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RESEARCH ARTICLE

Participatory mapping reveals biocultural and nature values in the shared landscape of a Nordic UNESCO Biosphere Reserve

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Abstract

1. Making the right decisions for sustainable development requires sound knowledge of the values and spatial distribution of the services co-produced by ecosystems and people. UNESCO's Man and the Biosphere programme and associated Biosphere Reserves (BRs) are key learning sites or model regions for sustainable development providing key entry points for transdisciplinary work on sustainable development. However, there is limited research exploring spatial distribution of socio-cultural Ecosystem Service (ES) values in BRs and how those values vary according to the BR zonation.
2. We used a transdisciplinary approach to design and implement a public participation geographical information systems (PPGIS) survey in a recently designated BR to (a) asses the spatial distribution of ES values in the different zones, (b) identify hotspots of ES values, (c) identify spatial bundles of ES values and (d) assess the social-ecological characteristics that determine the distribution of those values.
3. We found that stakeholders identify high biocultural ES values, mapping predominantly places for outdoor recreation, biodiversity, agricultural products and cultural heritage. Buffer zones had high agricultural and cultural heritage values while extractive values were largely absent from cores zones. We identified five spatial ES-value bundles highlighting distinct places important for ES values related to ‘multifunctional landscapes’ located close to settlements, ‘cultural landscapes’ associated with agricultural land, ‘wild animal resources’ along the coastlines, ‘outdoor recreation and biodiversity’ and ‘passive cultural values’ widely distributed in high and moderately populated areas.
4. We found that accessibility was important for ES values and that people value nature close to where they live. We show the importance of biocultural values in the region, and agricultural landscapes were highly valued for multiple ES values beyond agricultural products alone.
5. We show that BRs have become places that link cultural heritage, agricultural and biodiversity values in multifunctional landscapes. We put our findings into the local context and suggest how they can inform land-use planning and management through policies aimed at maintaining key agricultural landscapes that

provide social-ecological resilience. Additionally, we discuss the value of our study for the wider BR network and how similar work can contribute to monitoring of BR implementation.

KEYWORDS

Biosphere Reserve, ecosystem services, Man and the Biosphere programme, nature's contributions to people, public participation geographical information systems, sustainable development, transdisciplinarity

1 | INTRODUCTION

Today, we are facing global sustainability challenges that are complex and interconnected. Human activities such as land-use change are contributing to the biodiversity crisis and simultaneously impacting our own well-being. To address these challenges, we need to develop a holistic understanding of multifunctional landscapes that work for biodiversity and people (Kremen & Merenlender, 2018). In 1971, UNESCO launched the Man and the Biosphere (MAB) programme which aims 'to establish a scientific basis for improvement of relationships between people and their environments' (UNESCO, 2017, p. 12). In 1974, MAB began designating Biosphere Reserves (BRs) which today comprises 727 BRs in 131 countries in the World Network of Biosphere Reserves. These BRs are examples of social-ecological systems spanning numerous biomes and ecosystems that have been described broadly as learning sites, living laboratories or model regions for sustainable development (Kratzer, 2018; Schultz et al., 2018; Starger, 2016) forming the basis for implementation of the recently updated *MAB Strategy* (2015–2025) and the *Lima Action Plan* (2016–2025) (UNESCO, 2017). The *Lima Action Plan* clearly highlights BRs as sites that are expected to be sources and stewards of ecosystem services (ES) and that contribute to achieving the UN Sustainable Development Goals (SDGs) (United Nations, 2015).

The Seville Strategy (UNESCO, 1996) gives BRs three primary interconnected functions: (a) conservation, (b) sustainable development and (c) logistic support for project, education, research and monitoring, and these are implemented through a system of zonation comprising core, buffer and transition zones. Importantly, 'conservation' across the BR refers not only to biodiversity conservation, but also to cultural diversity conservation. The focus on biocultural diversity and the consideration of 'people and nature' (Mace, 2014; Pascual et al., 2021) align BRs closely with changing conservation narratives (Bridgewater, 2002; Gavin et al., 2015; Pascual et al., 2021). It is important to understand whether BRs are achieving their three functions, as the periodic decadal reviews set out by *The Seville Strategy* have mixed compliance results (Coetzer et al., 2014; Price et al., 2010; UNESCO, 1996). Thus, developing processes to contribute to compliance monitoring of zonation in the early stages of a BR's lifetime will enable compliance and goal monitoring.

The ecosystem services (ES) concept is a powerful lens through which to understand human–nature relationships (Folke et al., 2011) and can contribute to meeting sustainability targets such as the SDGs (Plieninger et al., 2013; Wood et al., 2018). The ES concept was developed to highlight the importance of biodiversity for human well-being (Ehrlich & Ehrlich, 1981; Westman, 1977) with the intention to secure public interest and support in biodiversity conservation (Gómez-Baggethun et al., 2010). Ecosystem services are now mainstream in the social-ecological literature and becoming evident in policies related to land-use and land planning (Longato et al., 2021; Maes, Egoh, et al., 2012). Translating knowledge to action through policy is an important part of problem-driven research including several areas of ES research (Cowling et al., 2008; Crouzat et al., 2018), and initiatives like the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES, 2019) have provided impetus for broad-scale consideration of ES. While monetary valuation of ESs has generated political interest in their protection, preservation and enhancement, through initiatives such as Payments of Ecosystem Services schemes (e.g. Muradian et al., 2013; Vatn, 2010), there are very real concerns of nature commodification (Gómez-Baggethun et al., 2010). Moreover, the ways in which people value nature are diverse and often independent of monetary value which to date have been underrepresented in policy and decision-making (Pascual et al., 2017). For just and equitable decision-making, it is therefore important to explore alternatives for ES valuation that are not only dependent on market mechanisms and consider the multiple ways that people value nature (Pascual et al., 2017).

To inform sustainable land-use planning, we need to know how ESs vary quantitatively and spatially across different social-ecological contexts (Cowling et al., 2008; Schröter et al., 2014). The burgeoning field of ES mapping (Burkhard & Maes, 2017) has focussed on regulating and provisioning ES with fewer studies mapping cultural ES (Crossman et al., 2013; Egoh et al., 2012; Martínez-Harms & Balvanera, 2012). Over the past 15 years, there has been a shift in the methodologies and approaches used for assessing and mapping ES, from largely single discipline biophysical and economic methods, towards a higher proportion of pluralistic and socio-cultural methods (Martín-López et al., 2019; Schutter & Hicks, 2021). This methodological shift accompanies the conceptual developments in ES thinking that include the multiple contributions that nature makes to our well-being (e.g. Díaz et al., 2018; Maes et al., 2018; Pascual et al., 2017). Public participation geographical information systems (PPGIS) has emerged as a promising tool for mapping socio-cultural ES values (reviewed by Brown & Fagerholm, 2015; Maes et al., 2018), by asking participants to geolocate values for different ES on maps. Cultural, and to a lesser degree provisioning ES are prominent in PPGIS-ES research either due to the ES typology provided to participants (i.e. limited to cultural ES) or because of participant preferences for and/or ability to connect with cultural ES (Brown & Fagerholm, 2015). For example, Scholte et al. (2015) point out that people may not always perceive the capacity of an ecosystem to provide ES because our perceptions are shaped by our interactions with, and knowledge of nature. Therefore, we should expect that non-experts are more likely to values cultural ES which they experience regularly and less likely to appreciate complex regulating ES such as mass flow regulation.

The power of PPGIS to generate spatial knowledge on cultural ES, especially the values that people place on them, is a significant advantage over biophysical ES mapping methods that have been used for cultural ES to date. Spatial distributions of ES values can provide valuable information for planning and management since social acceptance is likely higher when decisions are informed by a wide section of society (Brown et al., 2020). However, there is little evidence that PPGIS has had much impact in real-world planning (Brown & Fagerholm, 2015; Brown et al., 2020). Likewise, the integration of ES in spatial planning remains uncommon (Longato et al., 2021). There are several barriers to the implementation of PPGIS and ES in land-use planning, related to the lack of political will to appreciate the value of local knowledge (Brown et al., 2020). There is therefore a need to find ways to negotiate a place for local knowledge in the political process of land-use planning and allow PPGIS to live up to its promise in planning decision support.

The BR framework and its World Network of BRs can provide an entry point to integrate a PPGIS approach to ES assessments into decision-making. Objective three of the MAB Strategy (UNESCO, 2017) makes clear reference to *sustainability science* defined by them as ‘an integrated, problem-solving approach that draws on the full range of scientific, traditional and [I]ndigenous knowledge in a transdisciplinary way to identify, understand and address present and future economic, environmental, ethical and societal challenges related to sustainable development’ (UNESCO, 2017, p. 19). This definition underscores the importance of Indigenous and local knowledge, science–society relationships through transdisciplinary processes, and learning and education (Reed, 2020). PPGIS is well suited to MAB objectives related to indigenous and local knowledge on ES because of the strong place-based dimension of that type of knowledge (Raymond et al., 2009). Indeed, a recent report has called for a common protocol for ES assessments in BRs that makes clear recommendations related to broad stakeholder inclusion as well as for the use of maps in stakeholder engagement (Vasseur & Siron, 2019).

Nordhordland UNESCO Biosphere (NBR) in Norway (Kaland et al., 2018) was designated in 2019. This BR is a collaboration between public, private and academic actors and presents an opportunity for baseline transdisciplinary studies on biocultural values, sustainable development and human–nature relationships in NBR. Such studies can contribute to all three aims as set out in the Seville Strategy. We use PPGIS to assess ES values of stakeholders in NBR in a participatory approach engaging key stakeholders to develop the ES typology and then more widely with inhabitants, part-time inhabitants, governance organisations and other key stakeholders to assess spatial distributions of ES values. First, we ask where hotspots of ES values are located within NBR. Second, we ask if there are distinct spatial bundles of ES values in NBR, what those bundles are, where they occur and what are the landscape characteristics associated with them. Third, we compare and contrast the ES values of the designated BR zones. Finally, we reflect on the ES values in relation to zonation in NBR and consider the wider potential for PPGIS in other BRs.

2 | METHODS

2.1 | Study area

Nordhordland UNESCO Biosphere is located on the west coast of Norway covering *c.* 6,698 km^2 stretching from the open Atlantic Ocean and coastal flats in the west, up to the mountains in the east reaching up to 1,313 m a.s.l. at Kleivfjellet (Figure 1). Extensive fjord systems comprise an important component of NBR, including Sognefjorden; Europe's longest, and Norway's longest and deepest fjord (205 km long and 1,308 m maximum depth). Terrestrial land-covers with the greatest areal extents are open and sparse vegetation, and forest along with marine ecosystems in the fjords and open ocean (Figure 1; Table S1).

The climate is a wet-temperate oceanic climate with mean annual precipitation of 2,400 mm and a strong west-east gradient from coast to the mountains; coastal areas receive 1,300 mm precipitation per year while the upland areas receive 3,000 mm. Mean temperatures of the warmest and coldest months are 13.0–14.5°C and 3.0–3.0°C, respectively, in the coastal areas. Temperature variation on the coast is modest with the difference between the warmest and coldest months being 11°C while inland the difference is greater at 16°C.

Employment is predominantly provided by public services while economic activity is dominated by the petroleum industry centred at Mongstad comprising Norway's largest oil refinery and other petroleum businesses. The region is an important provider of hydroelectricity at the national level with production centred in Modalen and Masfjorden municipalities. Although agriculture and fishing are not major economic players, they are nonetheless culturally significant. Aquaculture and fisheries are important industries with large pelagic fish stock and salmon aquaculture which is projected to expand in the future.

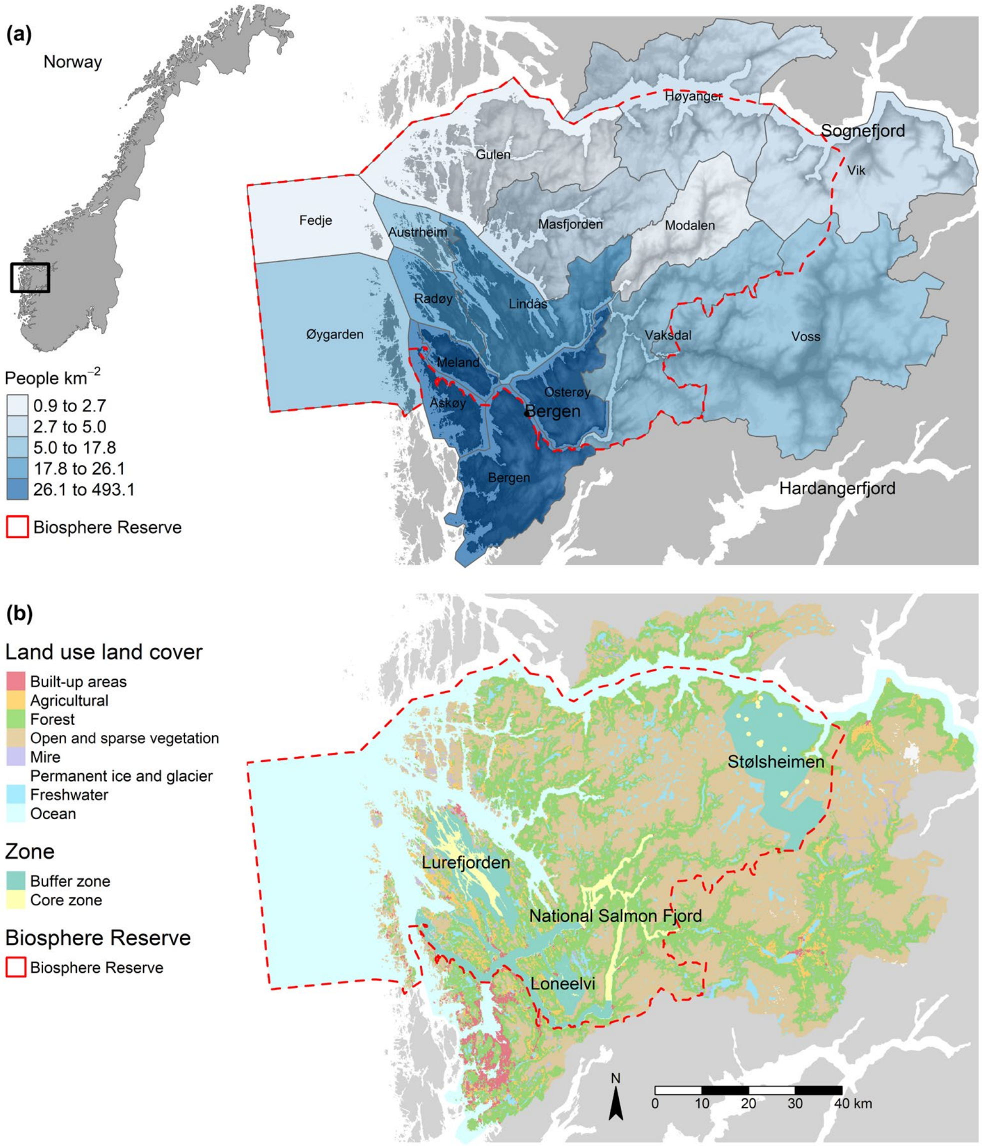

FIGURE 1 (a) Location and population densities of the municipalities and (b) land use-landcover and the location of the different zones and in Nordhordland UNESCO Biosphere on the west coast of Norway

NBR comprises nine municipalities that are contained entirely with its boundaries, with a further five partially within the boundaries (Figure 1). The permanent human population of the nine main municipalities is *c*. 54,000 concentrated in the low-lying south-western coastal areas (Figure 1a) along with an additional *c*. 15,000 seasonal residents comprising predominantly holiday-home owners (Kaland et al., 2018). A further *c*. 332,000 people live in the additional five municipalities, concentrated primarily in Bergen municipality (*c*. 281,190 people).

The zonation of NBR comprises four localities with a core and buffer zone associated with each of those localities (Kaland et al., 2018; Figure 1). The zones represent all the major landscape and seascape in NBR, including the coast and outer archipelago (Lurefjorden), the fjord landscape (National Salmon Fjord and Loneelvi River) and the mountain landscape (Stølsheimen; Figure 1). Each locality has its own unique characteristics encompassing the breadth biocultural diversity found in NBR including cultural heritage monuments and upland summer farms at Stølsheimen, agricultural and cultural landscapes in the buffer zones of Loneelvi and Lurefjorden, and important biodiversity and research sites in the core areas of Lurefjorden and the National Salmon Fjord.

2.2 | Survey design and ecosystem services typology

The ES typology and survey design was developed in three steps. First, we used the NBR UNESCO application document (Kaland et al., 2018) to identify locally relevant ES. Second, we used published literature on ES value mapping to identify ES not already included in the NBR UNESCO application document referring specifically to recent PPGIS-ES studies to guide the ES statements in the survey. The statements for each ES were based on previously published PPGIS-ES studies (e.g. Fagerholm et al., 2016, 2019; Plieninger et al., 2019) capturing the use and subjective perceptions components of socio-cultural values of ES (cf. Scholte et al., 2015). Finally, we used a workshop with local stakeholders to test the survey and typology asking whether the ES identified by us were perceived as relevant to them, or if there were any ES we had missed, and if the statements in the survey were interpretable by them. We assembled a stakeholder group facilitated by an existing relationship between NBR's coordinators, municipalities and scientists. The stakeholder group included local food producers (2), municipality planners (3), agricultural advisors (2) and members of the NBR working group (2). Two of the participants were both farmers and agricultural advisors. The final typology comprised 12 ES (Appendix 1). We have in general attempted to link the ES to the Common International Classification of Ecosystem Services (CICES; Haines-Young & Potschin, 2018). However, we modified both the typology and ES statements, so they were locally relevant and understandable to non-experts based on feedback obtained during the focus group. Thus, our ES statements and typology is a balance between a commonly accepted ES typology and interpretability for local stakeholders. Two of our ES, 'hunting and fishing' and 'wild plants, berries and mushrooms for food' can be classified as cultural and as provisioning ES since both provide food and are linked to social interaction, recreation and cultural traditions (Stryamets et al., 2015; Vári et al., 2020). However, we have considered these as cultural ES which is consistent with the socio-demographics of NBR and other studies in similar contexts (Malmborg et al., 2021; Meacham et al., 2016; Quieroz et al., 2015; Stryamets et al., 2015).

2.3 | Data collection

We used a web-based PPGIS survey in Maptionnaire (Mapita Oy, 2019, https://app.maptionnaire.com/en/6998/) to collect ES values in NBR. Survey participants were recruited through various methods including targeted email lists comprising local actors from organisations involved in resource management, local and regional government, agriculture, nature conservation, forestry and energy production; articles about the project and survey in one regional newspaper and two local newspapers; boosted social media adverts; and promotions on the NBR social media accounts. We encouraged key actors to share the survey through snowballing. In addition, we organised 18 workshops at local libraries and community halls in 12 municipalities between 10 February and 13 April 2020 (Table S2). The final four workshops scheduled after 11 March were cancelled due to COVID-19 restrictions. The restriction meant that there was one municipality entirely within, and one partially within NBR that we could not hold a workshop. Workshop participants were recruited using advertisements by posting flyers with the schedule on municipality webpages, library noticeboards and newspaper listings. At the workshops, a short presentation about the project was given, allowing for questions from participants, followed by an opportunity for attendees to take the survey on laptops provided by us. We provided guidance on functionality and clarified questions that participants had. The total number of participants at the 14 workshops we were able to hold was 30 ranging between zero and eight (median 2). See Table S2 for more details of workshop attendance.

The survey was open from 3 February to 2 June 2020. Participants mapped points related to ES within our typology and were able to map as many or as few points as they chose; we recommended between 10 and 20 points. In addition, we asked participants to provide socio-demographic information. Ethics approval was obtained from The Norwegian Centre for Research Data (Naturgoder i Nordhordland UNESCO Biosfæreområde, Ref no. 657151). All participants gave consent in accordance with the conditions approved by The Norwegian Centre for Research Data prior to filling out the survey.

2.4 | Analyses

2.4.1 | Hotspot analysis

We used kernel densities to represent and visualise hotspots of ES categories mapped by participants: provisioning, cultural and regulating (Brown et al., 2015; Hausner et al., 2015). Kernel density estimates were calculated in R (R Core Team, 2020) using the *sp.ke* function in the SPATIALECO package (Evans, 2020) using a cell size of 100 m and an appropriate bandwidth for each ES category (Brunsdon & Comber, 2019). We used nearest neighbour (NN) ratios to test for clustering in each ES category calculated with the *nni* function in SPATIALECO (Evans, 2020).

2.4.2 | Ecosystem service bundles

We assessed bundles of ES values—groups of repeatedly co-occurring ES (Raudsepp-Hearne et al., 2010)—at a grid scale. There is no 'perfect cell size' for determining bundles so we chose 500 m as it was large enough to capture multiple points per cell and closest to the most similar study of this type (Plieninger et al., 2019). We calculated the cell point-densities of each ES, removed all cells that contained zero mapped points and used principal component analysis (PCA) to reduce the dimensionality of the data (Brown et al., 2015; Plieninger et al., 2019). We selected the number of components that explained at least 65% of the variance and applied varimax rotation (Brown et al., 2015; Plieninger et al., 2019; Zoderer et al., 2019). The best number of clusters was determined using hierarchical clustering on the factor loadings with the 'NbClust' function in NBCLUST package (Charrad et al., 2014) setting the distance measure to 'euclidean', the method to 'ward.D', the index to 'alllong' and the Beale's index ('alphaBeale') to a significance value of 0.1 (Madrigal-Martínez & Miralles i García, 2020). Cells were then assigned to clusters using 'hclust' and 'cutree' functions (R Core Team, 2020). Finally, we calculated the mean number of points of each ES value per grid cell per cluster and visualised them with flower petal diagrams in GGPLOT2 (Wickham, 2016).

2.4.3 | Maximum entropy modelling

We used maximum entropy (MaxEnt) modelling to assess the importance of spatial landscape characteristics in determining the distribution of mapped ES-value bundles. MaxEnt modelling is used widely in ecology and biogeography for species distribution models (SDMs) and is increasingly used in modelling ES and landscape values from PPGIS surveys (e.g. Muñoz et al., 2020; Sherrouse et al., 2011, 2014). We selected 10 variables at a resolution of 500 m (distance from roads, buildings, and hiking trails, percentage cover of agricultural land, water, forest and open LULC types, and elevation, slope, and richness of LULC, see Table S3 & Figure S1) for the models based on previous studies (Bagstad et al., 2017; Muñoz et al., 2020; Sherrouse et al., 2014) and additional variables considered to be important social-ecological drivers of ES values in NBR. Modelling was performed with the 'maxent' function in the DISMO R package with withholding 20% of the points for model evaluation and 10,000 background points (Hijmans et al., 2020). Models were evaluated using area under the receiver operator curve (AUC) in which we considered scores of 0.5–0.7, 0.7–0.9 and 0.9 poor, moderate and excellent model performances, respectively. We compared predicted distributions of the bundles using 'calc.niche.overlap' with ENMTOOLS (Warren & Dinnage, 2021) which computes the overlap in predicted distributions ranging from 1 (identical distributions) to 0 (no overlap at all).

2.4.4 | Ecosystem service values and Biosphere Reserve zonation

We overlaid the PPGIS points with the different zones and counted the number of points for each ES value in each zone to assess stakeholders' ES values. Before overlaying the points, we created a polygon buffer of 10 m around each point to account for mapping precision inaccuracies (Fagerholm et al., 2019). We chose a smaller buffer than used in other studies to avoid too much overlap between terrestrial and aquatic values. Flower petal plots were used to visualise the relative differences in the proportion of ES values mapped within the whole of NBR, the three main zones and among the specific zones.

3 | RESULTS

3.1 | Socio-demographics of participants

The proportion of respondents per municipality was different to the proportion of the general population (X^2 = 105.79, $p < 0.001$, Table 1). There was an over representation of participants in the smaller municipalities with smaller populations, including Fedje, Masfjorden and Modalen (X^2 residuals = 4.43, 2.51 and 7.76, respectively) and an underrepresentation in Osterøy (X^2 residual = −2.95). The respondents were also typically older and had higher levels of education than the population in NBR (age: X^2 = 350.71, $p < 0.001$; education: X^2 = 74.66, $p < 0.001$; Table 1). There was no difference in sex representation between the sample and the population of NBR and in general respondents reported high levels of regional knowledge (Table 1).

3.2 | Mapped ecosystems services

Overall, 433 study participants mapped 3,155 individual points linked to ES values in NBR. Cultural ES values were the most mapped category (2,277 points), followed by provisioning (524 points) and regulating (354 points, Figure 2). Outdoor recreation was the most mapped (768 points) followed by appreciation of biodiversity (366 points). Protection for extreme events/weather, energy and climate change mitigation were the least mapped (51, 81 and 106 points, respectively).

3.2.1 | Biosphere Reserve zones

Mapped ES values within the transition zone were almost identical to those mapped across the whole of NBR (Figure 2). The buffer and transition zones differed only slightly with moderately higher agricultural and cultural heritage values in the buffer zone. There was, however, a marked difference between the core, and the buffer and transition zones with hunting and fishing, and clean air, water and soil values being higher in the core zone than the other two zones. Furthermore, agricultural values were largely absent from the core zone.

There were noticeable differences in mapped ES values between adjacent buffer and core zones aside from in the Stølsheimen area. Here, both the core and buffer zones were dominated by outdoor recreation values with relatively low frequencies of other ES values. The two buffer zones that are adjacent to aquatic core zones (i.e. Lurefjorden and Loneelvi) had high agricultural and outdoor recreation values. Lurefjorden buffer zone also had high cultural heritage values. All three zones located within marine environments (i.e. Lurefjorden core, Salmon fjord core and buffer) had high fishing values.

Values for all three ES categories were significantly clustered, although cultural ES more so than regulating and provisioning (Figure 3; Cultural—NN = 0.605, z-score = −36.0, p-value = 0.001, Provisioning—NN = 0.587, z-score = −18.1, p-value = 0.001; Regulating—NN = 0.710, z-score = −10.4, p-value = 0.001). In general, hotspots of all ES categories were associated with areas of high population densities closer to settlements in the low-lying coastal areas on the western side of NBR (Figure 3).

3.3 | Ecosystem service bundles and maximum entropy modelling

The PCA analysis identified seven factors that explained 66.6% of the variance with factor loadings. Hierarchical cluster analysis of the first seven varimax rotated PCA scores identified five distinct bundles of perceived ES at the grid scale (Figure 4). We classify these as

TABLE 1 Socio-demographics of survey participants and population. Numbers in the 'Study' column represent the number of respondents and percentages relative to total survey respondents, while number in the 'Population' column represent numbers and percentages of inhabitants in relation to the whole study area as reported in census data

Variable	Study *n*	Study %[b]	Population[a] *n*	Population[a] %
Municipality lived in				
Austrheim	10	3.1 (4.6)	2,393	5.5
Fedje	10	3.1 (5.7)	473	1.1
Gulen	9	2.8 (4.2)	1,947	4.5
Lindås	83	25.8 (31.4)	12,722	29.2
Masfjorden	15	4.7 (9.2)	1,402	3.2
Meland	29	9.0 (12.4)	6,318	14.5
Modalen	12	3.7 (2.1)	300	0.7
Osterøy	19	5.9 (8.1)	6,577	15.1
Øygarden	17	5.3 (6.4)	3,906	9.0
Radøy	30	9.3 (11.7)	4,171	9.6
Vaksdal	11	3.4 (4.2)	3,326	7.6
Does not live in the region	77	23.9 (–)	–	–
Education				
Less than a high school diploma	11	3.4	72,236	22.8
High school diploma or similar	83	25.8	112,428	35.5
Bachelor or technical degree	121	37.6	91,928	29.0
Master's and PhD degree	101	31.3	38,609	12.2
Not answered	6	1.9	–	–
Sex				
Female	151	46.9		49.7
Male	156	48.4		50.3
Other	3	0.9	–	–
Prefer not to answer	8	2.5	–	–
Not answered	4	1.2	–	–
Mean age	50.4		45.7	
Age range				
15–24	17	5.3		15.5
25–34	26	8.1		14.1
35–44	50	15.5		15.3
45–54	73	22.7		16.4
55–64	80	24.8		14.9
≥64	53	16.5		23.8
Not answered	23	7.1		–
Self-reported regional knowledge[c]				
0–20	5	1.6	–	–
21–40	6	1.9	–	–
41–60	26	8.7	–	–
61–80	87	27.0	–	–
81–100	179	55.6	–	–
Not answered	17	5.4	–	–

[a]Census data from Statistics Norway (2019c).

[b]Number in parentheses denotes the municipality that respondents know the best and includes respondents who do not reside in Nordhordland UNESCO Biosphere.

[c]Knowledge of the entire region was reported by participants on a sliding scale between zero and 100.

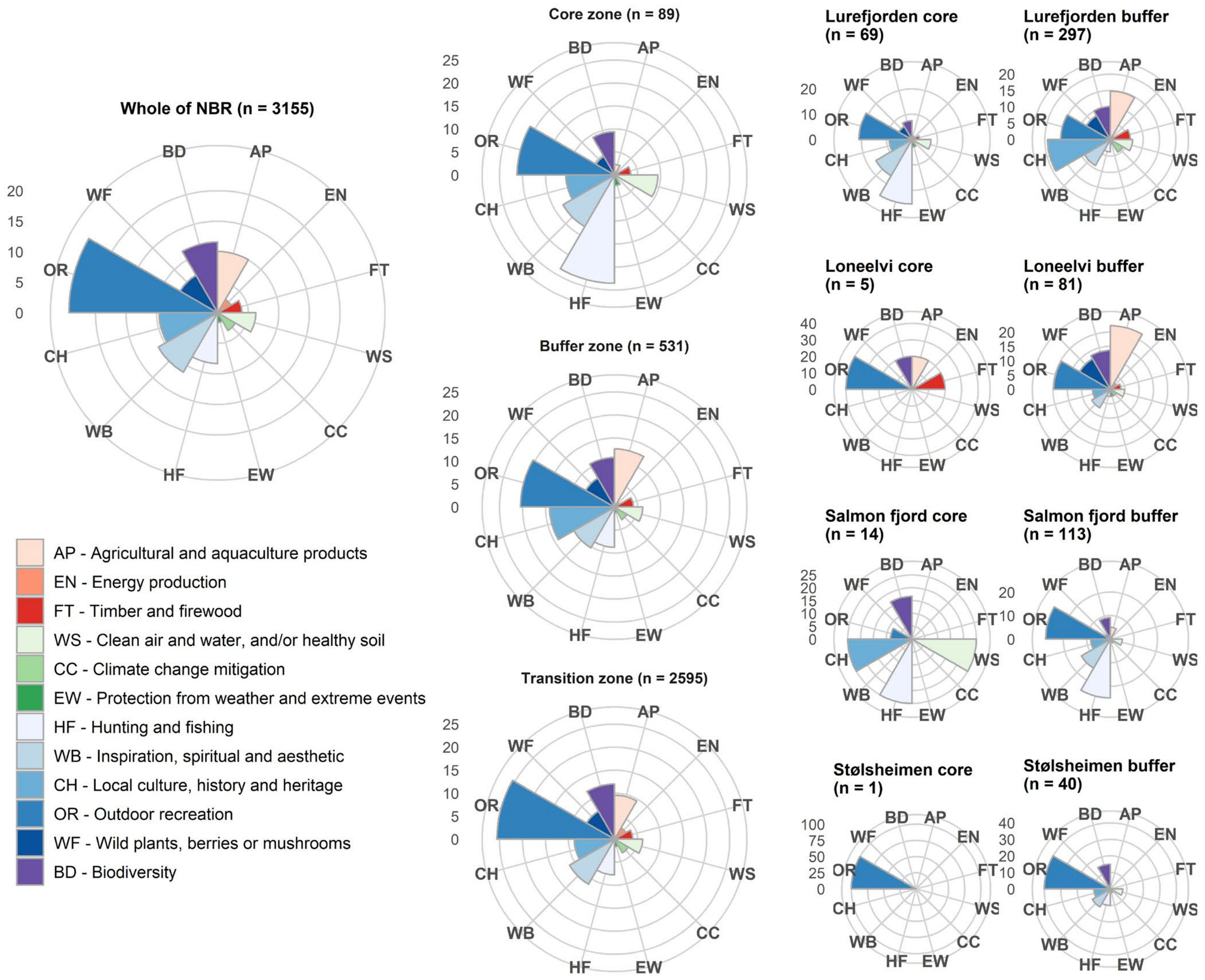

FIGURE 2 Proportion of points mapped for each ecosystem service (ES) value in the PPGIS in the whole of Nordhordland UNESCO Biosphere (NBR), the three biosphere zones and the specific zones. Petals are the percentage of points mapped per ES value within each zone and represent differences in ES values within each petal diagram

follows: 'passive cultural values' (Bundle 1, $n = 369$ cells), characterised by predominantly well-being and non-animal wild food values; 'multifunctional landscapes' (Bundle 2, $n = 229$ cells), characterised by a relatively even spread of ES values although a higher proportion provisioning relative to other ES classes; 'cultural landscapes' (Bundle 3, $n = 372$ cells), dominated by agriculture and cultural heritage values; 'active outdoor recreation' (Bundle 4, $n = 872$), characterised by dominance of outdoor recreation values, and to a lesser degree biodiversity values; and 'wild animal resources' (Bundle 5, $n = 216$ cells), dominated by hunting and fishing (Figure 4). The points in each bundle were spatially clustered, although to varying degrees. The points in 'multifunctional landscapes' was the most clustered (NN ratio = 0.34, z-score = 31.83), while the 'passive cultural values' was the least clustered (NN ratio = 0.73, z-score = −11.03).

The probability distributions from the MaxEnt models were generally similar in that highest probabilities tended to be located to the west and along the fjord coastlines (Figure 4). However, there were also clear differences in the probability distributions among the bundles. The 'passive cultural values' and 'outdoor recreation' bundles were the most similar (niche overlap = 0.895) with widely distributed, and higher distribution probabilities further inland and at higher elevations than the other bundles. The other three bundles were more restricted in their distributions with 'multifunctional landscapes' and 'cultural landscapes' being most similar (niche overlap = 0.832) and concentrated in the coastal strandflat and along the fjords. The 'wild animal resources' bundle distribution was least like all other bundles being least similar to 'cultural landscapes' (niche overlap 0.678) and most similar to 'active outdoor recreation (niche overlap 0.720), with moderate to high probability distributions in the marine environment within the fjords, and in freshwater lakes and rivers.

Topography (elevation and slope), motorised access (distance to roads) and settlements (distance to buildings) generally contributed the most to the MaxEnt models (Figure 5). Elevation, distance to roads, LULC richness and agricultural land were most important

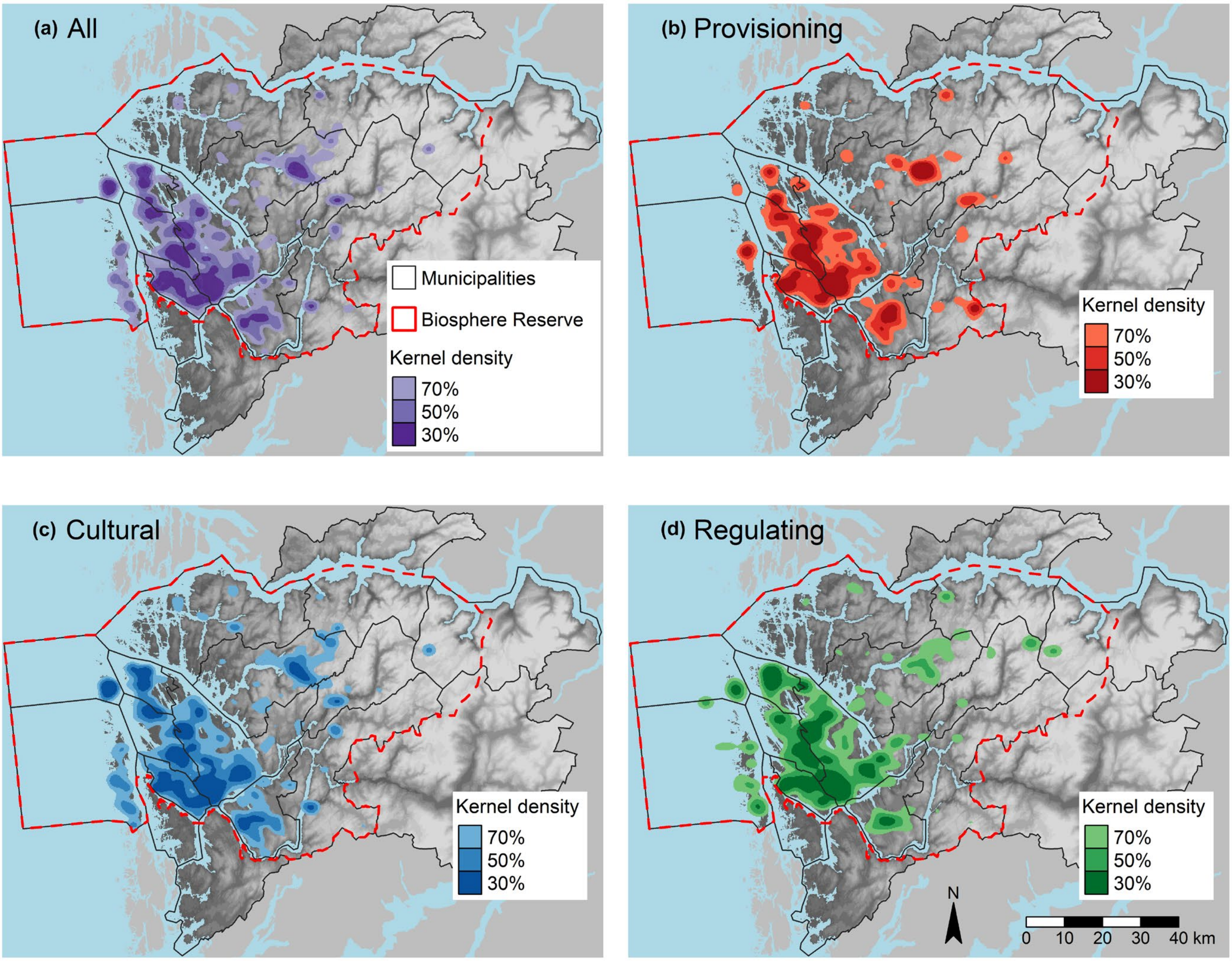

FIGURE 3 Hotspots of mapped (a) all, (b) provisioning, (c) cultural and (d) regulating ecosystem service categories in Nordhordland UNESCO Biosphere. Isopleths represent 30%, 50% and 70% of the mapped points for respective ecosystem service categories

for the passive cultural values. Motorised vehicle access, agricultural and forested land, and LULC richness were most important for the multifunctional landscapes. Distance to buildings and agricultural land were most important for the cultural landscapes bundle. Elevation, and to lesser degree distance hiking trails and buildings, and slope were important for the active outdoor recreation bundles. Distance to buildings and to a lesser degree motorised access trail, and cover of water and open land were most important for the wild animal resources bundle. Models performed moderately well with AUC scores > 0.79 for all bundles (passive cultural values = 0.81; multifunctional landscapes = 0.88; cultural landscapes = 0.86; outdoor recreation = 0.79; wild animal resources = 0.81).

4 | DISCUSSION

As places for fostering biocultural diversity and understanding the multiple connections between people and nature, BRs constitute model systems for the implementation of participatory methods for ES valuation. Our study highlights the importance of outdoor recreation, biodiversity, cultural heritage, mental well-being and agricultural values to stakeholders in NBR, and that these values tend to be highest close to where people live. We show that ES values differ in the different BR zones reflective of zonation goals, most prominently higher values for cultural and regulating services, and low values for provisioning services, in core relative to other zones. We also identify commonly co-occurring ES values, or bundles, in NBR along with the landscape characteristics that determine the spatial distribution of those bundles.

4.1 | Biosphere reserves as biocultural landscapes of people and nature

Participants in NBR mapped substantially more cultural ES values than the two other ES categories. This predominance of cultural ES

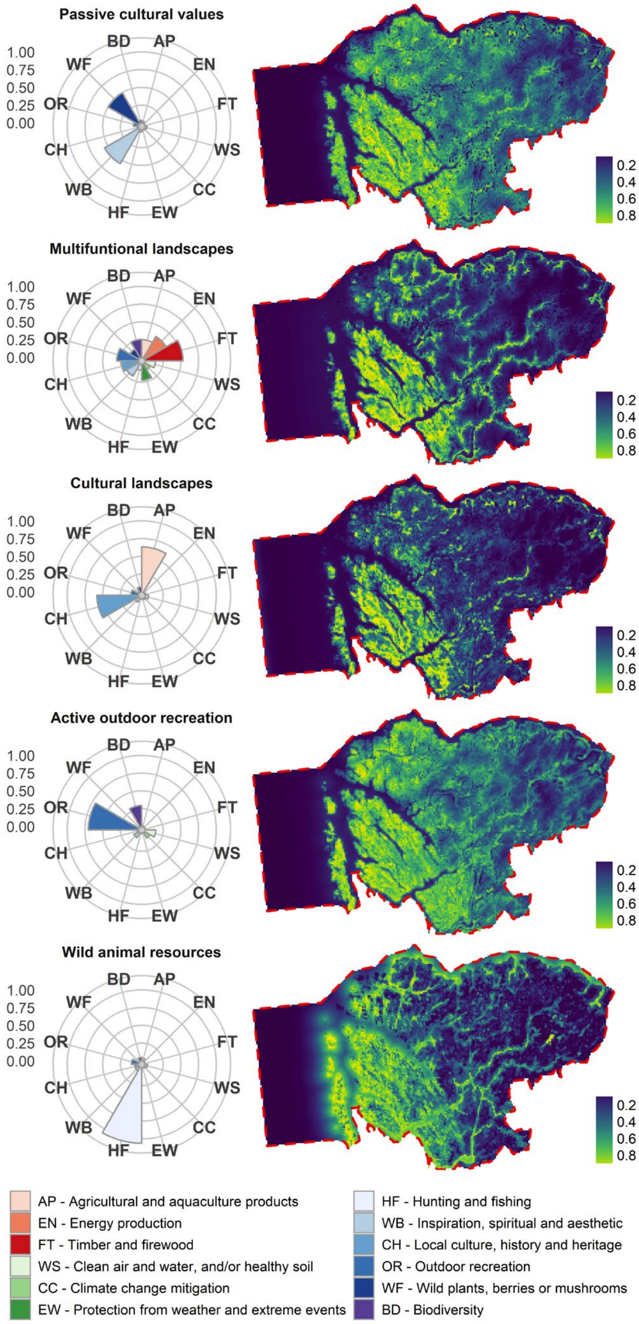

FIGURE 4 The five bundles of ecosystem service (ES) values and the MaxEnt probability surface of those clusters in Nordhordland UNESCO Biosphere. Grid cells are 0.25/km^2 and petals represent the mean number of points per 0.25/km^2 grid cell for each ES in the clusters

values is a distinctive feature of PPGIS-ES studies and the European context (e.g. Brown et al., 2012; Fagerholm et al., 2016, 2019; Raymond et al., 2009). Likewise, the low frequency of regulating ES values is also a typical characteristic of such studies. While it is acknowledged that there were more choices for cultural ES (five) than other categories (three or fewer), this is insufficient to explain the dominance of mapped cultural ES. The ability to connect with well-being associated with place-based outdoor recreation (e.g. exercise) is an important factor determining how ES are likely to be valued, resulting in higher mapping frequency for cultural ES values (Brown, 2012). This is a strength of the PPGIS method since mapping cultural ES is challenging using biophysical indicators (e.g. viewshed analysis, hiking trail density) or social media data (e.g. georeferenced social media photographs; Crossman et al., 2013). Thus, PPGIS combined with modelling approaches such as MaxEnt greatly advances the capacity to map cultural ES.

Stakeholders in NBR value places for outdoor recreation significantly more than any other ES values. Indeed, high values for outdoor recreation is also consistent with other similar studies in Europe (Baumeister et al., 2020; Fagerholm et al., 2016, 2019) and within Norway (Brown et al., 2015; Hausner et al., 2015; Muñoz et al., 2020). The deep connection that Norwegians have with outdoor recreation is a fundamental part of the cultural identity that is written into law though *Allemannsretten* (everyman's right/freedom to roam) in the Outdoor Recreation Act (Klima- og miljødepartementet, 1957) allowing freedom of access to all land apart from cultivated land. People that exercise outdoors choose to do so for many reasons, but convenience and experiencing nature have been identified among the most important factors that influence that decision in Norway (Calogiuri & Elliott, 2017). Furthermore, exercise has clear physical well-being benefits though for example improved cardiovascular function, but there is also evidence that species and ecosystem diversity have positive mental well-being benefits (Aerts et al., 2018). Thus, our 'active outdoor recreation' bundle which includes biodiversity values is consistent with the mental and physical well-being co-benefits of recreation and biodiversity and further supports the biocultural conservation paradigm of biosphere reserves (Bridgewater, 2002). Through our work, we also highlight the importance of increasing the uptake of participatory methods that reflect these kinds of nature values into landscape and urban planning.

Our novel use of MaxEnt to explain the spatial distribution ES value bundles of diverse stakeholders provides further insight into the landscape characteristics influencing accessibility to those bundles. We find that specific landcover types had little influence on the distribution of the 'active outdoor recreation' and 'passive cultural values' bundles suggesting that different landcovers are equally valued for both 'active' and 'passive' recreation. Rather the distributions of these two bundles are determined largely by physical accessibility in the form of topography, road and trail access, and travelling distances from settlements, and in the case of 'passive cultural values', landscape configuration (i.e. LULC richness). This is consistent with *Allemannsretten* since there are few legal restrictions to movement (Hausner et al., 2015) and contrasts somewhat with the findings Fagerholm et al. (2016) who also found low preferences for LULC but disproportionately high number of mapped ES in small areas of common land in Spain where land access is more restrictive. Accessibility has been identified by other PPGIS studies as important in determining where participants map ES values (Fagerholm et al., 2016, 2019; Muñoz et al., 2020; Plieninger et al., 2019). Indeed, accessibility is

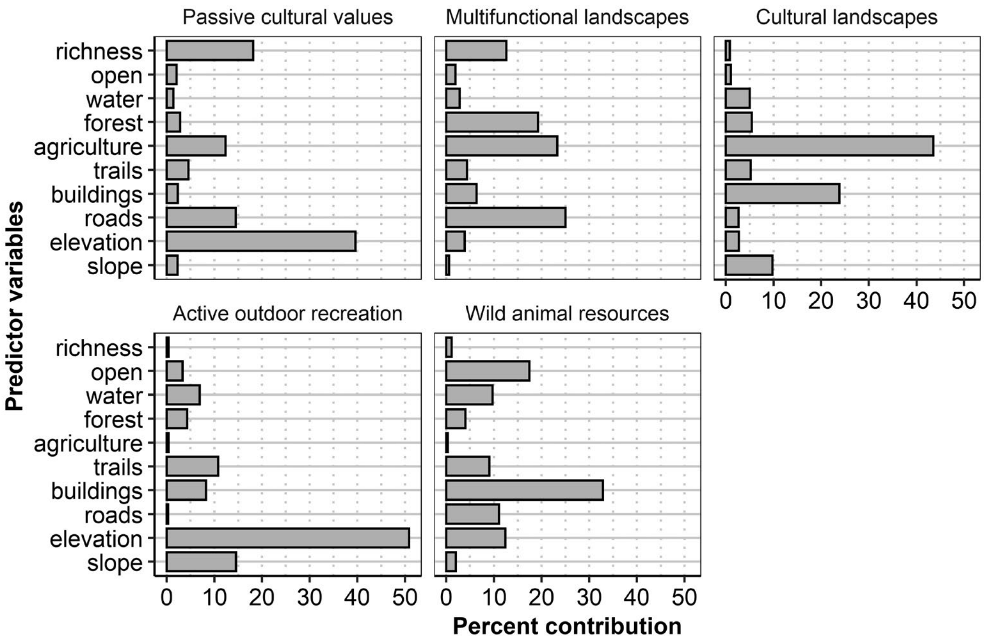

FIGURE 5 Variable contribution (%) of the 10 variables to the MaxEnt models for each of the five bundles in Nordhordland UNSECO Biosphere

increasingly important for biophysical mapping of cultural ES such as recreation (Ala-Hulkko et al., 2016; Paracchini et al., 2014). We infer that travelling time and accessibility as determined by infrastructure are likely to be more important for recreation choices than LULC type (Paracchini et al., 2014).

4.2 | Agriculture and cultural heritage are inseparable

Values for provisioning services were dominated by agricultural products reflecting the rural farming landscape of NBR while other provisioning ES were poorly represented in mapped ES values. The 'cultural landscapes' bundle captures both agricultural and cultural heritage values and represents a synergy between these ES values of respondents, adding to the recurring theme of the biocultural values of the region. Plieninger et al. (2019) report a similar bundle from their PPGIS study. Our results go further and highlight that values for agriculture and cultural heritage as assigned by a diverse group of stakeholders are largely inseparable. We interpret this as the cultural landscape of agriculture (*jordbrukets kulturlandskap*) strongly associated with agricultural sector discourses (Jones & Daugstad, 1997). The strong ties with these kinds of places can be understood by recognising that landscapes are places that have developed through human interactions with nature including cultural and social practices (Olwig, 2007). In the context of NBR, agricultural and cultural heritage ES values embody this landscape perspective due to the long history of agriculture and the strong interconnection between farming and culture in NBR (Kaland et al., 2018). The social-ecological system of western Norway has developed over millennia through the creation and maintenance of the cultural landscape from agricultural activities of grazing, mowing and burning (Hjelle et al., 2006; Webb, 1998). Human–nature relationships in the region are therefore strongly agrarian and linked to the agricultural and semi-natural ecosystems (e.g. heathlands and hay meadows) shaped by people. These semi-natural ecosystems associated with agriculture such as coastal heathland and hay meadows support high species diversity, numerous iconic species (e.g. *Hubo hubo*), keystone species (e.g. *Calluna vulgaris*), contain around 24% of all Red Listed species in Norway (Henriksen & Hilmo, 2015), and the ecosystems themselves are Red Listed (Artsdatabanken, 2018). Although biodiversity values were not bundled together with agricultural and cultural heritage ES values in our analysis, there is still a synergistic relationship between biodiversity and many other ES in certain agricultural land-use types in western Norway (Johansen et al., 2019; Wehn et al., 2018). In this we can see overlapping values of the discourses of the agricultural sector's cultural landscape of agriculture and those of the nature conservation sector's interpretation of the cultural landscape (Jones & Daugstad, 1997). Thus, from our results, we can conclude that in the context of NBR, conservation of cultural landscapes can have multiple ES benefits by preserving cultural, agricultural and biodiversity values (Linnell et al., 2015).

Our MaxEnt modelling shows high contributions of agricultural landcover and distance to buildings to the distribution of the cultural landscapes bundle. This shows the strong place-based dimension of cultural landscapes in NBR which has important implications for managing land-use change in rural settings in Norway and likely elsewhere in Europe. Like other parts of Europe with moderate-to-low agricultural production, there is a trend of agricultural land abandonment driven by factors such as low profitability for farmers and reductions in access to infrastructure (Beilin et al., 2014). Therefore, the loss of agricultural practices will not only reduce agricultural ES, but also erode cultural heritage values of the region. In the Norwegian context, farmers often perceive their roles in both food production and maintenance of cultural landscapes (Bernués et al., 2015, 2016; Kvakkestad et al., 2015). Part-time farmers and other stakeholders in Norway are more interested in maintenance of cultural heritage and landscapes than full-time farmers (Bernués et al., 2015; Kvakkestad et al., 2015). However, full-time farmers have greater interest in payments for food production rather than public goods associated with cultural landscapes (Kvakkestad et al., 2015). In this context, it is likely that policies aimed at maintaining diverse mixed agricultural jobs (i.e. part time and full time) will provide social-ecological resilience against drivers of change that affect linked cultural heritage and agricultural values.

The diversity of ES values in the multifunctional landscapes bundle is distinctive among the bundles and similar to 'Ecosystem Services hotspots' reported by Plieninger et al. (2019), as is the importance of roads and settlements in determining their distribution. We found that forested land and agricultural land as well as landscape configuration (LULC richness) were important contributors further supporting the multifunctionality of this bundle, including firewood and timber, and agricultural ES values. Importantly, ES values mapped by participants do not necessarily reflect the potential of an area to supply ES, but rather more specifically their place-based values, and in the case of cultural ES, their actual supply. This tendency of higher densities of ES values mapped closer to settlements can likely be attributed to geographical discounting (people choose to be close to the things they value on the one hand but prefer to be more distant from what they have an aversion to on the other; Brown & Kyttä, 2014), highlighting the importance of nature close to where people live for ES delivery and well-being (Fagerholm et al., 2016, 2019). In the regional context of urbanisation, spatial data produced by a diverse group of local actors demonstrating the multiple benefits that the community gets from nature near urban and peri-urban areas can provide useful information for prioritisation in urban expansion planning.

4.2.1 | Biosphere Reserve zonation and the new generation of Biosphere Reserves

The ES values mapped by stakeholders in the different zones in NBR reflect the new generation of BRs, with biocultural values well represented in the buffer and transition zones, including biodiversity, agricultural and cultural heritage (Coetzer et al., 2014; Price, 2017; Winkler, 2019). The terrestrial buffer zones in NBR have proportionately higher agricultural land than the transition zone (see Table S3) which explains the high agricultural values in the buffer zone. Importantly, agricultural practices in NBR are predominantly on small holdings (<14 ha) with low intensity livestock farming at relatively low stocking densities in a highly heterogeneous landscape with mixed LULC types (<1 livestock unit per hectare; Statistics Norway, 2019a, 2019b, 2019c). Thus, high values for agricultural ES as well as biodiversity values is consistent with ecologically compatible practices intended for BR buffer zones. However, although the agricultural practices can be considered relatively ecologically compatible at the local scale, agricultural intensification may lead to less ecologically favourable practices such as high nutrient inputs or the use of imported soy-based powerfeed resulting in telecoupled environmental impacts (Hull & Liu, 2018; Schaffer-Smith et al., 2018). The relative absence of extractive values in the core zones, aside from recreational fishing, and a higher presence or regulating and cultural values, is also consistent with BR aims for biodiversity conservation and reduced human impact in core zones that does not prohibit human presence (Winkler, 2019).

Our study is the first, to our knowledge, that uses a participatory and transdisciplinary approach to investigate spatial distributions of ES values in relation to BR zonation. Importantly, transdisciplinary participatory processes in BRs have been shown to result in multiple benefits including enhanced social learning, facilitate relationships among actors and improve the understanding of varying perspectives among actors (Onaindia et al., 2013). Our assessment of ES values in NBR touches on several important issues related to BRs. First, the ES concept fits well within the BR focus on human–nature relationships and our approach of spatial assessment of ES values has rarely been undertaken in BRs. There are few studies that have mapped ES in biosphere reserves (but see Kermagoret & Dupras, 2018; Poikolainen et al., 2019), and even fewer that explicitly consider zonation in their analyses (but see Castillo-Eguskitza et al., 2018, 2019). Second, we have used a participatory approach which is an important criterion of BR governance. Indeed, participatory processes may be one of the most important in supporting the goals of BRs and contribute towards the other goals (Schultz et al., 2011). Such methodology is key to the aims of BRs and is an important step in addressing sustainability and equity challenges faced within BR territories (Barraclough et al., 2021; Hill et al., 2020; IPBES, 2019). Third, our work constitutes the first empirical investigation into the alignment between a BR zonation plan and the values BR inhabitants place on a landscape, providing an understanding of the potential mismatches between zonation theory and implementation (Mehring & Stoll-Kleemann, 2011).

The five spatial bundles we find in NBR are highly distinctive, with values for one or two ES dominating each bundle aside from the 'multifunctional landscapes' bundle. This contrasts with biophysical ES bundle studies in which bundles tend to have several co-dominant ES and mirrors the results of a similar study by Plieninger et al. (2019). Our results also confirm that there are more synergies in PPGIS-ES compared to biophysical ES bundling studies that typically find less synergy between provisioning and cultural ES (e.g. Crouzat et al., 2015; Maes, Egoh, et al., 2012; Queiroz et al., 2015; Raudsepp-Hearne et al., 2010; Turner et al., 2014). However, trade-offs between cultural and provisioning ES are not universal in all biophysical studies (e.g. Malmborg et al., 2021) and other socio-cultural studies have found agricultural and cultural heritage ES values do bundle together (Quintas-Soriano et al., 2019; Zoderer et al., 2019). A combination of biophysical and social-cultural methods is likely to yield a more holistic picture of ES values in a region, expanding the knowledge base for land-use planning and management (Bagstad et al., 2017; Scholte et al., 2015).

Lastly, we find energy production being mapped at the second lowest frequency of all ES values to be a striking finding. This is surprising given that Vestland is the highest energy producing county, predominantly hydroelectricity, in Norway. Many hydroelectricity generators are located in areas with low population density and thus their value might not be reflected in our results because people tend to map values for ES closer to home (Fagerholm et al., 2016). Another possible explanation is the land-use conflicts with energy production (hydro and wind) in NBR arising from the impacts that energy production has on biodiversity, visual aesthetics, recreation and cultural heritage (Bakken et al., 2012; Idsø, 2017; Saha & Idsø, 2016). Furthermore, there are major plans to expand wind electricity generation in the region which have been met with opposition from many groups. Brown and Raymond (2014) propose methods to use PPGIS for identifying conflicts in land-use planning whereby participants map landscape values along with development preferences. Our study points towards the need for further work using PPGIS to investigate the potential conflicts between land-uses like power generation and other ES values, particularly in the context of human–nature coexistence and management of BRs as multifunctional landscapes.

5 | CONCLUSIONS

Biosphere reserves (BR) are key learning sites or model regions for sustainable development. Our novel use of PPGIS to explore the spatial distribution of ES in relation to BR zonation shows that stakeholders clearly identify ES values that are broadly representative of BR zonation goals. Buffer zones have high biocultural values linked to outdoor recreation, cultural heritage, biodiversity and agricultural products, while ES values for agricultural products were absent from in core zones. These combinations of ES values in the different zones as perceived by a diverse range of stakeholders show how a modern BR reflects the key goal of biocultural conservation. Furthermore, we show that PPGIS is a valuable means to assess the ES values in BR zones that can be used for BR monitoring. Our bundling approach combined with MaxEnt modelling highlights important ES values related to agriculture and cultural heritage, recreation and biodiversity, and the importance of accessibility to nature for ES provision. First, stakeholders identify a strong link between agriculture and cultural heritage reflecting the long history of farming in the region that remains fundamental part of the local identity. Our demonstration of linked agricultural and cultural heritage values in agricultural areas complements existing knowledge of notable biodiversity and high ES provision in western Norway's agricultural landscapes. Thus, a reduction of agricultural practices will not only reduce agricultural ESs, but also erode cultural heritage ES values and contribute to biodiversity loss, and policies aimed at maintaining key agricultural landscapes provides social-ecological resilience against drivers of change that affect linked cultural heritage and agricultural values. Second, we find high values for outdoor recreation in our study which often co-occur with biodiversity values. This finding emphasises the importance of mental and physical co-benefits that people receive from nature-based recreation. Third, accessibility of nature strongly influences ES values and people map more ES values closer to human infrastructure. Accessible and healthy nature close to home is therefore important to support physical and mental well-being. The transdisciplinary approach of our study facilitated by NBR gives an entry point for a multidirectional flow of knowledge between local actors, municipalities and academia. The development and strengthening of existing relationships can play a key role in BR success (Bridgewater, 2016), and the incorporation of multiple knowledge systems can contribute planning support and shared visioning (Pretty, 2011; Tengö et al., 2014). Perhaps most importantly, planning decisions based on shared visions are likely to have the greatest community backing (Brown et al., 2020) and, in the case of multifunctional landscapes, support sustainable management and supply of locally relevant ES (García-Llorente et al., 2012).

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHORS' CONTRIBUTIONS

J.C., A.M.D.B. and I.E.M. conceived the ideas for this study; J.C. and A.M.D.B. designed the PPGIS survey, facilitated the focus group session and administered the PPGIS survey for data collection; J.C. performed all data manipulations and analyses and wrote the first manuscript draft; A.M.D.B. and I.E.M. contributed significantly to review and editing of the draft manuscript.

DATA AVAILABILITY STATEMENT

PPGIS data used in this study are deposited in the Dryad Digital Repository https://doi.org/10.5061/dryad.5hqbzkh6v (Cusens et al., 2021). All other data sources are listed in Supporting Information.

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