive uses such as fishing, hunting of wild reindeer, forestry, and grazing connected to four historically important summer farms. The state commons also includes the most highly visited peaks in Norway and is ser-

**Table 5**
Associations of mapped activity/use preferences by land tenure with statistically significant associations (chi-square with $p < 0.05$) highlighted in yellow. Residuals less than/equal to −2.0 (pink) or greater than/equal to +2.0 (green) are also highlighted.

| Preference | | State commons | Village commons | Private | Totals | $X^2$ | Preference | | State commons | Village commons | Private | Totals | $X^2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Home/cabin | Count | 15 | 13 | 117 | 145 | 7.7, $p < 0.05$ | Snowmobile use | Count | 15 | 4 | | | |
| hbox126 | 145 | 10.0, $p < 0.01$ | | | | | | | | | | | |
| Increase | % | 10.3% | 9.0% | 80.7% | 100.0% | | Increase | % | 10.3% | 2.8% | 86.9% | 100.0% | |
| | Residual | −2.4 | 1.7 | 1.1 | | | | Residual | −1.6 | −2.5 | 2.9 | | |
| Decrease | Count | 30 | 6 | 111 | 147 | | Decrease | Count | 29 | 17 | 128 | 174 | |
| | % | 20.4% | 4.1% | 75.5% | 100.0% | | | % | 16.7% | 9.8% | 73.6% | 100.0% | |
| | Residual | 2.4 | −1.7 | -1.1 | | | | Residual | 1.6 | 2.5 | −2.9 | | |
| Tourism dev. | Count | 34 | 7 | 123 | 164 | 1.3, $p > 0.05$ | Boating | Count | 9 | 10 | 66 | 85 | 3.8, $p > 0.05$ |
| Increase | % | 20.7% | 4.3% | 75.0% | 100.0% | | Increase | % | 10.6% | 11.8% | 77.6% | 100.0% | |
| | Residual | .0 | −1.1 | .6 | | | | Residual | .9 | 1.6 | −1.9 | | |
| Decrease | Count | 16 | 6 | 55 | 77 | | Decrease | Count | 2 | 1 | 34 | 37 | |
| | % | 20.8% | 7.8% | 71.4% | 100.0% | | | % | 5.4% | 2.7% | 91.9% | 100.0% | |
| | Residual | .0 | 1.1 | −.6 | | | | Residual | −.9 | −1.6 | 1.9 | | |
| Industry/energy Increase | Count | 12 | 6 | 88 | 106 | 1.7, $p > 0.05$ | Grazing | Count | 27 | 14 | 131 | 172 | 3.6, $p > 0.05$ |
| | % | 11.3% | 5.7% | 83.0% | 100.0% | | Increase | % | 15.7% | 8.1% | 76.2% | 100.0% | |
| | Residual | −1.2 | −.2 | 1.2 | | | | Residual | −1.9 | .6 | 1.3 | | |
| Decrease | Count | 19 | 7 | 84 | 110 | | Decrease | Count | 7 | 1 | 14 | 22 | |
| | % | 17.3% | 6.4% | 76.4% | 100.0% | | | % | 31.8% | 4.5% | 63.6% | 100.0% | |
| | Residual | 1.2 | .2 | −1.2 | | | | Residual | 1.9 | −.6 | −1.3 | | |
| Logging | Count | 14 | 5 | 109 | 128 | 3.6, $p > 0.05$ | Predator control | Count | 54 | 41 | 123 | 218 | 7.6, $p < 0.05$ |
| Increase | % | 10.9% | 3.9% | 85.2% | 100.0% | | Increase | % | 24.8% | 18.8% | 56.4% | 100.0% | |
| | Residual | −1.9 | .1 | 1.6 | | | | Residual | −.3 | 2.7 | −1.8 | | |
| Decrease | Count | 7 | 1 | 21 | 29 | | Decrease | Count | 9 | 0 | 24 | 33 | |
| | % | 24.1% | 3.4% | 72.4% | 100.0% | | | % | 27.3% | 0.0% | 72.7% | 100.0% | |
| | Residual | 1.9 | −.1 | −1.6 | | | | Residual | .3 | −2.7 | 1.8 | | |
| Helicopter access | Count | 5 | 0 | 34 | 39 | 3.2, $p > 0.05$ | Fishing | Count | 26 | 13 | 139 | 178 | 2.9, $p > 0.05$ |
| Increase | % | 12.8% | 0.0% | 87.2% | 100.0% | | Increase | % | 14.6% | 7.3% | 78.1% | 100.0% | |
| | Residual | −.6 | −1.6 | 1.4 | | | | Residual | −1.5 | 1.0 | .7 | | |
| Decrease | Count | 13 | 5 | 58 | 76 | | Decrease | Count | 9 | 1 | 27 | 37 | |
| | % | 17.1% | 6.6% | 76.3% | 100.0% | | | % | 24.3% | 2.7% | 73.0% | 100.0% | |
| | Residual | .6 | 1.6 | −1.4 | | | | Residual | 1.5 | −1.0 | −.7 | | |
| Roads/ATV | Count | 7 | 0 | 69 | 76 | 12.8, $p < 0.01$ | Hunting | Count | 14 | 18 | 89 | 121 | 5.0, $p > 0.05$ |
| Increase | % | 9.2% | 0.0% | 90.8% | 100.0% | | Increase | % | 11.6% | 14.9% | 73.6% | 100.0% | |
| | Residual | −1.6 | −3.0 | 3.2 | | | | Residual | −1.0 | 2.1 | −.9 | | |
| Decrease | Count | 19 | 12 | 77 | 108 | | Decrease | Count | 5 | 0 | 22 | 27 | |
| | % | 17.6% | 11.1% | 71.3% | 100.0% | | | % | 18.5% | 0.0% | 81.5% | 100.0% | |
| | Residual | 1.6 | 3.0 | −3.2 | | | | Residual | 1.0 | −2.1 | .9 | | |

**Table 6**
Social landscape metrics for mapped ecosystem values and land use preferences.

| Ecosystem Values | Area (Sq. km.) | Dominant ES ($D$)[a] | Count (P0)[b] | Percent (P1)[c] | Richness (R)[d] | Dominance (D1)[e] | Density (D2)[f] | Diversity (D3)[g] |
|---|---|---|---|---|---|---|---|---|
| Protected areas | 6284 | Recreation ($n$ = 429) | 1830 | 34% | 14 | 0.18 | .29 | .87 |
| State commons | 4702 | Recreation ($n$ = 237) | 989 | 18% | 14 | 0.22 | .21 | .87 |
| Village commons | 1972 | Hunting/fishing ($n$ = 95) | 446 | 8% | 14 | .03 | .23 | .87 |
| Private | 8700 | Recreation ($n$ = 737) | 3149 | 58% | 14 | 0.32 | .36 | .88 |
| Village commons & protected | 1528 | Hunting/fishing ($n$ = 71) | 322 | 6% | 14 | 0.23 | .21 | .87 |
| State commons & protected | 2959 | Recreation ($n$ = 176) | 693 | 13% | 14 | 0.24 | .23 | .86 |

| Land use preferences | Dominant Pref. ($D$)[a] | Count (P0)[b] | Percent (P1)[c] | Richness (R)[d] | Dominance (D1)[e] | Density (D2)[f] | Diversity (D3)[g] | Conflict index (rank) (C1)[h] | Weighted (rank) (C2)[i] | Weighted (rank) (C3)[j] |
|---|---|---|---|---|---|---|---|---|---|---|
| Protected areas | Increase predator control ($n$ = 114) | 838 | 34% | 24 | .37 | .13 | .94 | 4.9 (2) | 333.3 (2) | 8967 (2) |
| State commons | Increase predator control ($n$ = 54) | 397 | 16% | 24 | .37 | .08 | .94 | 4.7 (3) | 156.0 (3) | 4648 (3) |
| Village commons | Increase predator control ($n$ = 41) | 188 | 8% | 20 | .56 | .10 | .91 | 3.0 (5) | 40.8 (5) | 1338 (5) |
| Private | Increase fishing ($n$ = 106) | 1409 | 57% | 24 | .03 | .16 | .95 | 5.9 (1) | 766.4 (1) | 18579 (1) |
| Village commons & protected | Increase predator control ($n$ = 30) | 109 | 4% | 18 | .60 | .07 | .90 | 2.1 (6) | 16.0 (6) | 676 (6) |
| State commons & protected | Increase predator control ($n$ = 41) | 269 | 11% | 24 | .39 | .09 | .93 | 4.7 (4) | 98.8 (4) | 3257 (4) |

[a] $D$ = The most frequently mapped category within area.

[b] P0 = Total number of mapped points within category.

[c] P1 = Percent of total mapped points (values or preferences) by land tenure category.

[d] $R$ = Number of ecosystem value categories or preferences mapped within the landscape unit. Range is from 0 to 14 for ecosystem values and 0 to 24 for pReferences.

[e] D1 = Number of points in largest category less the number of points in second largest category divided by number of points in largest category. Ranges from 0 to 1 where 1 = largest category is completely dominant; 0 = two largest categories have same number of mapped points.

[f] D2 = Number of points mapped within area divided by number of square kilometers.

[g] D3 = Simpson's diversity index calculated as follows: $D3 = 1 - \left(\frac{\Sigma n(n-1)}{\Sigma N(N-1)}\right)$ where $n$ = number of points for an ecosystem value (or preference) and $N$ is the total number of ecosystem values (preferences). Values range from 0 to 1 with values approaching 1 having greater diversity. The diversity index was calculated for the total area of land tenure category.

[h] See formula in body of article. Higher index = greater potential for conflict.

[i] Index weighted by number of preference markers.

[j] Index weighted by number of ecosystem value markers.

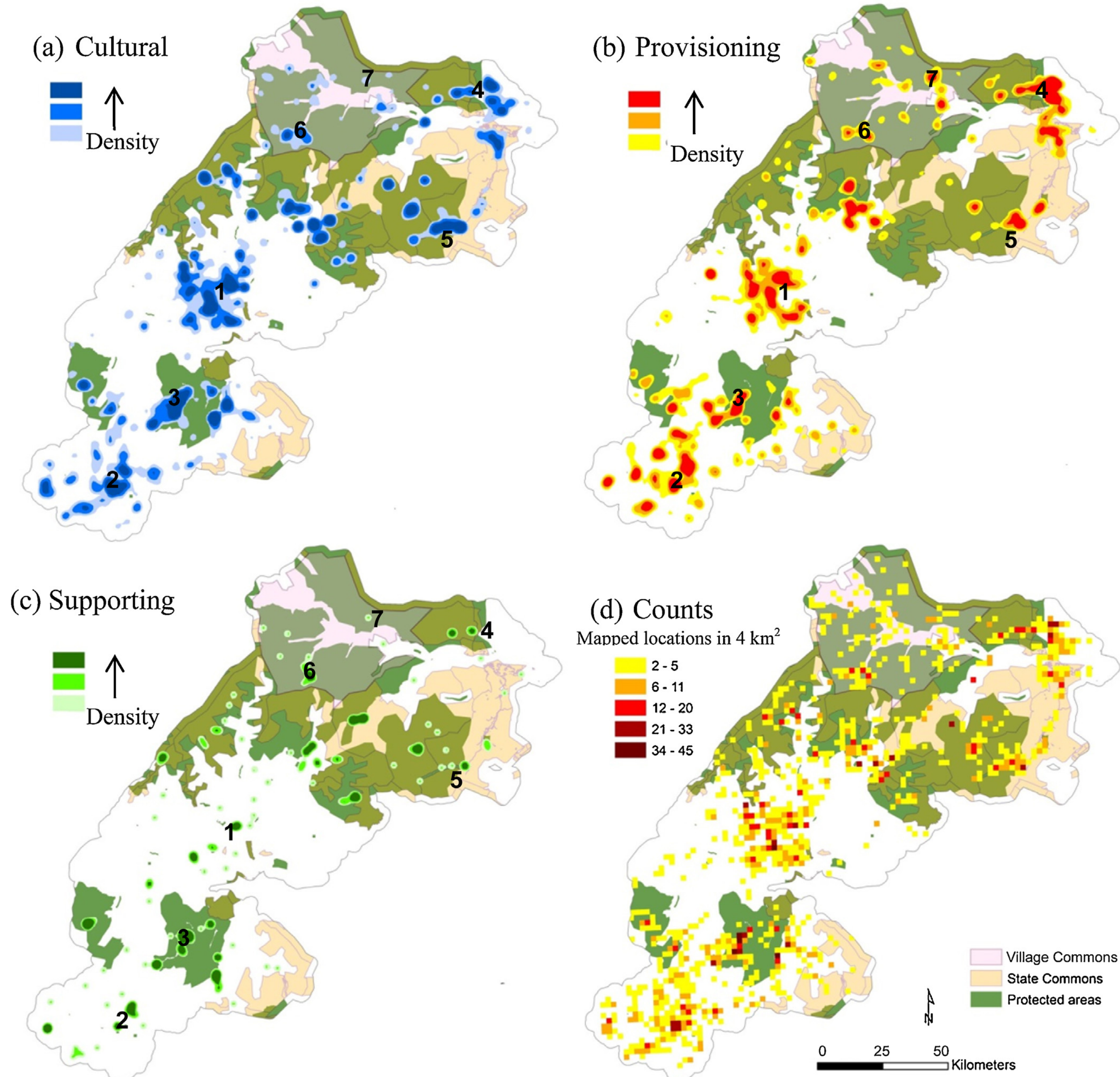


**Fig. 3.** Distribution of mapped ecosystem servicesin study region: (a) Cultural services; (b) Provisioning services; (c) supporting services (biological diversity), and (d) marker counts. The density legend shows isopleths capturing 30, 50, and 70% of markers. The numbered geographic places on the maps are described in the results section.

viced by an upland cruise ship that starts in Gjende in Jotunheimen and provides access to three staffed tourist cabin complexes (**5**). In the village commons (**6**) there is a large summer farm complex that includes therapeutic values connected to nature—culture trails, sauna, and recreational hunting and fishing. Whereas state commons have cultural hotspots associated with tourism activities, the village commons areas are primarily valued for their provisioning services. Places important for hunting and fishing are dispersed throughout the village commons, but there are hotspots located in the Otta valley (7).

To determine whether values were mapped in spatial ecosystem "bundles", we performed factor analysis on the quantities of values found within two kilometer grid cells across the study region. The results of the factor analysis appear in Table 7. Three factors were extracted from the 14 values that account for 50 percent of the overall variance. The values that load on the first factor and capture 32% of the variance are items that relate to physical qualities of place—the scenic beauty, clean water, biological diversity, undisturbed character, and recreational opportunities that are intrinsic to the place. The special place marker also loaded on this factor with marker annotations indicating these places also had values associated with scenic beauty, undisturbed nature, recreation, or a mix of these. One interpretation of this factor is that the non-cultural values of biological diversity and clean water are physical place qualities that enable the cultural services identified in this factor—scenic beauty, undisturbed nature, and the desire to recreate in these places. The second factor, explaining 10% of the variance, loads values that relate more to the psychological state of the participant rather than the physical qualities of place. The places where people go to socialize are also places

**Table 7**
Results of factor analysis derived from spatial distribution of ecosystem values (marker counts per 2 km grid cell) using principal components extraction (PCA) with varimax rotation. Three factors account for 50% of the overall variance. Item loadings on each factor are underlined and highlighted.

| | PCA component/ecosystem service bundle | | |
|---|---|---|---|
| Thematic content<br>Ecosystem value classification[a] | 1<br>(λ = 4.5, 32%)<br>Cultural (place) | 2<br>(λ = 1.3, 10%)<br>Cultural (personal) | 3<br>(λ = 1.1, 8%)<br>Provisioning |
| (P) Hunting/fishing | .135 | .235 | .666 |
| (P) Pastures/fodder | .079 | .007 | .681 |
| (P) Gathering | .111 | .047 | .670 |
| (P) Clean water | .578 | −.017 | .239 |
| (C) Recreation | .560 | .159 | .548 |
| (C) Beautiful areas | .672 | .237 | .360 |
| (C) Culture/identity | .547 | .396 | .239 |
| (C) Income | .448 | .531 | .163 |
| (C) Undisturbed nature | .677 | .099 | .088 |
| (C) Social | .173 | .705 | .250 |
| (C) Spiritual | .109 | .596 | −.042 |
| (C) Therapeutic/health | −.012 | .759 | .146 |
| (C) Special places | .433 | .421 | −.059 |
| (S) Biological diversity | .638 | .105 | −.028 |

[a] P = provisioning, C = cultural, S = supporting.

that result in feeling better physically (therapeutic/health value) and emotionally (spiritual). Places like this also tend to be tourist destinations and hence the potential rationale for the loading of income value on this factor. The third factor, explaining 8% of variance, perhaps has the most intuitive interpretation, as places for provisioning—hunting/fishing, pasturing animals, or gathering items from nature such as mushrooms and berries. That recreation value also loads on this factor is not surprising given that Norwegians consider hunting/fishing and gathering as a type of recreation as much as a type of subsistence activity.

## 5. Discussion

Few studies have addressed the relationship between overlapping land tenures, protected areas, and ecosystem services (Holland et al., 2014; Robinson et al., 2014). This study presents the results of the first PPGIS study in Norway, and the first study to examine the distribution of ecosystem values by land tenure and protected area designation. Our results indicate that land tenure is a significantly stronger predictor of the distribution of ecosystem values in southern Norway than protected area status. The difference between the village and the state commons is striking, given their location in the uplands and their shared origin as subsistence agroecosystems. State commons are valued for their biological diversity and undisturbed natural quality, while village commons are valued for their hunting and fishing opportunities. Ecosystem values on private lands were concentrated in lowlands near settlements and reflect a strong cultural identity to engagement with gathering activities. Private lands also have more diverse social values with a greater potential for land use conflict. Relatively recent protected area designations on top of existing land tenures that emerged from the global conservation movement were not equally represented by the values and preferences that participants mapped in the underlying land tenure classes. Our results confirm the importance of the customary land tenure associated with grazing, fishing and hunting for understanding local values and preferences (Berge, 2006; Hausner et al., 2012).

According to Berge (2006), values and preferences inherent in the old land tenures in Norway that were built on usufruct rights to consumptive uses and passed through generations, are likely to come in conflict with more urbanized values that promote conservation through protected areas. However, like Bonilla-Moheno et al. (2013) we found that the different common properties cannot be pooled together when analyzing relationships with land use values or preferences. Despite the shared roots of subsistence uses such as grazing, hunting, fishing, firewood, and timber, the state commons do not share all values and preferences with the village commons. The protected areas that overlay state commons, Jotunheimen and Jostedalsbreen, are tourist hotspots in Norway, and provision of tourism facilities in the park is a major source of income for the villages nearby. There was also less emphasis on hunting, fishing and grazing than expected in the state commons. Ecosystem values and land use preferences identified in the state commons appear consistent with the biodiversity, wilderness, and amenity values that are typically associated with protected areas. These values also form ecosystem service bundles and overlap in our study area (Table 7; Appendix C, E of Supplementary information). Our results are confirmed by Haukeland et al. (2011) who showed that allocation of hunting and fishing rights to locals versus visitors could cause conflict in the state commons, but in general, both rural users and tourism interests are supportive of park values. The main potential for land use conflict on state commons is second homes or cabins, suggesting the potential overuse of these commons areas, or respondent preferences for traditional values, or a combination of these reasons.

In the village commons, all members have hunting and fishing rights that reflect strong traditional values associated with consumptive uses. The hunting of large game, particularly wild reindeer, is especially valuable for these communities and could explain the strong interest in predator control and the negative attitudes toward disturbances by motorized use (Kaltenborn et al., 2015). Traditional common rights are not affected by protected area regulations, but studies show that local people are negative to Breheimen National Park as they feel the right of disposal has been curtailed by establishing protected areas on their land (Reiten, 2013).

On private lands, land use is more diverse and concentrated near settlements and tourism hubs (Appendix A of Supplementary information, Fig. 3). Areas near people's homes are important for cultural identity, for socializing, and for gathering wild berries. Compared to PPGIS results in other countries such as Australia (Brown et al., 2014) and the U.S. (Brown and Reed, 2009), Norwegians do not specifically select protected areas or parks for recreation. This pattern can be explained by the principle of common access (*allemannsretten*) incorporated in the Outdoor Recreation Act in 1957. Similar to the rest of Scandinavia, *allemannsretten* includes access rights on ski and foot (on uncultivated land), and the right to gather wild berries, mushrooms, and other plants for non-commercial use (Kaltenborn et al., 2001). This right is fundamental to the outdoor recreation culture in Norway where as much as 70% of the population ski or hike, and more than 50% pick berries or fish (Bjerke et al., 2006). The access right limits cycling and horse riding and it does not permit motorized access. Motorized use, especially recreational snowmobiling, was a major source of land use conflict in our study area.

The protected areas designated on private lands are typically Protected Landscapes (IUCN V) with the purpose of conserving cultural landscapes that are maintained by grazing. Protected area overlays on private land were valued less for being undisturbed and more for grazing and gathering than protected area overlays on commons lands. Pasture use is usually not restricted in protected landscapes, but farmers are strongly against protected area designations and maintain that landscapes are best preserved by use rather than protection (Fjellstad et al., 2009). A recent study showed that Norwegians are generally supportive of predator control, with sheep farmers and big game hunters less in favor of conservation than other groups (Gangaas et al., 2015).

### 5.1. Study limitations

As the first PPGIS study in Norway to examine ecosystem values and land use preferences through the lens of land tenure and protected area status, there were limitations on study. First, the study area was purposively selected to include the breadth of land tenures that are present in Norway. However, other areas of Norway have different distributions of commons lands and protected areas from the chosen study area. Further, selected groups such as the Sami Council exert stronger influence over land use policies in northern Norway compared to the south.

The PPGIS response rate in the study was low by survey research standards (14%), but within the range of other reported general public sample PPGIS studies (Brown and Kyttä, 2014). There were some technical, internet access problems early in the administration of the study website that prevented some users from accessing the survey. These access problems likely frustrated some prospective participants, thus reducing the potential response rate by several percentage points. The respondents were representative of residents living in the region on the sociodemographic variables of age, income, and family structure, but somewhat biased toward higher male participation and higher levels of formal education.

All PPGIS studies require limits on the number of spatial attributes that are requested to be mapped. In this particular study, the spatial attributes were limited to those thought most important by the research team after pre-testing. The research team would have liked to include more spatial attributes for mapping, but participant effort to do the mapping is finite. The addition of more spatial markers does not actually yield more spatial data, but simply dilutes the mapping effort across the range of markers.

With any type of mapping activity, there will be some spatial error in marker placement. Previous research on the spatial accuracy of PPGIS mapping suggests that the spatial error is often less than expected and that participants achieve a reasonably high level of accuracy (Brown, 2012; Brown et al., 2014). Although the spatial accuracy of the PPGIS data collected in this study has not been benchmarked, there is no evidence that study participants were more or less accurate than PPGIS studies reported elsewhere. Further, an intentional design of the study was not to identify village and state commons areas on the base map. Thus, spatial markers were placed by participants blinded to the actual commons boundaries, allowing significant spatial associations to emerge inductively without the potential for information bias.

## 6. Conclusion

Our results demonstrate the need to understand protected area overlays on existing lands as overlapping tenures with complex bundles of rights (Holland et al., 2014) that influence perceived ecosystem values and land use preferences. Land tenures that have existed since pre-medieval times were more strongly associated with ecosystem values and land use preferences than protected area designations. The empirical identification of ecosystem values through participatory mapping provides spatial data that complements and contextualizes traditional ecological indicators such as deforestation. In Norway, conservation conflicts associated with protected areas and predator control in Norway can be understood in terms of rural traditions based on consumptive uses such as grazing, gathering, and big game hunting. Some common lands have evolved into tourism hubs due to the presence of iconic national parks and residents now identify these areas as having values more aligned with those promoted by protected areas. Finally, the values that were mapped most frequently, recreation and scenic values, were unrelated to both land tenure and protected areas. Closeness to homes, summer farms, second homes or cabins may provide a potential explanation for the distribution of such place-based ecosystem service bundles, but distance analysis was not included in the present study.

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## Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.landusepol.2015.08.018.

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