An empirical evaluation of spatial value transfer methods for identifying cultural ecosystem services

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ARTICLE INFO

Article history:
Received 18 December 2015
Received in revised form 24 March 2016
Accepted 29 March 2016

Keywords:
Benefit transfer
Norway
Regional assessment
Cultural values
Participatory mapping

ABSTRACT

A significant barrier to the assessment of ecosystem services is a lack of primary data, especially for cultural ecosystem services. Spatial value transfer, also known as benefits transfer, is a method to identify the probable locations of ecosystem services based on empirical spatial associations found in other geographic locations. To date, there has been no systematic evaluation of spatial value transfer methods for cultural ecosystem services identified through participatory mapping methods. This research paper addresses this knowledge gap by examining key variables that influence value transfer for cultural ecosystem services: (1) the geographic setting, (2) the type of ecosystem services, and (3) the land cover data selected for value transfer. Spatial data from public participation GIS (PPGIS) processes in two regions in Norway were used to evaluate spatial value transfer where the actual mapped distribution of cultural ecosystem values were compared to maps generated using value transfer coefficients. Six cultural ecosystem values were evaluated using two different land cover classification systems GlobCover (300 m resolution) and CORINE (100 m resolution). Value transfer maps based on the distribution of mapped ecosystem values produced strongly correlated results to primary data in both regions. Value transfer for cultural ecosystems appears valid under conditions where the primary data and value transfer regions have similar physical landscapes, the social and cultural values of the human populations are similar, and the primary data sample sizes are large and unbiased. We suggest the use of non-economic value transfer coefficients derived from participatory mapping as the current best approach for estimating the importance and spatial distribution of cultural ecosystem services.

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1. Introduction

A logical consequence of the Millennium Ecosystem Assessment (2005) has been increased effort to identify and map the distribution of ecosystem services globally, but ecosystem services are resource-intensive to identify, inventory, and map. In the absence of primary data in most places, a common method has been the use of proxies based on “benefits transfer” Plummer (2009), also known as “spatial value transfer” (Troy and Wilson, 2006). These methods involve estimating ecosystem benefits from a small region and applying them over a larger area, or stated more generally, the transfer of primary data to areas where no data exist. A common approach is to estimate ecosystem services from land cover data and then apply economic valuation as transfer coefficients (e.g., Sutton and Costanza, 2002; Troy and Wilson, 2006; Turner et al., 2007; Petrosillo et al., 2009).

Cultural ecosystem services (CES) are a subset of ecosystem services that provide non-material benefits such as spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences (MEA, 2005). Identifying the spatial distribution of CES presents special challenges because they are not adequately defined or integrated within the ecosystem services framework (Chan et al., 2012; Daniel et al., 2012), are usually intangible and incomensurate with economic valuation methods (Chan et al., 2012; Hernández-Morcillo et al., 2013), may be “bundled” with other ecosystem services (Raudsepp-Hearne et al., 2010), and involve complex psychological dimensions in the valuation process (Kumar and Kumar, 2008). Due to these methodological challenges, cultural ecosystem services are rarely fully considered in ecosystem services assessments (Plieninger et al., 2013).

Most CES are not directly observable in the physical landscape and require (1) proxy or indicator measures derived from observed or inferred human behavior, or (2) direct human inquiry about the
benefits received. Proxies may be used to identify the location of CES, for example, the number of tourist attractions as a proxy for tourism benefits or the number of observations of rare species as a proxy for nature appreciation benefits (Raudsepp-Hearne et al., 2010). However, the validity of proxies, especially for CES, is often questionable (see Eigenbrod et al., 2010a). Research to collect primary data on CES has increasingly used participatory mapping methods, variously called public participation GIS (PPGIS), participatory GIS (PGIS), and volunteered geographic information (VGI) (see Brown and Fagerholm, 2015; Brown and Kyttä, 2014, for a review of applications). The mapping of place-based values using PPGIS/PGIS/VGI methods appears valid for identifying CES under the assumption that the values elicited identify locations that directly or indirectly contribute to human well-being. The terms ecosystem “service” and “value” are often conflated in the literature as the terms are closely related. Ecosystem services are the benefits people obtain from ecosystems while ecosystem values are measures of how important ecosystem services are to people. An assumption of participatory mapping is that when a place is identified as valuable by a participant, it is providing a benefit or service. The mapping of ecosystem values identify relationship values (Brown and Weber, 2012) that bridge held values (what is important to the person mapping) and assigned values (the physical place features that contribute to the value).

Participatory mapping methods are a desirable method for identifying CES given their flexibility and adaptability to a wide range of physical and social settings. Specifically, participatory mapping can be designed to identify a full range of CES from landscape esthetics to “sense of place”, can use digital or non-digital mapping technologies, can use qualitative or quantitative methods, and can target different sampling groups ranging from randomly selected households, to stakeholder groups, to crowd-sourced volunteers. But this methodological pluralism also means that “best practice has yet to coalesce” in the mapping of ecosystem services (Brown and Fagerholm, 2015, p. 119) resulting in continuing trials and case studies that map CES. Given the effort required to collect primary CES data, there is benefit if the participatory mapping of CES can be meaningfully spatially transferred to other places where primary data does not exist.

The spatial value transfer of CES involves describing the spatial associations between CES and the physical landscape in one area and then applying these associations to other areas or regions. One of the challenges to spatial value transfer is the heterogeneity in global physical environments and diversity in human cultures. For example, the cultural ecosystem service of recreation may be found in a wide range of physical environments, from mountains to lakes to urban parks, while preferences for specific types of recreation activities are typically embedded in cultural norms. Significant spatial associations between CES and land cover have been identified in multiple empirical studies (e.g., Brown, 2013; Brown et al., 2012; Brown and Brabyn, 2012a,b) but the associations vary by place and cultural setting. The distribution of CES may also be influenced by land tenure and protected area status (Brown et al., 2015b; Hauser et al., 2015).

Generalization errors are the major threat to the validity of spatial transfer methods. As described by Plummer (2009), generalization error can be subdivided into three components of uniformity, sampling, and regionalization. Uniformity error occurs when ecosystem values are not constant (uniform) for a particular physical environment such as land cover, sampling error results from too few study areas being used to develop transfer indices or coefficients, and regionalization error occurs when the study area is not representative of the area being transfer mapped. Results from benefit transfer of primary recreation data in England using 10 km × 10 km grid cells and land cover proxies show that generalization errors are “sufficiently large to undermine decisions that might be based on such extrapolated maps” (Eigenbrod et al., 2010b, p. 2487). They found that variation in ecosystem services within the land cover classes (uniformity error) resulted in a poor fit to primary data, while sampling effects and area extrapolation also contributed to reductions in fit with primary data. The high degree of uniformity error was not surprising given that recreation value tends to be spatially clustered, even within a given land use cover class.

The generalization errors depend on the scale and the quality of land use/land cover maps used for benefit transfer. Multiple studies indicate that benefit transfer results are sensitive to both the choice of land cover data, especially for value transfer of biophysical ecosystem services, and the value-transfer population in the case of cultural ecosystem services such as recreation. Foody (2015) found ecosystem service values based on six land cover classes in the U.S. changed almost two-fold when adjusted for misclassification bias, while Konarska et al. (2002) showed the estimated economic value of ecosystem services could increase by a factor of three when using land cover classification derived from 30 m spatial resolution imagery instead of 1 km resolution imagery. Grét-Regamey et al. (2014) found that the use of too coarse resolutions (250–300 m) underestimate the presence of spatially aggregated ecosystem services compared to finer resolutions (25–30 m). Similarly, Whitham et al. (2015) used six different methods to assess ecosystem service values in a protected area in China and showed that locally based, and more time and skill-intensive economic valuation approaches produced different results from global assessments developed by Costanza et al. (1997). These generalization errors have been assessed for biophysical indicators of ecosystem services and appear applicable to value transfer processes that assess CES.

No studies have previously evaluated the validity of spatially transferring multiple CES from one location to the other using participatory mapping. In the value transfer study most closely related to this study, Brown et al. (2015a) used participatory mapped data that identified places as important for recreation (primary data) in two separate study regions in Norway. In the analysis, the primary spatial data collected in one region was value-transferred to the second region based on the proportion of recreation values found in each land cover class. The value-transfer map was compared to the map generated from primary recreation data. The correlation coefficient between the primary data map and the value transfer map was 0.98 indicating a good fit across regions. However, the Brown et al. (2015a) value-transfer study did not explore the full potential of participatory mapping whose strength lies in the potential to assess multiple CES values while identifying their relative importance. With the value transfer of CES, one might hypothesize that participatory maps generated from local or regional populations would produce large generalization errors in the value-transfer process. And similar to findings from previous value transfer studies of biophysical services, the transfer of CES may be highly sensitive to the type and resolution of land cover data used to implement the value transfer. This study expands on Brown et al. (2015a) by providing a more comprehensive, empirical evaluation of value-transfer for multiple CES and by using two land cover classification systems with different spatial resolutions.

1.1. Research aims and objectives

The purpose of this study is to empirically evaluate value transfer for CES by examining key variables that can potentially influence value-transfer outcomes for CES, including the human population and region sampled, the choice of land cover data, and the type and quantity of primary CES data collected. Thus, the specific research questions to be examined in this study are as follows:
(1) Does the type of cultural ecosystem value being measured affect spatial value-transfer outcomes?

(2) Do regional differences in physical landscapes and sampled human populations influence spatial value-transfer outcomes?

(3) Given the importance of land cover data as the value-transfer medium, does the choice of land cover data affect transfer outcomes?

(4) Under what conditions does spatial value transfer appear appropriate to identify the distribution of cultural ecosystem services?

2. Methods

2.1. Study locations

Two study areas in Norway were selected that provide for contrast in physical landscapes, land tenure systems, and populations (see Fig. 1). The southern study area is located in the Sogn region and is characterized by fjords, glaciers, and mountain plateaus. Less than 5% of the study area is used for cultivation or forestry (Mathiesen et al., 2013). Primary economic activities in the region include livestock grazing, tourism, and hydroelectric power generation, with greater diversity of land use in lowland areas such as cruise tourism, aquaculture, and fruit cultivation. Most villages are small but there are two major hubs, Voss and Sognsdal, with 14,006 and 7623 inhabitants, respectively. There are four national parks located in the study region (Breheimen, Jotunheimen, Reinheimen, Jostedalsbreen) situated primarily in the uplands.

The northern study area, Nordland region, is characterized by a narrow coastline with connection to the open sea with small fjords. About half of the study area is owned by the state through the state-owned company Statsskog SF. The alpine areas in the region are important for reindeer husbandry with lichen-rich, good pasture for reindeer. Most of the study area is characterized by rural settlements with residents employed in primary industries. The municipalities of Bodø and Fauske have about 50,000 and 9000 inhabitants, respectively. There are five national parks in the study region: Rago, Sjunkhatten, Junkerdal, Saltfjellet-Svartisen, and Lahko, and five protected landscape areas.

2.2. Public participation GIS (PPGIS) implementation

The research team designed, pre-tested, and implemented two internet-based PPGIS websites for the North and South regions in Norwegian language for data collection. The websites consisted of a Google® maps interface where participants could drag and drop digital markers onto a map of the study area. A panel containing markers with 14 ecosystem values was provided and participants were instructed to drag and drop the markers onto map locations that are important for the values listed (see Table 1). The selection of ecosystem values was based on a typology first developed by Brown and Reed (2000) that was modified and adapted for use in Norway following consultation with protected area managers in the two study areas. The different types of markers and their spatial locations were recorded for each participant in a web server database.

Household sampling was used in both the North and South study areas to recruit PPGIS participants. In the South region, about 10% of the adult population (>18 years) were randomly sampled for a potential 3104 participants. Sampled individuals were sent a letter of invitation and a reminder two weeks after the initial invitation. Parallel to household recruitment, regional organizations (n = 274) were contacted, either by email or Facebook, to inform them about the study and to encourage volunteer participation.

A similar, random household sampling design was used in the North region for a potential 3054 participants. A total of 216 organizations were also contacted for potential volunteer participation. A total of 440 and 486 individuals from the South and North regions participated in the study between November 2014 and January 1, 2015 for response rates of 14% and 16%, respectively. A detailed profile of study participants is provided in Brown et al. (2015a,b). A total of 19,134 markers were mapped by participants across both study areas.

2.3. Analyses

2.3.1. Selection of ecosystem values for spatial value-transfer

We selected six of the 14 ecosystem values to evaluate value-transfer outcomes. Three of the ecosystem values would be classified as prima facie indicators of cultural ecosystem services
(recreation, scenery, cultural identity) per the MEA (2005), and three would generally be classified as indicators of provisioning services (hunting/fishing, grazing, gathering). In Norway, however, these three provisioning services also have strong cultural importance given that few people in Norway rely on these services for subsistence. Hunting/fishing and gathering activity appears more important for recreation in Norwegian society while the pasturing of animals is valued for maintaining cultural landscapes. We included these multi-function ecosystem values for contrast and comparison with the cultural value results.

### 2.3.2. Data preparation and land cover databases

Two land cover databases were selected for evaluating value transfer methods. The first land cover database, called GlobCover, was developed by the European Space Agency in collaboration with the Université Catholique de Louvain (Bontemps et al., 2011). This is a global land cover with a spatial resolution of 300 m with 22 land cover classes. The overall accuracy weighted by class area was 67.5% using 2190 globally distributed covers, including homogeneous and heterogeneous landscapes (Bontemps et al., 2011, p. 47). GlobCover is created from automated image processing of satellite data provided by the European Space Agency where land cover classes are classified based on spectral signatures for pixels. The second land cover database, called CORINE Land Cover (CLC), was developed by the European Union and is maintained by the European Environment Agency. The land cover database has as spatial resolution of 100 m with 44 classes and a Minimum Mapping Unit (MMU) of 25 ha. The thematic accuracy of CLC exceeds 85% (Büttner and Maucha, 2006).

CLC is created from a semi-automated interpretation of higher resolution satellite imagery, with land cover classes visually interpreted by experts from each country. Local expert interpretation is able to consider landscape context and land use patterns, so land classes may better represent functional land units which include human interactions affecting land cover (Verburg et al., 2009).

The two land cover layers were clipped to the boundaries of the North and South study areas and spatially intersected with the mapped ecosystem value points. Thus, each mapped ecosystem value was associated with a specific land cover class. The spatial benefit transfer coefficient was calculated for the two study regions and was simply based on the proportion of ecosystem values that were spatially associated with land cover classes.

#### Table 1

<table>
<thead>
<tr>
<th>Ecosystem value</th>
<th>Operational definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hunting/fishing*</td>
<td>Areas are important because of hunting and/or fishing</td>
</tr>
<tr>
<td>Pastures/fodder*</td>
<td>Areas are important because they are used for haymaking and pastures for reindeer, sheep, cows</td>
</tr>
<tr>
<td>Gathering*</td>
<td>Areas are important for berries, mushroom or collecting herbs/plants here</td>
</tr>
<tr>
<td>Recreation*</td>
<td>Areas are important for outdoor recreation activities (e.g., camping, walking, skiing, alpine, snowmobiling, cycling, horse riding, etc.)</td>
</tr>
<tr>
<td>Scenic areas*</td>
<td>Areas are important because they include beautiful nature and/or landscapes</td>
</tr>
<tr>
<td>Culture/identity*</td>
<td>Areas are important because of their historical value, or for passing down the stories, myths, knowledge and traditions, and/or to increase understanding of the way of life of our ancestors</td>
</tr>
<tr>
<td>Water quality</td>
<td>Areas are important because they provide clean water</td>
</tr>
<tr>
<td>Biological diversity</td>
<td>Areas are important because they provide a variety of plants, wildlife, and habitat</td>
</tr>
<tr>
<td>Income</td>
<td>Areas are important because they provide tourism opportunities, mining, hydroelectric power or other potential sources of income</td>
</tr>
<tr>
<td>Undisturbed nature (naturalness)</td>
<td>Areas are relatively untouched, providing for peace and quiet without too many disturbances</td>
</tr>
<tr>
<td>Social</td>
<td>Areas are important because they provide opportunities for social activities (e.g., associated with fireplaces, picnic tables, ski – or alpine arrangements, shelters, shared cabins, cabin complexes)</td>
</tr>
<tr>
<td>Spiritual</td>
<td>Areas are important because they are valuable in their own right or have a deeper meaning; emotionally, spiritually, or religious</td>
</tr>
<tr>
<td>Therapeutic/health</td>
<td>Place are valuable because they make me feel better, either because they provide opportunities for physically activities important for my health and/or they give me peace, harmony and therapy</td>
</tr>
<tr>
<td>Special places</td>
<td>Please describe why these places are special to you</td>
</tr>
</tbody>
</table>

#### Table 2

<table>
<thead>
<tr>
<th>GlobCover Classification</th>
<th>Percent South</th>
<th>Percent North</th>
<th>Recreation South North</th>
<th>Scenic South North</th>
<th>Cultural South North</th>
<th>Hunting/fishing North</th>
<th>Grazing North</th>
<th>Gathering North</th>
</tr>
</thead>
</table>
2.3.3. Data analysis

For both GlobCover and CORINE land cover data, Chi-square statistics with standardized residuals were calculated to determine whether the number of mapped points for each ecosystem value differed significantly from the expected number of points in each land cover class under the assumption that ecosystem value and land cover class are independent. Standardized residuals greater than +1.96 or less than −1.96 indicate significantly more or fewer mapped points, respectively, than expected in each class.

In the second analysis, we examined whether the proportion of ecosystem values mapped in each land cover class where significantly different between the North and South regions. Statistical tests for proportional differences between regions were calculated, with z-scores >1.96 (two-tailed test, α = 0.05) indicating proportionally more or fewer points were mapped in each land cover class.

The percentages of ecosystem values spatially associated with each land cover class were used as value-transfer coefficients. This method assumes that ecosystem values would be similarly distributed across land cover classes where primary data was not collected. The coefficients in the North region were applied to land cover classes in the South, while the coefficients in the South were applied to the North region. This process was completed for both GlobCover and CORINE land cover data. Thus, for each region and for each ecosystem value, there was a primary or “actual” distribution and a spatial “value-transfer” distribution for each type of land cover data (GlobCover and CORINE).

To assess the similarity between the actual (primary) and value-transfer distributions, we generated color-coded maps to provide for qualitative, visual contrast. The maps were generated by applying the proportion of ecosystem values associated with each land cover class in the North study region to the same land cover classes in the South region and vice versa, for each ecosystem service. The same defined intervals (5 classes) of transfer coefficients (percentages) and color ramps were applied to the two maps (primary and spatial value transfer). To quantify the overall similarity in maps, we calculated Pearson’s product moment correlations between spatially paired cells in the primary and value-transfer maps for each region. This aggregate measure of map similarity accounts for the similarity (or difference) between the primary and transfer values in each land cover class as shown in Tables 2 and 3 (similar primary and transfer values increase the map correlation coefficient) and the proportion of the study region contained in the land cover class (similar primary and transfer values in the largest land cover classes increases the map correlation coefficient).

### Table 3

<table>
<thead>
<tr>
<th>CORINE Land Cover Classification</th>
<th>Percent South</th>
<th>Percent North</th>
<th>Recreation South</th>
<th>North</th>
<th>Scenic North</th>
<th>Cultural North</th>
<th>Hunting/ﬁshing North</th>
<th>Grazing North</th>
<th>Gathering North</th>
</tr>
</thead>
<tbody>
<tr>
<td>112 Discontinuous urban fabric</td>
<td>0.1</td>
<td>0.2</td>
<td>* 0.0</td>
<td>*</td>
<td>* 0.0</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>121 Industrial or commercial units</td>
<td>0.0</td>
<td>0.0</td>
<td>* 0.0</td>
<td>*</td>
<td>* 0.0</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>123 Port areas</td>
<td>0.0</td>
<td>0.0</td>
<td>* 0.0</td>
<td>*</td>
<td>* 0.0</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>124 Airports</td>
<td>0.0</td>
<td>0.0</td>
<td>* 0.0</td>
<td>*</td>
<td>* 0.0</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>141 Green urban areas</td>
<td>0.0</td>
<td>0.0</td>
<td>* 0.0</td>
<td>*</td>
<td>* 0.0</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>142 Sport and leisure facilities</td>
<td>0.0</td>
<td>0.0</td>
<td>* 0.0</td>
<td>*</td>
<td>* 0.0</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>211 Non-irrigated arable land</td>
<td>0.5</td>
<td>0.0</td>
<td>* 0.0</td>
<td>*</td>
<td>* 0.0</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>231 Pastures</td>
<td>0.0</td>
<td>0.0</td>
<td>* 0.0</td>
<td>*</td>
<td>* 0.0</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>242 Complex cultivation patterns</td>
<td>0.4</td>
<td>0.1</td>
<td>* 0.0</td>
<td>*</td>
<td>* 0.0</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>243 Agriculture, w/significant areas natural vegetation</td>
<td>1.5</td>
<td>1.2</td>
<td>* 0.0</td>
<td>*</td>
<td>* 0.0</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>311 Broad-leaved forest</td>
<td>11.8</td>
<td>14.1</td>
<td>13.1</td>
<td>12.0</td>
<td>12.0</td>
<td>14.5</td>
<td>19.4</td>
<td>13.7</td>
<td>13.6</td>
</tr>
<tr>
<td>312 Coniferous forest</td>
<td>5.9</td>
<td>1.2</td>
<td>6.2</td>
<td>1.9</td>
<td>1.4</td>
<td>6.7</td>
<td>1.7</td>
<td>6.8</td>
<td>7.4</td>
</tr>
<tr>
<td>313 Mixed forest</td>
<td>1.2</td>
<td>0.6</td>
<td>1.7</td>
<td>1.1</td>
<td>1.1</td>
<td>1.0</td>
<td>0.4</td>
<td>2.2</td>
<td>1.2</td>
</tr>
<tr>
<td>Total (Classes 311-313)</td>
<td>18.9</td>
<td>15.9</td>
<td>24.6</td>
<td>23.9</td>
<td>21.4</td>
<td>19.5</td>
<td>15.7</td>
<td>39.8</td>
<td>31.1</td>
</tr>
<tr>
<td>322 Forest and heathland</td>
<td>14.0</td>
<td>12.1</td>
<td>14.0</td>
<td>12.3</td>
<td>12.3</td>
<td>15.2</td>
<td>12.2</td>
<td>17.3</td>
<td>16.1</td>
</tr>
<tr>
<td>332 Bare rocks</td>
<td>18.8</td>
<td>10.3</td>
<td>19.7</td>
<td>10.9</td>
<td>6.8</td>
<td>8.6</td>
<td>3.4</td>
<td>3.2</td>
<td>3.5</td>
</tr>
<tr>
<td>333 Sparserly vegetated areas</td>
<td>31.7</td>
<td>28.6</td>
<td>21.4</td>
<td>28.1</td>
<td>21.1</td>
<td>27.9</td>
<td>21.7</td>
<td>20.4</td>
<td>31.9</td>
</tr>
<tr>
<td>335 Glaciers and perpetual snow</td>
<td>5.4</td>
<td>3.2</td>
<td>4.8</td>
<td>0.5</td>
<td>5.8</td>
<td>0.3</td>
<td>2.5</td>
<td>2.8</td>
<td>0.0</td>
</tr>
<tr>
<td>412 Peat bogs</td>
<td>0.9</td>
<td>1.2</td>
<td>1.4</td>
<td>3.3</td>
<td>1.1</td>
<td>1.8</td>
<td>1.3</td>
<td>2.2</td>
<td>1.2</td>
</tr>
<tr>
<td>423 Intertidal flats</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>511 Water courses</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.1</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>512 Water bodies</td>
<td>3.6</td>
<td>4.9</td>
<td>* 3.6</td>
<td>2.3</td>
<td>3.5</td>
<td>3.5</td>
<td>7.7</td>
<td>12.2</td>
<td>11.2</td>
</tr>
<tr>
<td>Unclassified</td>
<td>3.6</td>
<td>21.7</td>
<td>2.2</td>
<td>3.2</td>
<td>3.9</td>
<td>7.6</td>
<td>3.9</td>
<td>1.9</td>
<td>14.3</td>
</tr>
</tbody>
</table>

### Table 4

<table>
<thead>
<tr>
<th>Ecosystem value</th>
<th>South Region (Sogn)</th>
<th>North Region (Nordland)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>GlobCover</td>
<td>CORINE Land Cover</td>
</tr>
<tr>
<td>Scenic</td>
<td>0.98</td>
<td>0.97</td>
</tr>
<tr>
<td>Recreation</td>
<td>0.98</td>
<td>0.95</td>
</tr>
<tr>
<td>Cultural</td>
<td>0.99</td>
<td>0.94</td>
</tr>
<tr>
<td>Grazing</td>
<td>0.95</td>
<td>0.78</td>
</tr>
<tr>
<td>Hunting/ﬁshing</td>
<td>0.98</td>
<td>0.95</td>
</tr>
<tr>
<td>Gathering</td>
<td>0.94</td>
<td>0.89</td>
</tr>
</tbody>
</table>
3. Results

3.1. Relationships between ecosystem values and land cover

Norway’s actual land cover classes comprise a smaller subset of the 22 possible land cover classes identified in the GlobCover system and 44 classes in the CORINE system. With GlobCover, 10 of the 22 land classes comprise 1% or more in the North and South study areas compared to 11 of 44 CORINE land classes. Land cover in the two study areas is dominated by mixed forests, sparse vegetation, and bare areas with relatively little land in agriculture, grassland, or developed area (see Tables 2 and 3). Within each region, mapped ecosystem values exceeded expected counts based on areal proportions in forest-related land classes including moors and heathland, while most ecosystem values were underrepresented in bare, sparsely vegetated, and areas of permanent snow and ice. Scenic, recreation, and hunting/fishing values were disproportionately more abundant in sparsely vegetated areas in the North compared to the South. Cultural values were especially abundant in both study regions in lower elevation areas proximate to human development areas. The data suggest a type of topographical gradient of values with greater abundance of cultural ecosystem values located in lowlands, especially in the South region.

There were significant proportional differences between regions in the distribution of ecosystem values by land class, with many differences attributable to differences in the land cover classification system. For example, recreation, scenic, and cultural values were mapped significantly more in the South region in the GlobCover class for closed to open mixed forest (Class 100) while in contrast, these same ecosystem values were mapped disproportionately more in the North region in the CORINE land class for broad-leaved forest (Class 311). When general forest cover classes were aggregated in the GlobCover and CORINE systems, the proportion of the area occupied in each region were similar (within 3–4%), but the relative abundance of ecosystem values within the forest cover classes was greater in the GlobCover system compared to the CORINE system. Another illustrative example is the difference between areas identified as having “sparse” vegetation (Class 150 in GlobCover, Class 333 in CORINE). With GlobCover, 43.6% and 35.6% of the South and North regions were classified as sparsely vegetated, respectively, compared to 31.7% and 28.6% with the CORINE classification system. These proportional differences in land cover classes between the two classification systems influenced the distribution of mapped ecosystem values falling within specific land cover classes, but the more general patterns of spatial association held, i.e., cultural ecosystem values were disproportionately abundant in vegetated and developed areas, and less abundant in bare, sparse, and glaciated areas. The most striking proportional difference between the North and South regions was for sparse vegetation where North participants mapped significantly more of all ecosystem value types than South participants. These associations between ecosystem values and land cover type determine the spatial value transfer coefficients, which in turn, influence the value transfer outcomes between regions.

![Fig. 2](image-url)
### 3.2. Spatial value transfer results with ecosystem value and land cover associations

The percent of mapped ecosystem values associated with each land cover class were used as spatial value transfer coefficients between the North and South regions. When maps of scenic, recreation, and cultural values in the North region were generated using the proportion of the same ecosystem values from land cover classes in the South region, the resulting maps were quite similar to the actual distribution (see Figs. 2 and 3). The overall measure of map similarity was large and significant for all cultural ecosystem values using either GlobCover or CORINE land cover data. With GlobCover, map similarity was $r = 0.98$ for scenic, recreation, and cultural values, and with CORINE data, map similarity was slightly less for scenic ($r = 0.95$), recreation ($r = 0.96$), and cultural ($r = 0.92$) values (see Table 4). The spatial value transfer process generated similar results for gathering, grazing, and hunting/fishing values, with somewhat higher correlation coefficients using GlobCover. Of the six ecosystem values, the spatial value transfer of hunting/fishing values to the North produced the least similar maps with correlations of $r = 0.91$ and $r = 0.73$ for GlobCover and CORINE, respectively (see Table 4).

When primary data from the North region was used to generate value transfer maps for the South region, the transfer maps were very similar to primary data maps for scenic, recreation, and cultural values (see Figs. 4 and 5). The correlation coefficients were large and significant for all ecosystem values, and somewhat larger using GlobCover data (see Table 4). The gathering value transfer map was least similar to the primary data map with $r = 0.78$ using CORINE land cover data.

### 4. Discussion

We evaluated spatial value transfer outcomes for six cultural ecosystem values using primary data collected in two regions of Norway and two different land cover classification systems. The spatial value transfer maps were similar to primary data maps, indicating relatively small regionalization and sampling error in the value transfer process. The sample size of one region (transfer from North to South or vice versa) would suggest a potentially large sampling error, but the more homogeneous the physical landscape and population sampled, the smaller the sample size required. The Norwegian landscape, while topographically diverse, is not diverse in land cover and is dominated by sparse or bare vegetation in the uplands, and mixed forests in the lower elevations. Although the North study region has more coastal area than the South region, the two study areas share common land cover classes in relatively similar proportions. And the two sampled, resident populations that mapped the cultural ecosystem services were similar in socio-demographic profile and used the same participatory mapping protocol to minimize measurement error (Brown et al., 2015a,b). The similarity in physical landscape features and human populations provided a favorable scenario for demonstrating the accuracy
of spatial value transfer methods across the two regions. We posit, however, that regionalization error would be larger, for example, if the primary data from the North or South regions were value-transferred to the more urban-influenced and developed areas of southern Norway.

And what of uniformity error, defined as the constancy or uniformity of ecosystem values within a given land cover class? As indicated by the distribution of ecosystem value points plotted in Figs. 2–5, the mapped locations were not uniformly distributed within land cover classes. In this study, the uniformity error is assumed to be large based on the distribution of point locations. However, uniformity error is expected to be large for cultural ecosystem values given their strong tendency toward spatial clustering (Brown and Donovan, 2014; Brown and Weber, 2012). Uniformity errors could be reduced by choosing the appropriate land cover data for value transfer. As shown by Grét-Regamey et al. (2014), too coarse resolutions may inaccurately represent clustered data. Cultural identity values, in particular, tend to be associated with specific historical and cultural sites, while non-dispersed recreation activities tend to cluster in locations with features such as campgrounds, lakes, cabins, and trails. Scenic values also exhibit tendencies toward spatial clustering and would not be expected to be uniform within a given land cover class. Thus, uniformity error is to be expected with cultural ecosystem values but this propensity for clustering does not negate the potential utility of spatial value transfer methods, especially if the other sources of generalization error, sampling and regionalization, are relatively small.

4.1. Conditions for using spatial value transfer for cultural ecosystem services

We suggest the conditions for conducting spatial value transfer for cultural ecosystem services differ from other biophysical ecosystem services that would be expected to be more tightly coupled with physical land cover characteristics. In their analysis of spatial value transfer error, Eigenbrod et al. (2010b) concluded there is a limited range of circumstances where transfer mapping may be suitable: (1) when the heterogeneity of ecosystem services within a land cover type is low, such as in smaller study areas; and (2) where the goal of transfer mapping is to simply to rank the relative importance of a small number of highly distinct land cover types in terms of their importance for one or more ecosystem services. In this study, the heterogeneity of cultural ecosystem services found within the majority of land cover classes was relatively high as evidenced by calculated diversity metrics, but this diversity did not negatively influence the spatial value transfer results. Further, the spatial value transfer was effective across relatively large regions in Norway. In view of these results, we propose a set of conditions to reduce generalization error for cultural ecosystem services in spatial value transfer:

1. There should be similarity in the physical land cover classes and areal proportions between the primary data collection region and the spatial value-transfer region. Greater landscape homogeneity in the primary and value transfer areas will reduce the
potential for sampling and regionalization error. In the absence of similarity, more than one region should be sampled.

(2) There should be similarity in the social and cultural values, beliefs, and norms of the human populations living in the primary and value transfer areas. Human populations can be demographically similar in profile but express different cultural ecosystem values. Greater cultural homogeneity in the primary and value transfer area populations will reduce the potential for regionalization error.

(3) The sampling methods for mapping cultural ecosystem values should ensure large and unbiased samples, to the fullest extent possible. Participatory mapping processes that rely on volunteer sampling (VGI) or that contain significant participant bias will increase the potential for all error types in the value transfer process.

The suitability of spatial value transfer methods ultimately depends on the intended purpose of the maps. Given the expected uniformity error of cultural values within land cover classes, spatial value transfer methods would be inappropriate as the sole source for identifying place and project-specific impacts, for example, in assessing the social impact of a mining or hydroelectric project. In this situation, primary data should be collected. Spatial value transfer appears more appropriate for identifying broader scale risks to human well-being, for example, from larger-scale land use changes from deforestation, agriculture, or the effects of climate change. In the case of Norway, land use change is the most important driver of biodiversity loss (Norwegian Environment Agency, 2015) and given the high level of cultural ecosystem services associated with forest cover described this study, large-scale deforestation may be considered a critically important driver of cultural ecosystem service loss.

Finally, spatial value transfer is also dependent on the reliability and spatial data quality of the primary data (see Brown, 2016). Our primary data were derived from an internet-based PPGIS, which is known to recruit more mid-aged men with higher education and income (Brown and Kyttä, 2014). In previous analyses we also found that gender, age and education matters in terms of what kind of ecosystem values the participants mapped (Brown et al., 2015a,b). While spatial weighting schemes could be used to correct some of the sampling biases, the non-participation of ethnic groups and minorities need additional sampling approaches to fully capture the whole range of cultural ecosystem services. For example, the values of Sami reindeer herders in the North need to be addressed by other approaches than internet-based PPGIS.

4.2. Conclusion

This is the first study to empirically evaluate value-transfer for CES using primary data derived from participatory mapping. We examined the conditions that could influence the validity of value transfer based on the proportion of ecosystem values in different land cover classes. The limitations identified with value-transfer of biophysical ecosystem services previously identified in the literature – generalization errors, sensitivity to choice of land cover data, and weak correspondence with land use planning
purposes – were less apparent in these study results. However, our study conditions were favorable to demonstrating that CES can be reliably transferred to other regions provided certain conditions are met. The relative homogeneity of the Norwegian landscape and sampled populations, in combination with significant sample sizes in both study regions, were the key factors responsible for the results. It is also important to note that the value-transfer of CES in this study did not involve, nor does it require, the monetization of cultural values for value transfer. The generation of estimated economic values for use as value transfer coefficients introduces a potentially large source of transfer error. Further, other participatory mapping studies have identified the challenge (or refusal) of participants to express intangible cultural ecosystem services in monetary values (Klain and Chan, 2012). The bundled qualities of provisional and cultural services are intricately linked to place providing an additional challenge for value transferring. Bundled qualities of ecosystem values are evident as uniformity errors, but we show that value transfer is possible as long as the other sources of errors are small. For decision making the most important information about CES is not estimated economic value, but rather their place value. The relative importance of place locations in the provision of CES is important to land use planning decisions that invariably involve place-based trade-offs.

The relative importance of CES distributed by land cover can be determined by alternative criteria to economic value such as abundance, density, proportionality, or diversity of services (Brown, 2013). Spatial value transfer using participatory mapped data can be implemented using coefficients derived from any of these criteria, with the choice of criterion determining the rankings of land cover importance. In this study, spatial value transfer of CES was evaluated using the proportionality criteria to derive the value transfer coefficients. The proportionality criteria was found empirically to generate land cover importance rankings for CES most similar to those based on economic values as identified by Sutton and Costanza (2002), with the principle of scarcity posited to underpin both economic and proportionality criteria (Brown, 2013). In the absence of contradictory research, we suggest that the use of participatory mapping, in combination with non-economic value transfer coefficients, as the preferred approach to estimating the spatial distribution and importance of CES.

As a study limitation, we did we did not evaluate how the value transfer results might vary with even finer resolution land cover data or analyses at multiple scales. Where scale and resolution have been evaluated for estimating ecosystem services (Grêt-Regamey et al., 2014), significant differences can occur due consistency in land cover classifications and terrain variability. Future research should examine the sensitivity of value transfer of CES to the spatial scale of analysis and to the resolution of the proxy data used for the value transfer process. Further, the validity of CES value transfer methods in more heterogeneous physical landscapes and human populations remains to be tested.

Acknowledgements

The research leading to these results has received funding from the Polish–Norwegian Research Program operated by the National Centre for Research and Development under the Norwegian Financial Mechanism 2013–2016 in the frame of Project Contract No. POL-NOR/196105/2/2013.

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