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Socio-cultural values and biophysical supply: How do afforestation and land abandonment impact multiple ecosystem services?

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ABSTRACT

Humans have significantly modified the planet's ecosystems with negative consequences for biodiversity and human wellbeing. However, not all land use is equal, and many traditional land uses, and emergent cultural landscapes support important biodiversity and provide multiple benefits to society. Despite their importance, cultural landscapes are threatened by several factors, the most prominent being abandonment of the traditional practices that maintain them. Afforestation schemes to mitigate atmospheric carbon are an additional emerging threat. Abandonment and afforestation threaten both ecological processes and socio-cultural values, but surprisingly, there is little knowledge on the concurrent social and ecological impacts. We used a multi-method approach of ecological field surveys to quantify the biophysical supply and socio-cultural values of ecosystem services (ES) in four different vegetation types representing managed open vegetation, natural forest types for abandonment and planted forests to represent afforestation. We explored the match and/or mismatch between socio-cultural values and biophysical supply of ES in those vegetation types and investigated the socio-demographic factors that influence socio-cultural values for ES. Biophysical supply of ES was variable across vegetation types and synergies were as common as trade-offs. Socio-cultural values were high for most ES in open vegetation and natural forests and low for planted forests. Biophysical supply and socio-cultural values were well matched across the vegetation types for biodiversity and agricultural products, but strongly mismatched for climate regulation. We show that although trade-offs occur both within value- and between value domains, synergies are also common. Our results show that abandonment would impact on the biophysical supply and socio-cultural values of some ES but that this impact would be lower than that of afforestation. We argue that our approach can be used to manage trade-offs and enhance synergies between value domains for a holistic approach to landscape stewardship that supports both people and nature.

1. Introduction

1.1. Landscape changes and the impact on ecosystem services

Humans have modified between 69% and 76% of Earth's surface to some extent or another, much of which is due to agricultural activities and food production over the last 2000 years (Ellis and Ramankutty, 2008; IPCC, 2019). However, for much of the past 12,000 years the rate of land-use change, and land-use intensity have been moderate and by and large most of the adverse effects on biodiversity are relatively recent (Ellis et al., 2021). Since the on-set of the industrial revolution approximately 300 years ago the rate of land-use change in concert with land-use intensification has accelerated markedly (Ellis, 2021; Steffen et al., 2015). Consequently, land-use change is now the most significant global change driver with substantial adverse effects on biodiversity and ecosystem services (ES) (Díaz et al., 2019; IPBES, 2019; Pereira et al., 2012).

1.2. Changes to the cultural landscape

Cultural landscapes are landscapes that have been modified or influenced through human usage (Jones and Daugstad, 1997). Although the term is used differently across academic disciplines, e.g., geography, ecology and agricultural economics, cultural landscapes are clearly

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distinguished in contrast to natural landscapes. Here, we use cultural landscape as identified by Jones and Daugstad (1997) to include agrarian or rural landscapes that comprise semi-natural vegetation elements with links to cultural heritage. These traditional cultural landscapes are threatened by several factors, most prominently rural abandonment or agricultural intensification. The former is widespread globally and across large parts of Europe with multiple drivers and consequences (MacDonald et al., 2000; Queiroz et al., 2014; Rey Benayas et al., 2007). The drivers of rural abandonment are often a combination of socio-economic and biophysical/ecological factors (reviewed by Rey Benayas et al., 2007), for example the relatively low productivity of agricultural land which has poor economic return for farmers (Beilin et al., 2014). Indeed, these drivers can also result in abandonment and intensification occurring in concert. Intensification of cultivated land occurs using artificial fertilisers and feed concentrates, while rangeland grazing is decreased or completely abandoned (Asheim et al., 2020). A major consequence of rural abandonment is forest regrowth or reversion of habitats through successional processes that are halted or modified by farming practices such as mowing, grazing or fire (Måren, 2009). On the one hand, the regrowth of forests can bring benefits to biodiversity and ES, particularly in places that have undergone substantial forest clearance (Pereira et al., 2012). On the other hand, regrowth can also negatively impact biodiversity and ES in cultural landscapes (e.g., Johansen et al., 2019; Quintas-Soriano et al., 2022; Wehn et al., 2018). For example, semi-natural open ecosystems within the cultural landscape such as heathlands can have high biodiversity values, supporting iconic (e.g., Eurasian eagle-owl/*Bubo bubo*), Red Listed (e.g., lapwing/*Vanellus vanellus*) and keystone species (e.g., common heather/*Calluna vulgaris*).

In Norway, substantial areas of agricultural land have been abandoned since the 1950 s, particularly along the coast and in mountain regions (Bryn et al., 2013). This abandonment of agricultural management through cessation of grazing, cutting or mowing, and timber and firewood harvesting has resulted in forest regrowth in many areas (Bryn et al., 2013). Large areas of western Norway's agricultural system are classified as High Nature Value Farmland (Paracchini et al., 2008). These areas typically comprise heterogeneous landscape mosaics with relatively small, cultivated infields for hay production, infield pastures which are inaccessible to machinery, and outfield areas of extensive grazing including heathlands, grasslands and woodlands. These heterogenous agricultural landscapes with patches of non-production elements and vegetation are important for supporting biodiversity and ES (Case et al., 2020; Erdős et al., 2018). Further, coastal lowland heathlands are classified as greatly endangered in the EU Habitats Directive (92/43/EEC), and coastal heathlands and hay meadows are Red Listed ecosystems in Norway (Artsdatabanken, 2018). The heterogeneity of these cultural landscapes, and their long history of development with the local human population (Hjelle et al., 2006), means that they are important for human wellbeing and include instrumental, intrinsic, and relational values which are often inseparable or bundled together (Pascual et al., 2017). For example, the instrumental values from agricultural products (such as wool or meat), and relational values of sense of place and cultural heritage are deeply connected in western Norway (Cusens et al., 2022). A loss of these semi-natural vegetation types within cultural landscapes through abandonment will likely have a negative impact on human values, ES and biodiversity (Cusens et al., 2022; Johansen et al., 2019; Wehn et al., 2018).

In addition to land abandonment related forest regrowth, Norway has proposed tree planting or afforestation in abandoned agricultural areas as a climate change mitigation measure (Haugland et al., 2013). The programme has four primary criteria for guiding afforestation (Haugland et al., 2013): (1) planting of Norwegian native tree species, (2) planting in open areas and areas in the early regrowth phase, (3) planting in areas with high production capacity and where a low change in the albedo effect is expected, and (4) planting in areas that are not important for natural diversity, outdoor interests, important cultural-historical values or valuable cultural landscapes. The native species criterion is addressed by using Norway spruce (*Picea abies*) as the main species for afforestation. It is argued that because of high relative growth rates this species is optimal for carbon sequestration as well as the additional co-benefit from timber production (Bøe et al., 2019). There is limited scoping for the use of other species like birch (*Betula* spp.) because of the high cost associated with producing high quality timber from hardwood species. The second two criteria can be assessed on a case-by-case basis. The fourth criterion, however, has received less attention, particularly with regards to "outdoor interests, important cultural-historical values or valuable cultural landscapes" and the impact of afforestation on cultural values is less studied (Liu et al., 2021).

Several studies have investigated either the ecological or socio-cultural impacts of land abandonment and afforestation in Norway (e.g., Grimsrud et al., 2020; Iversen et al., 2021; Johansen et al., 2019; Liu et al., 2021; Wehn et al., 2018). However, few studies have combined the potential socio-cultural and ecological impacts of both afforestation and land abandonment in general (Beilin et al., 2014; Quintas-Soriano et al., 2022). Focussing on either ecological or socio-cultural impacts is not likely to capture the full breadth of impact on values offered by multifunctional landscapes (Meyfroidt et al., 2022). Integrating different value domains and ways of measuring (e.g., biophysical, and socio-cultural) in a mixed- or multi-methods approach is an important step in understanding complex social-ecological systems and the multifaceted consequences of land use change (Cusens et al., 2023; de Vos et al., 2022; Martín-López et al., 2014). An integrated approach can provide support and guidance for decision making in complex issues where trade-offs and conflicts are inevitable and so-called 'win-wins' are rare (Jacobs et al., 2016; Turkelboom et al., 2018).

1.3. Aims and approach

In the present study we investigate how changing and future land-use from afforestation and/or abandonment might affect both the biophysical supply of ES and the socio-cultural values for those ES associated with closed versus open vegetation. The ES framework is useful for such integrated assessments because ES bridges the ecological (biophysical) and social systems (Martín-López et al., 2014; Spangenberg et al., 2014). To approach this question, we use a multi-method approach assessing socio-cultural values and biophysical supply of ES in four different vegetation types (one open and three forest types). We define socio-cultural values for ES as "the importance people, as individuals or as a group, assign to (bundles of) ESs" (Scholte et al., 2015, p. 68). First, to assess biophysical supply we used ecological field surveys to measure indicators for six ES in four vegetation types. Second, we evaluate trade-offs and synergies in biophysical supply of the ES. Third, we evaluate the socio-cultural values for the six ES in the four different vegetation types using data from a Public Participation Geographic Information Systems (PPGIS) survey. Fourth, we ask what the socio-demographic factors that influence preferences for those ES in the different vegetation types are. Finally, we compare the socio-cultural values for the ES with their biophysical supply in the four different vegetation types. We discuss our results in the context of the potential impact of land abandonment and afforestation on ES biophysical supply and socio-cultural values in Norwegian cultural landscapes and reflect on the possible policy implications.

2. Materials and methods

2.1. Site description

This study was situated in Alver municipality (former Meland, Radøy and Lindås municipalities) on the west coast of Norway (Fig. 1) which is one of 9 municipalities that form part of Nordhordland UNESCO Biosphere Reserve. The information that follows was taken

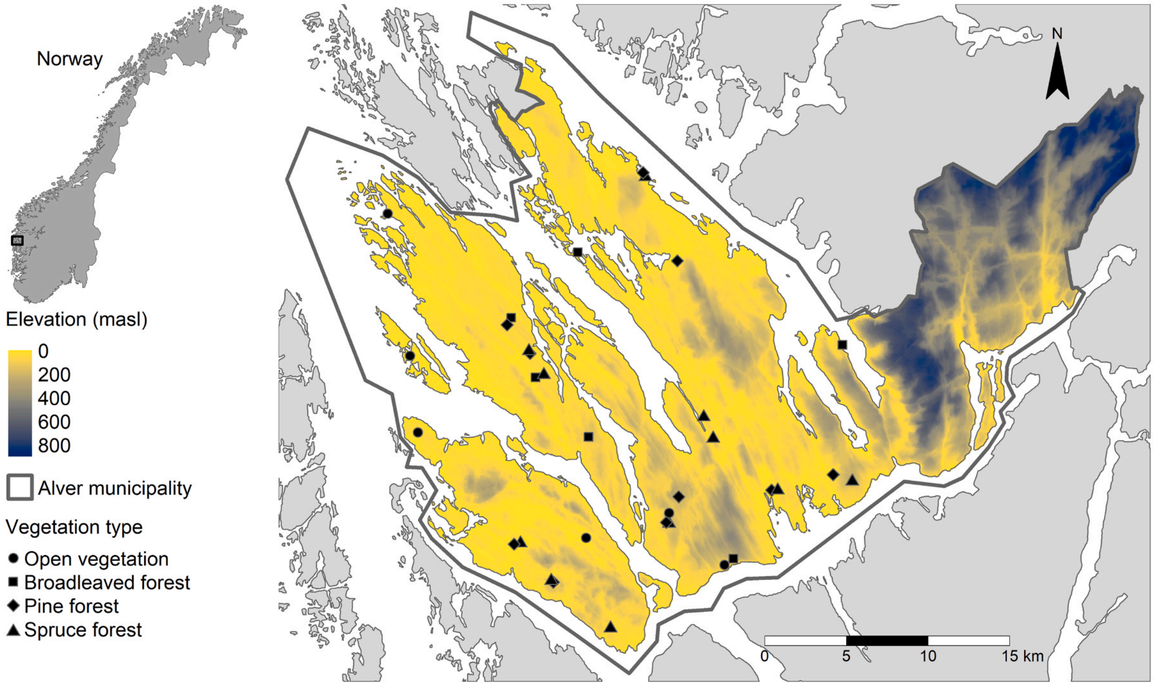

Fig. 1. Location and elevation profile of the study area in Alver municipality on the west coast of Norway, and the location of the 33 sampling sites.

predominantly from the biosphere reserve application document which compiled many of the primary resources unless otherwise cited (Kaland et al., 2018). The population of Alver has been steadily increasing since the 1980 s from below 20,000 and was approximately 30,000 in 2020 (Statistics Norway, 2020). There is evidence of settlement from more than 10,000 years ago. Historically people in the area were farmer-fishers who made effective use of the natural resources at hand, including fish from the sea, rivers and lakes, and livestock (sheep, goats and cows) grazing in the coastal heathlands, forest outfields of the fjords and in the mountains. Much of the in-migration in recent times can be related to industrial growth around the Mongstad oil refinery and related petrochemical industry. Roughly half of the terrestrial land area of Alver is forest followed by open vegetation types excluding wetlands (24%) (Statistics Norway, 2022). Agricultural land makes up 13% of the land cover which is substantially higher than the county Vestland as a whole (3%) (Statistics Norway, 2022). Geologically the area is largely located on the *strandflat* formed by glacial erosion which is generally flat with isolated hills. The municipality comprises several large islands as well as many smaller islands to the west in an extensive fjord system and parts of the mainland in the east. In the eastern areas there are larger mountains up to 800 masl but none of the sample sites were located there (Fig. 1).

2.2. Field data collection

We selected 33 sites for field sampling in Alver municipality (Fig. 1): six open semi-natural heathlands (hereafter open vegetation), six natural mixed broadleaved forests dominated by birch (*Betula* spp.) (hereafter broadleaved forest), 10 coastal Scots pine forests (*Pinus sylvestris*) (hereafter pine forest), and 11 planted spruce forests (*Picea* spp.) (hereafter spruce forest; see Table 1 descriptions of the vegetation types). We selected these broad vegetation types to represent (i) currently managed open vegetation, (ii) natural forests (broadleaved and pine forest) that are the likely outcome of ceased management and (iii) afforestation. Broadly, sites were selected by identifying vegetation types with a land use/land cover map to represent the three main forest types and open heathland vegetation (Ahlstrøm et al., 2019; Astrup et al., 2019). We used criteria for selecting plots ensuring that they did not comprise more than 25% bare rock or mire, and that they were at least 10 m from the forest edge to avoid edge effects. In addition, plots were at least 20 m from roads, access ways or paths to reduce the possibility of substantial influence by people. At each of the sites we established three subplots of 100 m^{-2} that were 10 m × 10 m (Supplementary material, Fig. S1) aside from two, which were 2 m × 50 m due to topographic constraints. In each subplot we identified and measured the diameter at breast height (DBH) of all trees (i.e., DBH $\geq$ 5 cm), including standing dead individuals. We use a standardised breast height of 135 cm from the ground and define trees as having a DBH equal to or larger than five centimetres. All saplings (taller than 30 cm and having a DBH < 5 cm) were identified and counted. In addition, we visually estimated canopy cover and estimated mean canopy height with a laser rangefinder (Nikon 5050). The measurements were taken once between August and October 2020.

Within each subplot we established three 1 m^{-2} replicates for understorey and field layer vegetation and soil sampling (for detailed plot layout see Supplementary material, Fig. S1). We identified all vascular plants and estimated their percent cover and the percentage cover of plant functional types (forbs, grasses, sedges, rushes, broadleaved shrubs, coniferous shrubs, non-vascular plants, lichen). We collected topsoil samples (down to 20 cm) with a handheld soil corer and pooled the samples from the three replicates to make a 500 ml composite soil sample for each subplot. All soil samples were analysed by Eurofins Environment Testing Norway AS for multiple properties such as nutrient content and soil type. For this study we used only loss on ignition values.

2.3. Biophysical supply of ecosystem services

We calculated six subplot-level ES indicators, including two cultural, two provisioning and two regulating and maintenance ES (Table 2). The six ES we chose were (i) locally relevant, (ii) indicators could be measured at the site or plot scale using standard field techniques, (iii) included ES from each of the three categories in Common International Classification of Ecosystem Services (CICES; Haines-Young and Potschin, 2018), and (vi) we had data on the social-cultural values of those ES. Some of the indicators we measured relate to the same ES, (e.g.,

Table 1
Generalised descriptions of the four vegetation types considered in this study along with a representative photograph of each.

Vegetation type	Description	Representative photograph[1]
Open vegetation[2]	Open vegetation comprised predominantly heathlands comprising dwarf shrubs and patches of graminoids without a dominant tree layer. Common heather (*Calluna vulgaris*) was the dominant species with frequent occurrences of other Ericaceae. Graminoids included moor grass (*Molina cearulea*) and, in wetter sites (*Eriophorum vaginatum*) in wetter sites.	
Broadleaved forest	Broadleaved forest comprised predominantly a birch canopy although other deciduous species such as rowan (*Sorbus aucuparia*), and black alder (*Alnus glutinosa*) in wetter sites, occurred at lower proportions. The composition of field layer was generally mixed and diverse varying from site to site although bilberry and wavy hair-grass (*Deschampsia flexuosa*) were common at many sites.	
Pine forest	Pine forests comprised a canopy of Scots pine with occasional broadleaved species (e.g., birch, rowan) in the sub-canopy at some sites. The field layers were variable among sites but often comprised bilberry, wavy-hair grass and occasionally lingonberry. Many sites had thick moss layers.	
Spruce forest	Spruce forests were dense plantations of Norway spruce with no other tree species present. Field layers of vascular plants were largely absent with ground layers dominated by either moss or needle litter. Occasional patches of wood sorrel (*Oxalis acetosella*) and common polypody (*Polypodium vulgare*)	

1. All photographs taken by the first author Jarrod Cusens.
2. These heathlands are semi-natural vegetation types that have developed over millennia through processes of cultivation, burning, clearing and grazing.

flower colour richness and herb to graminoid cover ratio for aesthetic appreciation; Table 2). In these cases we combined the indicators into a single composite indicator per ES by calculating the mean of the normalised values of the respective measures (Johansen et al., 2019; Taugourdeau and Messad, 2017). We normalised all values between 0 and 1 to allow comparison among different ES.

2.3.1. *Wild food*

We used two measures of wild food provision based on the biomass of wild edible mushrooms and wild edible berries. We harvested the caps of

Table 2
Summary of the different ecosystem services assessed in the study and the indicators and units used to quantify them.

Ecosystem service	Indicator (s)	Units	Reference
Cultural			
Wild food[1]	Berries; mushrooms	kg/ha	(Schulp et al., 2014)
Aesthetics	Ratio of herbs to grasses; flower colour richness	%; flower colours/ha	(Ford et al., 2012; Johansen et al., 2019)
Provisioning			
Forage provision	Cover of graminoid species	%	(Johansen et al., 2019; Lavorel et al., 2011)
Timber and firewood	Volume of timber	m^3/ha	Haines-Young and Potschin (2018)
Regulating & maintenance			
Global climate regulation	Biomass carbon; soil carbon (loss on ignition)	ton/ha; %	(Haines-Young and Potschin, 2018; Johansen et al., 2019)
Habitat provision (biodiversity)	Species richness of vascular plants; standing dead wood	species/ ha; m^3/ha	(Gamfeldt et al., 2013; Gao et al., 2015)

1. Wild food is often classified as a provisioning service. However, we have classified wild food as a cultural service since wild food harvesting has been shown to be predominantly a recreational and cultural activity in places with similar socio-cultural contexts to our study region (Reyes-García et al., 2015; Stryamets et al., 2015).

all edible mushroom species (e.g., *Boletus edulis*/penny bun, *Cantharellus cibarius*/chanterelle) larger than 2 cm diameter in the 100 m^{-2} subplots and all edible berries species (e.g., *Vaccinium myrtillus*/bilberry, *V. vitis-idaea*/lingonberry) in the three 1 m^{-2} replicates used for understorey vegetation sampling. We weighed the berries and mushrooms fresh and then dried them to constant weight at 60 °C and reweighed them. In 2020 we sampled mushrooms twice at all sites while in 2021 we sampled mushrooms fortnightly between July and October. Mushroom and berry data are both from 2021 since mushrooms have multiple flushes through the season and two samplings in 2020 would underestimate mushroom production. Following Pilz et al. (1998) we report fresh weight because it is more meaningful for social and economic values.

2.3.2. Vegetation aesthetics

We calculated a composite indicator from two measures of vegetation aesthetics based on the ratio of forb species cover to graminoid species cover, and on the richness of flower colour in the field layer of forests and open habitats. Flower colour for all flowering species was determined from published floras. Both indicators are hypothesised to have a positive relationship with aesthetic appreciation of the vegetation (Ford et al., 2012; Johansen et al., 2019). Studies with choice experiments have shown that people tend to have higher aesthetic appreciation for a greater diversity of flower colours (Hoyle et al., 2018; Tomitaka et al., 2021) while a higher proportion of forbs relative to graminoids has been shown to be perceived as more attractive (Lindemann-Matthies et al., 2010).

2.3.3. Global climate regulation

We used two measures of carbon storage as a composite indicator of global climate regulation. We first calculated aboveground biomass for each tree using species- and Köppen climate zone-specific allometric equations from DBH measured in the field (Gonzalez-Akre et al., 2022). Then, we estimated root biomass from species-specific root:shoot biomass ratios (Levy et al., 2004; Smith et al., 2016). Finally, we summed the above- and belowground biomass and converted biomass to carbon using published species-specific biomass carbon conversion factors (Wutzler et al., 2011). We used loss-on-ignition as a measure of soil carbon storage in the top 20 cm of the soil (Johansen et al., 2019; Maskell et al., 2013).

2.3.4. Habitat provision

We used two measures to estimate the composite indicator of the capacity of sites to provide habitat for biodiversity. The first was standing dead wood volume which is an indicator of saproxylic beetle and wood-living fungal species richness. In a review of biodiversity indicators across Europe, Gao et al. (2015) found strong evidence for a positive relationship between dead wood volume and saproxylic beetle and wood-living fungal species richness. The second indicator was a direct measure of vascular plant species richness including herbs, forbs, shrubs, and trees.

2.3.5. Forage provision

We used the data from the vegetation survey calculating the percentage cover of all graminoid species in the field layer of the forests and open vegetation as an indicator of forage available for domestic grazers, primarily sheep in the our study region and the vegetation types investigated (Johansen et al., 2019; Wehn et al., 2018).

2.3.6. Timber and firewood provision

We used the volume of timber as an indicator for timber and/or firewood. We first calculated tree volume for each individual tree in each subplot from tree DBH and height measurements (see 2.2 *Field data collection*) using species specific volume equations (following Braastad, 1966; Brantseg, 1967; Vestjordet, 1967). We then summed the total timber volume (m^{-3} ha^{-1}) for each subplot.

2.4. Socio-cultural values

We used a web-based PPGIS survey on the Maptionnaire platform (Mapita Oy, 2019) to collect socio-cultural values for ES in Nordhordland UNESCO Biosphere Reserve (NBR). The statements for each ES in the survey were based on previously published PPGIS-ES studies (Fagerholm et al., 2019; Plieninger et al., 2019) and were designed to capture the subjective perceptions of socio-cultural values and use of ES (see Table 3 for the specific statement attached to each ES) (cf. Scholte et al., 2015). Participants were presented with a list of statements associated to different ES and were asked to place markers on the map in places that they valued those ESs. We recruited participants with: (i) targeted email lists comprising local actors from organisations involved in resource management, local and regional government, agriculture, nature conservation, forestry and energy production; (ii) articles about the project and survey in regional newspaper and local newspapers; (iii) boosted social media campaigns; and promotions on the NBR social media accounts. We also encouraged key actors to share the survey through snowballing. In addition, we organised 14 workshops at local libraries and community halls in 11 municipalities between 10 February

Table 3
The statements used in the PPGIS survey to capture place-based social-cultural values for ecosystem services.

Ecosystem service	Social-cultural value statement used for PPGIS mapping
Cultural	
Wild food	I harvest wild plants, berries or mushrooms here
Aesthetics	I am inspired by the beauty of nature here
Provisioning[1]	
Agricultural products	I appreciate that local agricultural products are produced here; I produce agricultural products here
Timber & firewood	I appreciate that local forestry products are produced here; I harvest or produce timber or firewood here
Regulating & maintenance	
Global climate regulation	I appreciate how this place can store carbon and mitigate global climate change
Habitat provision	I appreciate the plants, animals, wildlife, ecosystems (biodiversity) here

1. The statements attached to the two provisioning ecosystem services include both social-cultural *value* prefaced by 'I appreciate' and *use* prefaced by 'I produce'.

and 13 April 2020. The online survey was open for four months in February-May 2020 and collected 3155 mapped points from 433 participants. For this study we used the data of mapped values for six ES (Table 3). We chose these specific ES because we were able to collect biophysical data on the same ES in the field and therefore could make comparisons between socio-cultural values and biophysical supply. In addition to the mapped values, we used socio-demographic data collected with the PPGIS survey, including participant age, gender, education, whether they lived in the region or not and whether they worked in agriculture or not. For more information regarding the PPGIS survey please see Cusens et al. (2022).

2.5. Data analysis

To test for differences in biophysical supply of ES among the different vegetation types we used pairwise Wilcox tests. We used Wilcox tests to account for the non-normal distribution of the data. To test for trade-offs and synergies between the pairs of biophysical ES indicators we used Pearson pairwise correlation analysis and report results for both composite indicators and the individual indicators. To determine the socio-cultural values of the different ES in the different open and forest types we used *z*-scores to assess whether the number of points mapped for each ES in each vegetation type were different from expected based on the areal extent of each vegetation type. Following the approach of Brown et al. (2015) we calculated *z*-scores for each vegetation-ES combination with the following equation:

$$Z = \frac{Ps - P\mu}{Sp}$$

Where Ps is the proportion of mapped points in a vegetation type, $P\mu$ is the proportion of a particular vegetation type within the study area, and Sp is the standard error of the proportions of all vegetation types. Using this approach, *z*-scores greater than 1.96 or smaller than -1.96 indicate that the proportion of mapped points in the vegetation type are significantly higher or lower than expected by chance, respectively. We used Pearson's Chi-squared tests to test for the effect of socio-demographic factors and habitat type on the number of points mapped per ES by PPGIS survey participants. In addition, we used Cramér's V to test for the strength of the association between those variables and the points mapped per ES (Fagerholm et al., 2019). The socio-demographic variables considered were age, self-reported regional knowledge, resident status (i.e., resident or non-resident), farming (i.e., works as a farmer or not), education and gender. To explore the association between the mapped socio-cultural values for ES in the different vegetation types, and socio-demographic characteristics of survey participants we used multiple correspondence analysis (MCA), a commonly used ordination technique for categorical data (Plieninger et al., 2013; Zoderer et al., 2019). We chose the variables for the MCA as those that were significant in the Chi-squared analysis above. The (mis)match between socio-cultural values and biophysical supply were qualitatively cross compared by considering the relative ranks of the *z*-scores for socio-cultural values and the mean biophysical supply among the vegetation types. We considered the match to be very strong if all the ranks were the same, strong for three matches, moderate for two matches, weak for one and very weak for no matches. We used *R* (R Core Team, 2021) for all data manipulation, analysis and visualisation (Table 4).

Table 4
R packages used for data manipulation, analysis and visualisation, and references to the sources.

Package	Analysis/task	Reference
allodb	Tree biomass	(Gonzalez-Akre et al., 2022)
corrplot	Correlation plot	(Wei and Simko, 2021)
FactorMineR	Multiple correspondence analysis	(Le et al., 2008)
ggplot2	Plotting	(Wickham, 2016)
ggrepel	Plotting	(Slowikowski, 2021)
sf	Vector data	(Pebesma, 2018)
sitree	Tree volume	(Antón Fernández and Astrup, 2021)
terra	Raster data	(Hijmans, 2021)
tidyverse	General tidy workflow	(Wickham et al., 2019)
tmap	Spatial plotting	(Tennekes, 2018)

3. Results

3.1. Biophysical ecosystem service supply

Aesthetic value was lowest in planted spruce forest but not different across the other vegetation types (Fig. 2). Wild food was highest in pine forests but not different among the other vegetation types. Habitat provision and fodder provision were equally highest in open vegetation and broadleaved forest followed by pine forest and then spruce forest. Global climate regulation was highest in broadleaved forest but not significantly different from spruce forest which in turn was not different from pine forest and open vegetation. Timber and firewood supply was highest in spruce forest followed by pine forest and broadleaved forest.

3.2. Relationships among biophysical ecosystem services

Significant relationships were common with two thirds of the pairs of ES indicators measured in the field although the direction of relationships was variable (Fig. 3). Mushroom supply had the fewest significant relationships while timber volume, species richness, standing dead wood and biomass carbon had the highest number of significant relationships. Among the 15 significantly negative relationships (i.e., trade-offs) between individual indicators, one third (6) were with timber and firewood production including ES from all categories. Similarly, in the composite indicators where we combined several measures for the same ES, half (2 of 4) significantly negative relationships were with timber and firewood.

3.3. Socio-cultural values for ecosystem services

Among the ES mapped in different vegetation types by survey participants, all ES except timber and firewood were significantly valued in open vegetation types (Fig. 4). Similarly, in broadleaved forests all ES were significantly valued, except global climate regulation which was valued lower than would be expected by chance. In planted spruce forest, only wild food was valued significantly more than expected. Ecosystem services in pine forests were the most variable with higher-than-expected values for inspiration, spiritual and aesthetic, wild food, and appreciation of biodiversity on the one hand, but lower than expected for global climate regulation and timber and firewood on the other.

There was moderate to very strong evidence (cf. Muff et al., 2022) that all except for self-reported regional knowledge affected the variation in the number of points mapped for different ES (Chi-squared test, $P < 0.02$; Table 5). Participation in farming had the strongest association with the mapped ES and is considered moderate in strength (Cramér's V $= 0.247$), while education had the weakest association (Cramér's V $= 0.111$). In general, for the rest of the variables the strength of the association between the number of points mapped for each ES and the respective variables was weak (Cramér's V, ≥ 0.1 to < 0.2).

The first five dimensions from the multiple correspondence analysis (MCA) retained 42% of the inertia of the mapped ES, habitat types, and four socio-demographic variables. The first dimension (12% of inertia) was related to younger female participants who were not resident within the study area, nor worked in farming, mapping values for biodiversity and climate regulation related primarily to open vegetation types

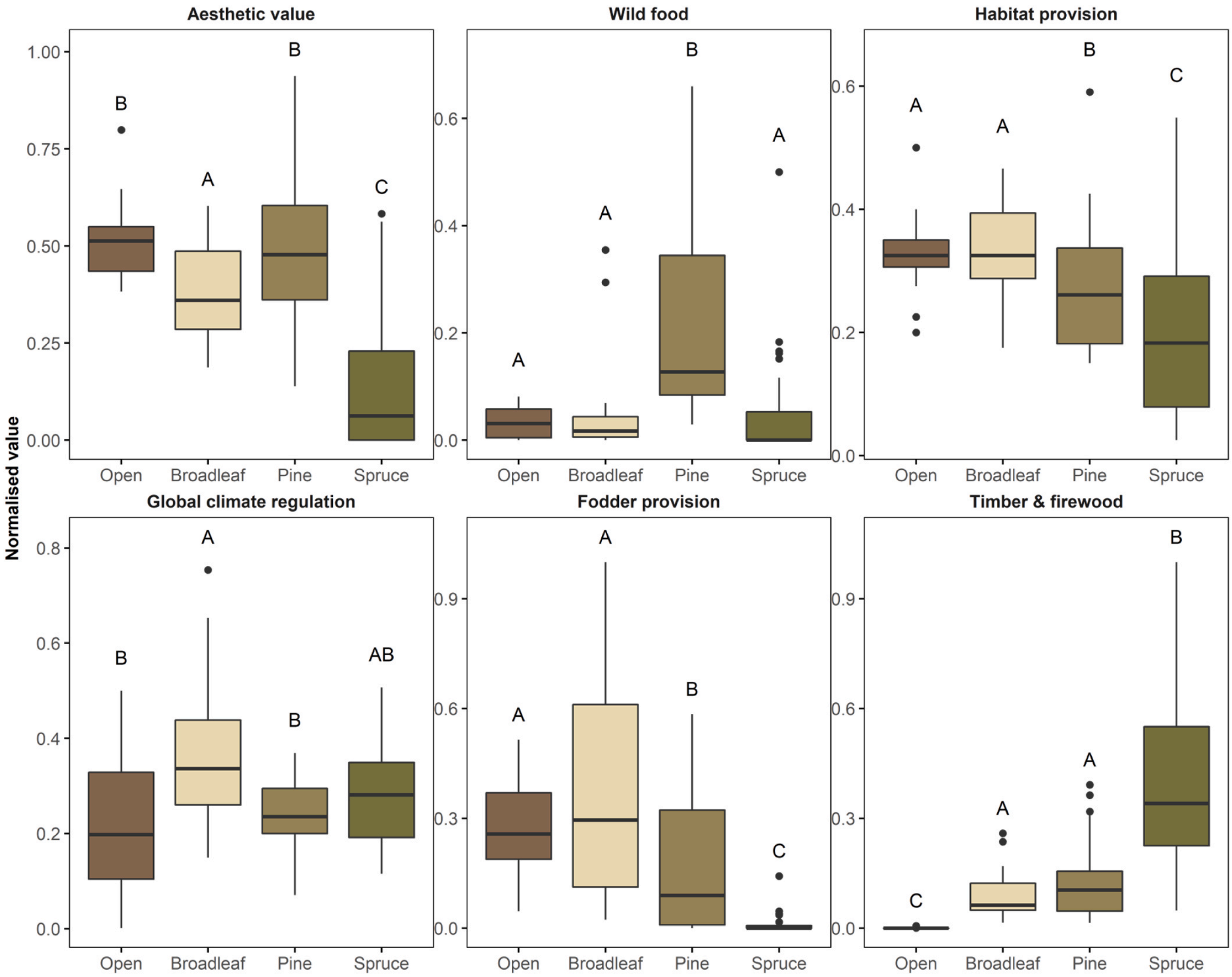

Fig. 2. Boxplots of the normalised values for each ecosystem service in the different vegetation types. Box and whiskers that have different letters are significantly different ($p < 0.05$, pairwise Wilcox test; n = 33 sites; pine = 10, spruce = 11, broadleaf = 6, open = 6). Note that y-axes are on different scales to aid visualisation.

(Fig. 5). On the opposing side of the first dimension were older male residents who worked in farming and mapped values for agricultural products, and timber and firewood. The second dimension (10% of inertia) was strongly associated with lower levels of education (high school diploma or lower) on the positive side and higher levels of education (bachelor's degree and higher) on the negative side. Among the variables, working in agriculture or not, residence status and gender were most strongly clustered in the first two dimensions (Supplementary information, Fig. S3).

3.4. *Comparing biophysical with socio-cultural value types across the vegetation types*

There were two very strong matches, three moderate matches, and one strong mismatch and one moderate mismatch between biophysical supply and socio-cultural values of ES across the different vegetation types (Table 6, Fig. 2; Fig. 4). The strong matches occurred in agricultural products/fodder provision and appreciation of biodiversity/habitat provision. The strongest mismatch was in global climate regulation with socio-cultural values being lower for all natural forest types, higher for open vegetation and the same in planted spruce forest. The moderate matches occurred in aesthetic values, wild food, and timber and firewood. For timber and firewood spruce forests had lower socio-cultural values while broadleaved forests had higher socio-cultural values than biophysical supply. In both aesthetic values and wild food, broadleaved forest had higher socio-cultural values, while pine forests had lower socio-cultural than biophysical supply. Considering the vegetation types, pine forests tended to be ranked higher in biophysical supply than socio-cultural values while for broadleaved forests it was the opposite. Spruce and open vegetation were ranked similarly.

4. Discussion

Our study explored the differences in both the biophysical supply and the socio-cultural values for ES in different vegetation types. The vegetation types we studied were chosen to understand the potential impacts of agricultural abandonment and afforestation on the biophysical supply and socio-cultural values for ES by considering (i) open vegetation as existing vegetation managed through agricultural practices of grazing, mowing and/or burning, (ii) broadleaved and pine forests as naturally occurring vegetation that would emerge through succession following abandonment, and (iii) spruce forests as areas that have been afforested.

4.1. *For whom, and what, should we manage landscapes for?*

Knowing how to maximise synergies and reduce trade-offs between the supply of different ES and the way they are valued, governed, and

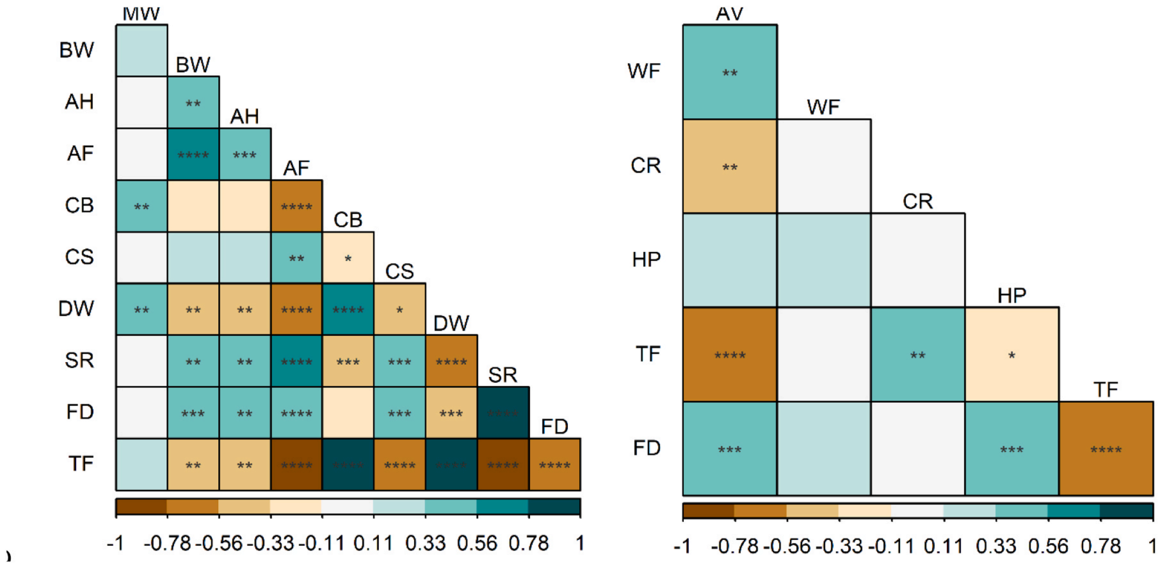

Fig. 3. Correlation plot of pairwise relationships between the ecosystem service (ES) indicators. On the left is all indicators and on the right is composite indicators. Test is Spearman correlation coefficient of mean values for the tree subplots per site (n = 33). Significance of relationships are indicated with asterisks (****, $p < 0.001$; ***, $p < 0.01$; **, $p < 0.05$; * $p < 0.1$). Abbreviations for all ES indicators are SR = Species richness of vascular plants, MW = Mushroom weight, BW = Berry weight, DW = Dead wood, AF = Flower colour richness, AH = Forb to graminoid ratio, FD = Fodder, CS = Soil carbon storage, CB = Tree biomass carbon storage, TF = Timber volume. Abbreviations for composite ES indicators are AV = Aesthetic value, WF = Wild food, CR = Climate regulation, HP = Habitat provision, TF = Timber and firewood, FD = Fodder.

managed is a key goal of landscape planning. Our results in this study and others within the same region support the contention that decisions about land use planning invariably involve trade-offs and win-wins are likely to be rare (Turkelboom et al., 2018). For example, previous work has shown that mismatches between socio-cultural values and governance and management of cultural ES in our study region are common (Barraclough et al., 2022).

We show that an increase in the biophysical supply of some ES from afforestation and/or abandonment can be beneficial for socio-cultural values of some ES but also detrimental for others by identifying (mis) matches between the socio-cultural values and biophysical supply of ES in different vegetation types. The clearest match occurred in habitat provision with both socio-cultural values and biophysical supply highest in open vegetation and lowest in planted spruce forests. This indicates that under afforestation there would be significant loss of biodiversity (Aarrestad et al., 2013) and the subsequent appreciation of that biodiversity because peoples' perceptions of biodiversity and actual biodiversity are relatively consistent (e.g., Lindemann-Matthies et al., 2010). In combination, these results are consistent with other work focussing on either biophysical data (Aarrestad et al., 2013) or socio-cultural values (Liu et al., 2021). Similarly, the match of socio-cultural values for agricultural products and biophysical fodder supply in open vegetation and broadleaved forests are consistent with the historical role of these vegetation types as outfield grazing areas. This suggests that abandonment would be more acceptable than afforestation since both values domains would be less impacted by successional changes to broadleaved forest. Perhaps the most surprising mismatch was in timber and firewood provision. Biophysical supply was expectedly high for spruce forest, lower for other forest types and negligible values for open vegetation. By contrast, socio-cultural values were only significant for broadleaved forest and surprisingly below expectations for pine forests. It is likely that people have socio-cultural value for firewood harvesting because it is an activity that individuals undertake in broadleaved forest (primarily birch). In contrast, timber harvesting is generally a commercial activity in spruce forest. Global climate regulation showed a somewhat messier picture in terms of (mis)match. For example, socio-cultural values for climate regulation were high for open vegetation but surprisingly low for the three forest types, contrasting with high biophysical supply in spruce and broadleaved forests. Given this is a central component of Norway's proposed climate forests we discuss further in the section '4.4 *What about climate forests?*'.

Although it is important that decisions about land use planning and management attempt to account for the overall values of society, it is important to recognise that values are not evenly spread across society. This means that some decisions could impact or benefit certain groups over others (King et al., 2015). For example, our study indicates that women and young people have higher values for regulating and maintenance, and cultural ES, while men and older people tend towards higher values for provisioning ES. Attempts to prioritise one ES category over the other will likely lead to trade-offs in the biophysical supply of ES and subsequently affect the interests and wellbeing of certain groups. It is often the case that ES associated with instrumental values (e.g., timber production) tend to take precedence over ES associated with relational and intrinsic values (e.g., sense of place or biodiversity) (Anderson et al., 2022). In our case, if provisioning ES are promoted this could have negative effects of the values of women and young people, two groups that are disproportionately under-represented in decision making in general and in environmental decision making in Norway (Lundberg, 2018). Excluding these groups is a missed opportunity because young people for example have broad comprehension of environmental challenges and are able to play an important role in meeting these challenges (Barraclough et al., 2021). Careful consideration of the implications for the values of specific groups that might arise from land-use change using an approach like ours can be an important component of a strategy aimed at avoiding or mitigating potential conflicts.

4.2. *Taking a landscape view*

We show that not all vegetation types supply the same ES in the same quantities, nor are they valued socio-culturally in the same way. Generally, socio-cultural values for all ES were high in open vegetation and broadleaved forests, lower in pine forests and very low in spruce forests on the one hand. Biophysical supply on the other hand was more variable among vegetation types although open vegetation and broadleaved forests still had among the highest values. These results support

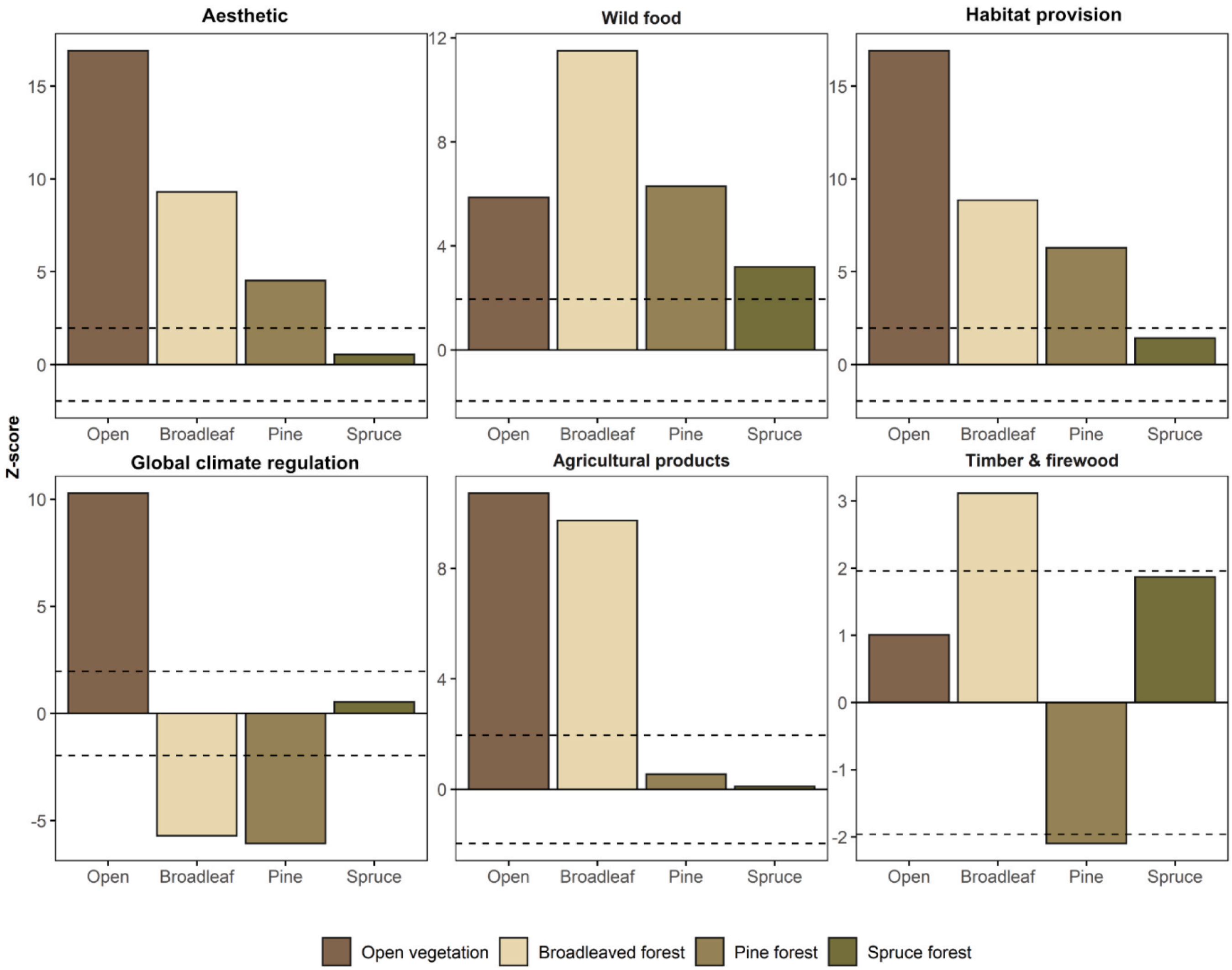

Fig. 4. *Z*-scores of socio-cultural values for ecosystem services in the four different vegetation types calculated from Public Participation GIS data. Residuals greater than 1.96 or less than − 1.96 (horizontal dashed lines) show that the values are significantly higher or lower than would be expected by chance, respectively. Note that y-axes are on different scales to aid visualisation.

Table 5
Chi-squared tests and Cramér's V statistics between mapped ecosystem services and habitat type, three socio-demographic variables and self-reported regional knowledge. Significant Chi-square tests are shown in bold. Cramér's V test shows the strength of the association between the variables (0.0 to < 0.1 negligible, ≥ 0.1 to < 0.2 weak, ≥ 0.2 to < 0.4 moderate).

Variable	X^2	*p-value*	df	Cramér's V
Age	57.34	0.000	25	0.126
Education	37.22	0.011	20	0.111
Farmer	46.27	0.000	5	0.247
Gender	13.43	0.020	5	0.135
Habitat	51.32	0.000	15	0.15
Regional knowledge	13.35	0.575	15	0.118
Resident status	27.52	0.000	5	0.191

planning choices that are more targeted towards allowing abandoned open vegetation to follow a successional trajectory towards broadleaved forest and pine forest to a lesser degree, rather than afforestation with spruce. Furthermore, our results highlight higher multifunctionality in open vegetation and broadleaved forests across value domains. However, we also show that important ES are not provided by those two vegetation types. Although, spruce forests tend to have lower biophysical supply of some ES than other vegetation types it was the only one to provide meaningful volumes of timber. Similarly, pine forests supplied substantially more wild food than the other vegetation types. A landscape without those vegetation types would therefore lack a meaningful supply those ES. Landscapes rarely comprise one or two ecosystems or land use/land cover types making it important to consider characteristics of the wider landscape that influence ES values and provision. For example, changes to single vegetation patches can have wider landscape impacts than at the local scale alone (Lindborg et al., 2008). Heterogenous agricultural landscapes with non-production elements tend to have positive effects on the habitat provision for biodiversity and other regulating and maintenance ES such as pollination and pest control (e.g., Case et al., 2020; Erdős et al., 2018; Pedersen and Krøgli, 2017; Tscharntke et al., 2021). Likewise, aesthetic preferences in agricultural landscapes tend to be positively influenced the richness and diversity of land use/land cover types, and the presence of non-production elements (Dramstad et al., 2006; Stokstad et al., 2020). High socio-cultural values for multiple ES also depends on the proportion of forest and agricultural land, as well as land use/land cover richness in various landscapes within this study region (Cusens et al., 2022). Heterogeneity is important within ecosystems too and in forested landscapes it appears that forest openings are also valuable for aesthetic appreciation (Gundersen and Frivold, 2008). Thus, if our results are considered at broader landscape scale, and across biophysical and socio-cultural domains, our

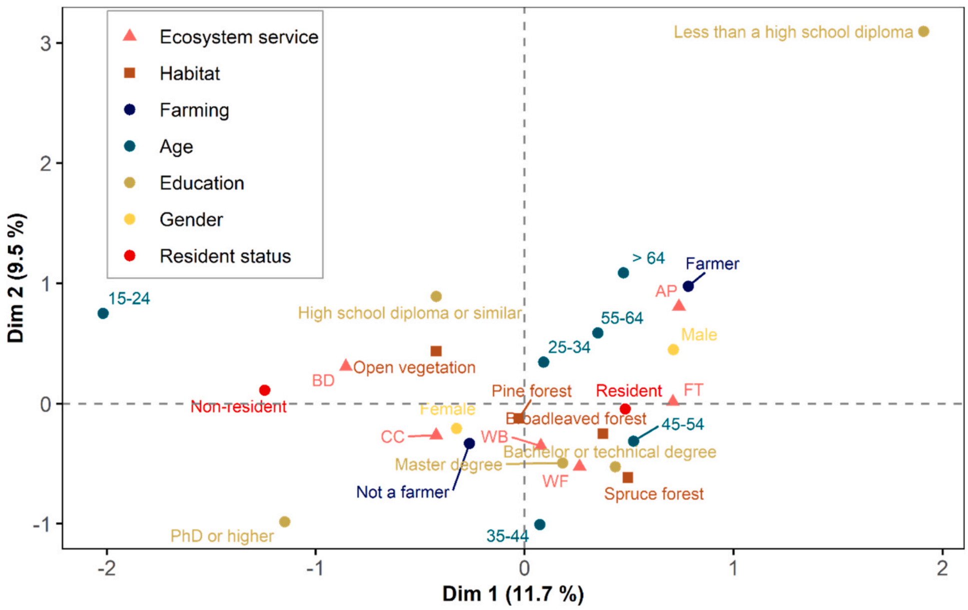

Fig. 5. Biplot of the first two dimensions of the multiple correspondence analysis of the mapped ecosystem services, habitat types, and three socio-demographic variables. CC = Climate change mitigation, BD = Appreciation of biodiversity, AP = Agricultural products, FT = Firewood & timber, WB = Inspiration, spiritual & aesthetic, WF = Wild foods.

Table 6
Cross comparison between socio-cultural values and biophysical supply for ecosystem services in the four vegetation types. The direction of the arrows and colours show whether the rank of socio-cultural value was higher (↑), lower (↓) or not different (↔) to biophysical supply in each vegetation type. See the legend for more details of colours and symbols.

Ecosystem service	Vegetation type				Overall (mis)match
	Open	Broadleaf	Pine	Spruce	
Aesthetic value	↔	↑	↓	↔	Strong
Wild food	↔	↑	↓	↔	Strong
Biodiversity	↔	↔	↔	↔	Very strong
Climate regulation	↑	↓	↓	↔	Weak
Agricultural products	↔	↔	↔	↔	Very strong
Timber & firewood	↔	↑	↔	↓	Moderate

Legend

Colour/ symbol	Description
↔	The same rank
↓↑	One rank higher or lower
↓↑	Two ranks higher or lower
↓↑	Three ranks higher or lower

Colour	Description
Very strong	All ranks match
Strong	Three ranks match
Moderate	Two ranks match
Weak	One rank matches
Very weak	No ranks match

results support the notion that multifunctional landscape requires a mosaic of vegetation types (Kremen and Merenlender, 2018).

4.3. Who should steward the cultural landscape?

Overall, our results show high socio-cultural values for ES open vegetation types that typify the cultural landscape of coastal western Norway, regardless of socio-demographic background. From our results we show that abandonment and afforestation in particular would negatively impact those values across a broad section of society. However, the ES that different groups value in these vegetation types are not the same. One the one hand, our results show that among the ES that we assessed, farmers, who tend to be male and older, value predominantly provisioning ES (agricultural products and firewood and timber), indicating that this group value the landscape predominantly for its production capacity. On the other hand, we show that non-farmers, especially younger non-resident females, valued more cultural and regulating and maintenance ES. Thus, although farmers are the primary managers of the open vegetation in the cultural landscape, the other elements in the landscape, and the entire landscape, are clearly valued by the wider society. The question is then how to manage the landscape for the vegetation types and elements that that benefits both farmers and society without the burden of management falling on the shoulder of farmers. Previous work in our study region has identified that farmers report a low levels of perceived respect from non-farmers, particularly those from outside of the local community (Riersen, 2019). This suggests that farmers largely are unaware of the values that people assign to the landscapes produced by their farming activities and management. Our results demonstrating high socio-cultural values for important components of the cultural landscape such as managed heathlands can help bridge the divide providing farmers with evidence of the benefits they provide to society. Appreciation of farmers' roles as stewards of the cultural landscape from 'outsiders' can provide encouragement and stimulate ongoing management (Stenseke, 2006), although this is unlikely to be enough. Policy instruments such as subsidies in agri-environmental schemes are one tool but not all farmers may want to participate (Kvakkestad et al., 2015). However, current subsidy support Norway for agriculture may be poorly targeted at production with inefficient gains for the public goods produced (Brunstad et al., 2005). Public engagement with management of the landscape from which they benefit could provide an additional means for managing those public goods. Our results can provide important guidance to inform campaigns for engaging groups that hold particular values to participate in landscape management. For example, we find that in general, younger people that do not reside in the region hold values for biodiversity and global climate regulation in open heathland vegetation. We can infer that this group is representative of university students, likely studying in environmental programmes pointing to fruitful places and themes for engagement. Involvement of farmers is critical not only because they are usually the landowners, but because of the important traditional ecological knowledge they hold. For example, the traditional practice of burning for managing the successional pathway of heathlands requires this form of knowledge (Kaland and Kvamme, 2014; Måren, 2009). Farmers also hold different values and take different roles as landscape stewards including conservationist, productionist or a combination of the two (Moroder and Kernecker, 2022; Raymond et al., 2016).

4.4. What about climate forests?

It is fundamental to the aim of climate forests that they store and sequester more carbon than the existing vegetation that they are replacing. But it is also important that the climate forests do not substantially encroach on other values identified related to biodiversity and cultural values, regardless of carbon gains (Dooley et al., 2022; Iversen et al., 2021). We did not find higher biophysical global climate regulation capacity in spruce plantation forests compared to other vegetation types, nor did we find significantly high socio-cultural values for spruce forest aside from wild food and even then, it was the least valued vegetation type we assessed. The only ES spruce forest had the highest biophysical supply was timber (and firewood) which is unsurprising given the primary function of those forests. The other biophysical ES indicators we used were also generally lower or not significantly different in spruce forest from the other vegetation types. Surprisingly, timber and firewood were not identified as important in the socio-cultural valuation. The low climate regulation capacity of spruce forests may be surprising considering the substantial biomass carbon in these forests. However, our use of a composite indicator that includes soil carbon offsets the gains from biomass carbon in the spruce forests. These results are generally consistent with other studies that find that soil carbon in coastal heathlands, meadows and agricultural soils in Norway are greater or not different from forests and woodlands (Bartlett et al., 2020; Haugum, 2021; Sørensen et al., 2018; Strand et al., 2021). In general, open vegetation and broadleaved forests were highly valued (five of six ES assessed) in the socio-cultural assessment. The lack of difference in global climate regulation between spruce and other vegetation types suggests that the primary objective of climate forests may not in fact be realised. Our results support the findings on social preferences for open vegetation and mixed forest types as has been previously reported in Norway, particularly western Norway (Liu et al., 2021). In this we argue that the values that people ascribe to nature are inherently place based, and thus careful consideration must be taken during land-use decision making to assess the values in each particular case and context. For example, our method uncovers a place attachment for historically common vegetation types like heathlands and livestock grazed open broadleaved forests that are typical of the mosaic cultural landscape in western Norway. So, while our results can have regional or potentially national applicability, careful consideration should be taken for their wider application.

4.5. Afforestation or managed abandonment?

Although the Norwegian afforestation programme focusses on native tree species, Norway spruce is the only species considered to be of value for climate forests. Critically, Norway spruce does not occur naturally in outer areas of western Norway (Birks et al., 2012) and therefore arguably does not meet the 'native' species criterion (VKM, Nielsen et al., 2021). Tölgyesi et al. (2022) have recently argued that the pervasive view of tree-planting as a climate solution needs to be reframed to focus on 'restoring native vegetation'. Their main point being that afforestation does not mean more carbon. Considering that our analysis indicates that other vegetation types store similar amounts of carbon to planted spruce forest it can be argued that spruce is not superior for climate mitigation and birch and/pine might be equally valuable. At a landscape scale pine and/or birch forest would come with greater additional synergies with other valued ES, providing greater overall multifunctionality in the landscape and higher overall benefits. Allowing forests to regrow through a successional trajectory where ongoing agricultural activity is not possible (e.g., not economically viable) could be a better alternative to planting spruce forests. Here it may be possible to consider different options including a form of low intervention rewilding or passive rewilding (Carver et al., 2019) with less impact on the biotic character of the open heathland vegetation than might be caused by native species like Scots pine (Saure et al., 2013). However, we acknowledge that strict rewilding typically considers the whole trophic cascade including predators which is a highly contentious issue with multiple societal and political challenges. Instead, stepping back and taking the landscape view once again and thinking about the whole landscape matrix as a target of conservation is likely to yield a more harmonious outcome for people and nature (Bridgewater et al., 2017).

4.6. Reflection on our approach

Although we have combined socio-cultural values and biophysical supply assessments there are some links between biophysical characteristics of the vegetation types and socio-cultural values, we were not able to disentangle. Firstly, the biophysical supply indicators and socio-cultural value assessment may not always capture the same thing. There are two instances where this occurred: (i) fodder production/agricultural production and (ii) vegetation aesthetics/aesthetic appreciation. We used fodder production as a biophysical indicator while we used agricultural production for the socio-cultural statement. Since virtually all agricultural production in our study area is livestock, predominantly sheep (Statistics Norway, 2019) fodder production is a good indicator of agricultural production as used in our socio-cultural values mapping. For aesthetics, the biophysical aesthetic indicator captures only the aesthetics of the vegetation field layer while aesthetic appreciation mapped by participants in the PPGIS survey is likely to represent a wider field of view incorporating different landforms and landscape elements. Despite the likely influence of the wider landscape on aesthetics our results for socio-cultural values of the same vegetation types are very similar to a photo elicitation study that considered only narrow fields of view of only the vegetation at eye level (Liu et al., 2021). Secondly, our mapping method only distinguished between the broad vegetation classes in the socio-cultural valuation without considering forest stand characteristics such as canopy openness, stand age and/or tree size. These characteristics have been shown to be important in preference studies in the Nordic region (reviewed by Gundersen and Frivold, 2008). For example, young planted forests that are typically dense are less preferred than older, naturally occurring mixed forests (Liu et al., 2021). However, older planted forests still tend to have lower appreciation than other forest types regardless of age. Thus, our results would likely be minimally impacted by the addition of those stand characteristics in the mapping method. We used standing deadwood as an indicator for habitat provision, but it has also been found to be associated with aesthetic values (Gundersen and Frivold, 2011). Despite this it is likely that other broad ecosystem elements overwhelm the aesthetic values of deadwood, and it may only be of value when comparing the same ecosystem type. It is therefore considered to be an appropriate indicator for habitat provision our work.

Our combination of biophysical supply and social-cultural values for ES is an advancement in nature valuation. However, recent work from IPBES (IPBES, 2022) and associated publications (e.g., Pascual et al., 2017; Raymond et al., 2023) points to the need to consider a broader perspective to account for plural and diverse values for nature in decision making. Our approach uses *value indicators* (cf. IPBES, 2022) without explicitly identifying the *specific values* (i.e., instrumental, relational or intrinsic) that are linked to the indicators, nor do we explore higher levels of value determination (i.e., *broad values* and *worldviews and knowledge systems*). Although we identified some socio-demographic characteristics of participants, these characteristics do not definitively uncover *worldviews* for example. A deeper understanding of higher levels of value determination would likely provide enhanced guidance for decisions makers and improve the likelihood of operationalising our findings (Raymond et al., 2023).

5. Conclusion

Land abandonment and afforestation of agricultural land have multifaceted effects on biophysical and socio-cultural value-domains. Our approach of integrating biophysical and socio-cultural values for ES in different vegetation types that are indicative of traditional agricultural use, natural forests and planted forests identifies trade-offs and synergies both within value-domains as well as between them. We show that biophysical supply of ES is more similar than different in the different vegetation types, but some contrasts are clear. Open vegetation and natural forests tend to be more multifunctional but are unable to supply some key ES, most prominently timber. Importantly, we find that planted forests are not superior at carbon storage compared to the other vegetation types calling into question their utility for climate mitigation. Instead, for biophysical multifunctionality natural forests allowed to grow along a successional trajectory may be a better choice and we echo calls for a focus on restoration rather than tree planting (Tölgyesi et al., 2022). The biophysical supply was similarly reflected with high socio-cultural values for open and natural forests. But some key matches and mismatches between the value-domains were evident: climate regulation was poorly matched with biophysical supply typically higher than socio-cultural values, and biodiversity and agricultural products were very well matched. Socio-cultural values were not evenly spread across the study participants. There were two distinct groups representing older farmers resident in the region with high values for provisioning ES on the one hand, and younger females that are not residents valuing regulating and maintenance ES. These results are important for considering how the landscape can be stewarded for multiple benefits across different actors. We argue that in addition to policy mechanisms such as agri-environmental schemes, broader public participation could be a key mechanism in landscape stewardship. This would require fostering of partnerships between farmers, local communities and authorities and nature conservation societies (Barraclough et al., 2023; Bridgewater et al., 2017). Our results can inform implementation of campaigns to target groups with special interests in specific landscape values.

Compliance with ethical standards

Research involving human participants.

Ethics approval was obtained from The Norwegian Centre for Research Data (Naturgoder i Nordhordland UNESCO Biosfæreområde, Ref no. 657151) to undertake the survey used to collect data in this research.

Informed consent

All participants gave consent in accordance with the conditions approved by The Norwegian Centre for Research Data prior to filling out the survey used to collect data in this research.

CRediT authorship contribution statement

Jarrod Cusens: Conceptualization, Methodology, Investigation, Data curation, Formal analysis, Writing – original draft, Visualization, Project administration, Funding acquisition. **Alícia Barraclough:** Conceptualization, Methodology, Investigation, Writing – review & editing, Supervision. **Inger Måren:** Conceptualization, Methodology, Investigation, Writing – review & editing, Supervision, Funding acquisition.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.landusepol.2023.106967.

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