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The relationship between social values for ecosystem services and global land cover: An empirical analysis

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ABSTRACT

Considerable effort has been directed into separate but related research foci—the study of ecosystem services and participatory mapping methods. The two research foci intersect in the mapping of place-based values, an operational form of social values for ecosystem services that uses public participation GIS (PPGIS) methods. The social valuation of ecosystem services through participatory mapping offers an alternative valuation approach to economic valuation of ecosystem services. This study analyzes the spatial associations between global land cover which provides a proxy indicator of ecosystem services, and place-based values from 11 PPGIS studies completed in the U.S., Australia, and New Zealand that comprise a diverse set of temperate ecoregions. Key findings include: the highest frequencies of social values for ecosystem services were associated with forested land cover; water bodies were highly valuable relative to area occupied; and agricultural land and areas of permanent snow and ice were least valuable. Most land cover classes demonstrated high diversity of social values. The importance of different land cover types varies based on the selected evaluation criteria. Additional research is needed to determine whether economic and social valuation approaches provide complementary, contradictory, or redundant measures of the importance of landscapes for providing ecosystem services.

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1. Introduction

Over the last decade, considerable research has been directed into separate but related research foci—ecosystem services and public participation GIS (PPGIS). Ecosystem services research seeks to identify, describe, and quantify the importance of natural landscapes that provide necessary and beneficial services for human well-being (Costanza et al., 1997; Daily, 1997; Millennium Ecosystem Assessment (MEA), 2003), while PPGIS uses geospatial technologies to support public participation with the goal of including and empowering marginalized populations. The two research foci intersect in the participatory mapping of place-based values for natural landscapes that provide an operational bridge between the geography of place and the psychology of place (Brown, 2005).

The concept of ecosystem services has garnered considerable academic attention with the publication of over 2400 papers (Costanza and Kubiszewski, 2012). Within this literature, considerable effort has focused on ways to identify and estimate the economic value of these services. Some concerns have been voiced that non-economic, social valuation of ecosystem services should also have a role in the decision-making process (Kumar and Kumar, 2008; Peterson et al., 2009) because “prices are not to be confused with values, and prices are not the only values that are important” (Cowling et al., 2008). If the identification and protection of ecosystem services is an important goal for humanity, it would appear essential to understand both the economic and non-economic social trade-offs that confront society in important land use and development decisions.

An alternative to the economic-based valuation of ecosystem services is place-based assessment which Potschin and Haines-Young (2013) argue provides a better understanding of landscape multi-functionality, the valuation of natural capital, and the role of landscape in framing debates about ecosystem services. A place-based assessment looks at bundles of ecosystem services across landscape units that have strong social relevance. But how does one assess the importance of these place-based services across landscapes, if not economically? The emergence of participatory mapping methods in the last decade provides an alternative valuation paradigm for analyzing ecosystem services that are place rather than economic-based. Place-based values explicitly link benefits to a physical landscape. Some researchers use the term “landscape services” as a bridging concept between landscape ecology and sustainable development where spatially explicit assessment methodologies can be used in local collaboration to better accommodate perceptions of value (Termorshuizen and Opdam, 2009; Fagerholm et al., 2012). Although the assessment of landscape or ecosystem services through participatory mapping

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is a valuation method, the analysis of the resulting place-based values shares more in common with landscape ecology than with economics. The importance of place-based values representing landscape or ecosystem services is determined by analyzing the spatial distribution of place-based values, often with analytical techniques and metrics used in landscape ecology (Brown and Reed, 2012).

Public participation GIS (PPGIS) is a type of GIS that seeks to enhance public participation and empower nongovernmental organizations, grassroots groups, and local communities. While the formal definition of PPGIS remains "nebulous" and inconsistent across applications (Tulloch, 2007), PPGIS generally describes the practice of having non-experts identify spatial information to augment expert information. Since the 1990s, the range of PPGIS applications has been extensive from community and neighborhood planning to environmental and natural resource management (see Dunn, 2007; Landscape Values & PPGIS Institute, (2012); Sieber, 2006).

In recent publications, the mapping of place-based values using PPGIS has been characterized as measuring the "social values of ecosystem services" (Bryan et al., 2010; Sherrouse et al., 2011; van Riper et al., 2012) which are defined as "the perceived qualities carried by a natural environment that provides benefits…to support human well-being…" (van Riper et al., 2012, p. 164). The MEA (2003) acknowledges the role of human perception in the assessment of conditions related to the ecosystem's ability to provide desired services and this ability can be assessed by a variety of quantitative and qualitative methods (p. 49). In PPGIS, human perception is a key process by which individuals assess landscapes for the presence of place-based values. These perceptions are usually solicited from individuals with lay knowledge and experience with the chosen study area using maps (hardcopy or digital). In one of the first PPGIS studies to examine the general public's ability to identify a range of provisioning, supporting, regulating, and cultural ecosystem services identified in the MEA (2003), the authors concluded that the general public has the capacity to identify cultural and provisioning ecosystem services but were skeptical about its ability to identify regulating and supporting services (Brown et al., 2012).

The purpose of this paper is to examine the capacity of PPGIS methods to identify the social values of ecosystem services found in a range of landscape types using global land cover. The use of land cover as a proxy indicator for the presence of various ecosystem services is a common technique used in ecosystem valuation (see e.g., Costanza et al., 2007; Naidoo et al., 2008, Troy and Wilson, 2006). The primary research question is whether place-based values, as operationalized through PPGIS methods, are spatially associated with landscape types found in different ecosystems. The methodological challenge is that perceived place-based values are contextual and depend on the needs, choices, and values of the people while ecosystems are likewise, highly diverse globally. The inherent variability and diversity in both humans and ecosystems make a meta-study of place-based values and ecosystems impossible without consistently applied PPGIS data collection measures and a uniform, global landscape classification system. Over the last decade, 11 different PPGIS studies were completed in diverse ecosystems in the U.S., Australia, and New Zealand that shared similar place-based value typologies and regional population sampling methods. In 2009, the European Space Agency produced a global, high resolution GIS land cover database (Bontemps et al., 2011) that provides a common landscape reference system across diverse ecosystems. These fortuitous circumstances provide the opportunity to explore whether significant spatial associations exist between place-based values, obtained through PPGIS, and landscape type as identified and mapped in global land cover.

Following a review of the literature relevant to this study context, this paper presents an inductive, spatial analysis of multiple PPGIS data sets to determine what claims, if any, can be made about the spatial association between place-based values identified using PPGIS methods and landscape types across diverse ecosystems.

1.1. Place-based value typologies in PPGIS

The systematic, participatory mapping of place-based values using a pre-defined typology began with a 1998 study of the Chugach National Forest in Alaska (Brown and Reed, 2000). The original values typology consisted of 13 values (see Table 1) adapted from Rolston and Coufal's (1991) forest values typology. These values were operationalized as place-based values and subsequently used in a variety of PPGIS applications related to public lands planning and management. In the evolution of the values typology, different terminology was applied to the same or similar pre-defined place values. The values were alternatively called *forest values* (Brown and Reed, 2000), *ecosystem values* (Reed and Brown, 2003), *environmental values* (Brown et al., 2002), *landscape values* (Alessa et al., 2008; Beverly et al., 2008; Brown, 2005; Zhu et al., 2010), *community values* (Raymond et al., 2009), and most recently, *social values for ecosystem services* (Bryan et al., 2010; Sherrouse et al., 2011; van Riper et al., 2012).

The original values typology was not explicitly linked with the concept of ecosystem services, but the typology became linked with ecosystem service frameworks through more recent publications (Raymond et al., 2009; Sherrouse et al., 2011). Place-based values collected for a national forest study in Colorado (Clement-Potter, 2006) were used to help the U.S. Geological Survey (USGS) develop a GIS model called *So*cial *V*alues of *E*cosystem *S*ervices or SolVES (Sherrouse et al., 2011; USGS, 2012) with the capacity to extrapolate or *value-transfer* mapped place values to landscapes where the values were not collected. The model's authors argued that the place-based value typology measures social values for ecosystem services because the values elicited represent measurable ecological end-products or endpoints of ecosystem services at their interface with human well-being (Boyd and Banzhaf, 2007). This characterization of place-based values as social values for ecosystem services was further justified on the grounds of expediency because the ecosystem service typology defined by the MEA (2003) or alternative ecosystem service typologies such as those proposed by Wallace (2007) or Raymond et al. (2009) would require additional research and data collection to validate while place-based value data was currently available for GIS modeling.

1.2. The inference from place-based values to ecosystem services

The supporting logic for linking place-based values in the typology with ecosystem services may derive from interpreting place-based values as part of a 'structure–function–value chain' (Termorshuizen and Opdam, 2009) wherein ecosystem functions become services when their benefits are valued by humans. The inferential difficulty with this position, however, is that in the PPGIS mapping of place-based values, the structure–function–value chain is likely unknown or at best, latent to mapping participants. PPGIS participants are not generally instructed to contemplate the structure and function of landscapes, but rather to reflect on the values and benefits they perceive or have experienced in the study area. Thus, the methodological focus on identifying values at the end of the chain without reference to the landscape structure–function component raises an important question about how much the perception of place-based values arises from the personal experience and knowledge of the participant (i.e., a phenomenological perspective) versus the participant's ability to identify (whether consciously or not) some

Table 1
The conceptual mapping of place-based values into general MEA ecosystem service categories and the list of PPGIS studies where the value was included.

Place-based landscape values	MA ecosystem service category	PPGIS studies included
Esthetic/scenic—these areas are valuable because they contain attractive scenery including sights, smells, and sounds	***Cultural***	(11) Chugach NF 1998 (AK), Kenai (AK), Kangaroo I. 2004 (AU), Otways (AU), Coconino NF (AZ), Deschutes/Ochoco NF (OR), Mt Hood NF (OR), Kangaroo I. 2010 (AU), South Island (NZ), Chugach NF 2012 (AK), Sierra Nevada NFs (CA)
Economic—these areas are valuable because they provide timber, fisheries, minerals, or tourism opportunities such as outfitting and guiding	***Cultural, Provisioning***	(11) All
Recreation—these areas are valuable because they provide a place for my favorite outdoor recreation activities.	***Cultural***	(11) All
Life sustaining—these areas are valuable because they help produce, preserve, clean, and renew air, soil, and water	***Regulation, Supporting***	(11) All
Learning/scientific –these areas are valuable because they provide places where we can learn about the environment through observation or study	***Cultural***	(11) All
Biological—these areas are valuable because they provide a variety of fish, wildlife, plants, or other living organisms.	***Provisioning, Supporting***	(11) All
Spiritual—these areas are valuable because they are sacred, religious, or spiritually special places or because I feel reverence and respect for nature here	***Cultural***	(11) All
Intrinsic—these areas are valuable in their own right, no matter what I or others think about them	***Cultural***	(10) All except South Island (NZ)
Historic—these areas are valuable because they represent natural and human history that matters to me, others, or the nation	***Cultural***	(11) All
Future—these areas are valuable because they allow future generations to know and experience the area as it is now	***Cultural***	(6) Chugach NF 1998 (AK), Kenai (AK), Kangaroo I. 2005 (AU), Otways (AU), Coconino NF (AZ), Chugach NF 2012 (AK)
Subsistence—these areas are valuable because they provide necessary food and supplies to sustain my life	***Provisioning***	(3) Chugach NF 1998 (AK), Kenai (AK), Chugach NF 2012 (AK)
Therapeutic—these places are valuable because they make me feel better, physically and/or mentally	***Cultural***	(10) All except South Island (NZ)
Cultural—these places are valuable because they allow me or others to continue and pass down the wisdom and knowledge, traditions, and way of life of ancestors	***Cultural***	(3) Chugach NF 1998 (AK), Kenai (AK), Chugach NF 2012 (AK)
Wilderness—these places are valuable because they are wild, uninhabited, or relatively untouched by human activity	***Cultural***	(10) All except Chugach NF 1998 (AK)

fundamental structure, pattern, or process in the landscape (i.e., a landscape ecology perspective) that relates to the landscape's capacity to provide various ecosystem services.

How does one know if PPGIS participants are identifying place-based values that relate to landscape features, qualities, or structure? Is it possible to detect the “signal” or evidence of value/landscape structure relationships amongst the high degree of “noise” or variability in the place-based values data as well as descriptors of physical landscape? Are the physical landscape features selected for use in social value-transfer models such as SolVES based on availability and convenience, or is there evidence to suggest *a priori* relationships with place-based values? In the initial SolVES GIS model, place-based values were analyzed for different PPGIS response groups relative to four landscape features —elevation, slope, and distance to water and roads (Sherrouse et al., 2011). The model indexes the place-based values to show the relative concentration of values by response group on each physical landscape variable. The initial SolVES model examined five place-based values for relationships with physical landscape variables and reported the most significant correlations were with the elevation and distance to roads variables, while there were fewer significant correlations with the slope and distance to water variables. In the second published SolVES study conducted in a national park in Australia (van Riper et al., 2012), four place-based values were assessed for relationship to the variables of slope, and distance to water and trails. No quantitative correlations were reported but the authors reported some general trends such as perceived biological value was associated with less steep slopes and closer to trails and water.

Brown and Brabyn (2012a, 2012b) took a different approach than SolVES by relating PPGIS place-based values to an extensive set of physical landscape variables contained in a comprehensive, hierarchical landscape classification system created for New Zealand (Brabyn, 1996, 2009) that included landform, land cover, dominant land cover, water body type, water views, and infrastructure. They argued that landscape variables used in SolVES are too generalized to reveal important place-based value/landscape structure relationships, to the extent that such relationships exist. For example, the elevation variable in SolVES masks the more relevant topographical landscape features such as mountains and hills that give rise to the value/landscape relationship. Similarly, distance to water masks potentially important relationships such as the attractiveness of different types of water bodies (e.g., lakes vs. rivers vs. oceans) or the ability to actually view the body of water. In their study of southern New Zealand, they found spatial associations between place-based values and topography (landform), natural vegetation (land cover), and water (both type and views). They concluded that assessing specific place-based values with specific landscape classes offers the greatest potential to detect landscape structure–value relationships that might exist. The SolVES modeling approach, in its current form, appears to have limited capacity to illuminate the landscape structure–function–value chain that might exist with PPGIS place-based values.

To infer that some or all place-based values collected in PPGIS are spatially associated with ecosystem services through physical landscape structure, a consistent, global landscape classification database is required. Ideally, a comprehensive landscape classification system such as the one developed for New Zealand would be used that includes landform, land cover, water classes, and infrastructure. However, no such uniform classification system exists for the countries of the U.S., Australia, and New Zealand where PPGIS place-based values data has was collected. In the absence of a comprehensive landscape classification system, this study examines the spatial associations of place-based values collected in 11 PPGIS studies with global land cover.

The analysis was guided by the following research questions: (1) how are place-based values spatially distributed by land cover class using the landscape metrics of abundance, proportionality,

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and diversity, (2) do these distributions indicate significant spatial associations between different place-based values and global land cover classes, and (3) given the results, how does one evaluate the importance of different landscapes in providing social values for ecosystem services?

2. Methods

To examine potential spatial associations between the social values of ecosystem services (place-based values) and global land cover, PPGIS data from 11 studies completed in the U.S., Australia, and New Zealand over the time period 1998–2012 were assembled for analysis. Two of the 11 studies were longitudinal studies of the same study region. The Chugach National Forest was the focus of two separate PPGIS studies in 1998 and 2012 while Kangaroo Island (Australia) was studied in 2004 and 2010. Table 2 provides the location, purpose, and sources to published references describing the individual studies. Common to all the PPGIS studies was (1) a typology with a set of place-based values that participants were requested to map, and (2) random sampling of households located in, or proximate to the study region. Table 1 provides operational definitions for each of the place-based values, their conceptual mapping into deGroot et al. (2002) and MEA (2003) classification system, and the number of studies where each place-based values was included. There were relatively small differences in the value typologies and definitions across the 11 studies. For purposes of this study, cultural and subsistence values were not included in the spatial analysis because these values only appeared in three of the 11 PPGIS studies.

The 11 study areas encompass a wide range of ecosystems from temperate forests to grass/shrublands to permanent snow and ice. The study areas ranged geographically from approximately 61° north latitude (Alaska) to 46° south (New Zealand). The majority of study areas consisted of natural landscapes, but four studies also included areas of built environment. All study areas consisted of a mix of public and private lands.

The global land cover GIS layer selected for data analysis was developed by the European Space Agency in collaboration with the Université catholique de Louvain. The global land cover map is the highest resolution land cover map completely validated with a spatial resolution of 300 m and was developed using the United Nation Food and Agriculture Organisation's (FAO) Land Cover Classification System (LCCS) consisting of 22 land cover classes. The map was validated by 16 experts with more than 3000 reference land cover points for an overall accuracy of 73 percent weighted by area (http://www.esa.int/esaEO/SEMXB7TTGOF_index_0.html).

Fig. 1 shows the distribution of land cover classes present in the nine distinct PPGIS study areas compared to the global distribution of land cover classes. The combined PPGIS study areas contain all global land cover classes with the exception of irrigated agricultural croplands (Class 11). The PPGIS study areas are over-represented in land cover classes containing closed needle-leaved evergreen forests (Class 70), several shrub/grassland classes, and the permanent snow and ice class (Class 220). The combined PPGIS study areas are under-represented in bare/desert areas (Class 200), open needle-leaved evergreen or deciduous forests (Class 90), and several mixed crop/vegetation classes (Classes 20 and 30). Thus, the PPGIS study areas have reasonably comprehensive coverage of global land cover classes, but deviate from global land cover proportionality in a number of individual land cover classes.

2.1. Data analysis

Three types of analysis were performed to determine whether significant spatial associations exist between placed-based values and land cover class—descriptive frequencies and crosstabs, proportional analysis, and diversity analysis. The spatial data was

Table 2
List of PPGIS studies (1998–2012) included in this meta-study with location, purpose, and references.

Year	Implementation Mode	Location	Ecoregions[a]	Planning Purpose	Published References
2012	Internet (Google Maps)	Alaska (Chugach National Forest) US	Northern Pacific coastal forests; Pacific Coastal Mountain icefields and tundra; Rock and ice	National forest planning	Brown and Donovan (in press).
2012	Internet (Google Maps)	California (Sierra, Sequoia, Inyo National Forests) US	Sierra Nevada forests; Great Basin shrub steppe; Great Basin montane forests; California montane chaparral and woodlands	National forest planning	Brown et al. (in press).
2011	Internet (Google Maps)	South Island (Otago and Southland Regions) NZ	South Island temperate forests; Fiordland temperate forests; Cantebury-Otago tussock grasslands; South Island montane grasslands	Regional conservation	Brown and Brabyn (2012a, 2012b)
2010	Internet (Google Maps)	Kangaroo Island (South Australia) AU	Mount Lofty woodlands	Tourism and development planning	Brown and Weber (2013)
2007	Internet (Flash)	Oregon (Mt. Hood National Forest) US	Central and Southern Cascades forests	National forest planning	Brown and Reed (2009)
2007	Internet (Flash)	Oregon (Deschutes/Ochoco National Forests) US	East Cascades forests and Blue Mountains forests	National forest planning	Brown and Reed (2009)
2006	Internet (Flash)	Arizona (Coconino National Forest) US	Arizona Mountains forests	National forest planning	Brown and Reed (2009)
2005	Paper maps	Otways Region (Victoria) AU	Southeast Australia temperate forests	Tourism and conservation	Brown and Raymond (2007)
2004	Paper maps	Kangaroo Island (South Australia) AU	Mount Lofty woodlands	Tourism and development planning	Brown (2006)
2002	Paper maps	Alaska (Kenai Peninsula) US	Cook Inlet taiga	Coastal area management	Alessa et al. (2008)
1998	Paper maps	Chugach National Forest (Alaska)	Pacific Coastal Mountain icefields and tundra; Rock and ice; Northern Pacific coastal forests	National forest planning	Brown and Reed (2000)

[a] Olson et al. (2001).

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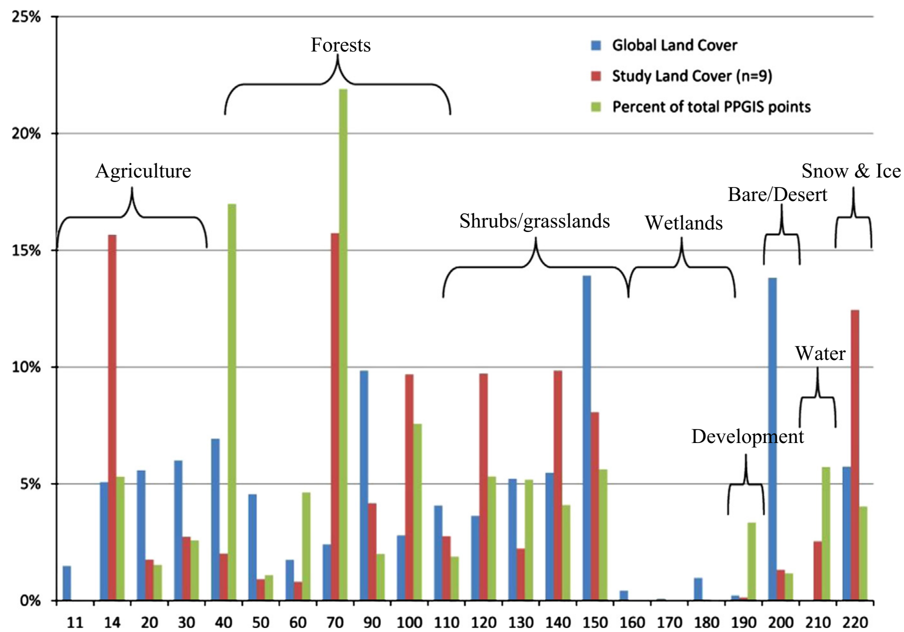

Fig. 1. Distribution of global land cover (terrestrial, non-water) vs. land cover classes located in the study areas ($n=9$). Also shown is the percent of total values (PPGIS points) located in each land cover class for all studies ($n=11$).

prepared by first clipping the global land cover raster data to each of the study area boundaries. The place-based values from each PPGIS study (collected as point data) were then spatially intersected with the land cover raster data to assign a land cover class to each value. Crosstabs of place-based values by land cover class were then generated for each study area with counts and percentages aggregated across the 11 studies.

To perform proportional analysis, the percentage of each study area occupied by the 22 land cover classes was calculated using GIS. This areal percentage of land cover became the expected distribution of PPGIS points by land cover class within each study under the assumption that the points should be distributed proportional to the area. For example, if a land cover class occupied 60 percent of a study area, 60 percent of the PPGIS points would be expected to fall within this land cover class. The number, type, and area of land cover classes varied by study area. Four land cover classes were present in all 11 studies.

To determine if the place-based values were proportionately distributed within the study area land classes, Z scores were calculated for each value/class category proportion as follows:

$$Z=\frac{P_s-P_\mu}{S_p}$$

where P_s=sample proportion (proportion of value points within a land cover class), P_μ=population proportion (proportion of study area occupied by the land cover class), and S_p=standard error of the population.

Z scores greater than 1.96 (two-tailed test, $\alpha=.05$) indicate that the proportion of value points falling within a given land cover class are significantly greater than expected, while Z scores less than -1.96 indicate the proportion of value points area significantly less than expected.

The proportion data was analyzed and presented two ways. In the first analysis, statistically significant deviations for each value/class were recorded in a table by study area. The evidence for value/class spatial associations was based on the number of individual PPGIS studies with statistically significant results. As an interpretive heuristic, three or more different studies with statistically significant value/class relationships suggest a positive or negative spatial association between the place-based value and the land cover class. In second analysis, the Z scores were summed for each value/cover pairing and presented to show the overall value/cover spatial association, regardless of statistical significance in proportional differences.

To examine the potential relationship between the diversity of place-based values and land cover class, the Shannon diversity index was calculated for each value/class pairing in each study. The Shannon index (Shannon, 1948) has been widely adopted in the ecology literature as a mathematical measure of species diversity in a community, but it has also been used to quantify and compare the diversity of social landscape values found within bounded landscape areas of interest (Brown and Reed, 2012). The Shannon diversity index accounts for both the abundance and evenness of placed-based values found within each of the land cover classes. Shannon index values typically fall within the range of 1.5–3.5 with higher index values indicating greater diversity. The Shannon index values were computed for each value and land cover pair within each PPGIS study and then averaged for each land cover class. The mean index values, as well as the minimum and maximum diversity indices for each land cover class were plotted for visual comparison. Independent samples t-tests were conducted to determine statistically significant differences in mean Shannon indices between land cover classes.

3. Results

3.1. Spatial associations between values and land cover

The percent of total place-based values (PPGIS points) identified within each land cover class were plotted in Fig. 1 along with the areal percentages of global terrestrial land cover and land cover in the aggregated study areas. About 22 percent of all place-based values were located in closed needle-leaved forests (Class 70) and 17 percent were located in broad-leaved evergreen or semi-deciduous forests (Class 40). This result is consistent with the general character of the nine study areas which contain national forests, parks, or reserves with large, forested areas. The land cover classes with the fewest number of mapped values were wetlands (Classes 160, 170, and 180) where the total area occupied by these classes was negligible (less than 1 percent). Developed areas (Class 190) comprise less than 1 percent of both the global and study area land cover but contained over 3 percent of the total mapped values.

In the proportional analysis, the individual place-based values falling within the land cover classes in each study were evaluated against the expected proportion based on the area covered by the land cover class. Table 3 shows the studies where individual place-based values appear over- or under-represented based on significant Z scores ($Z>1.96$ or $Z<-1.96$), $p\leq.05$). *Esthetic* values were under-represented in agricultural/crop areas ($n=4$ studies) and over-represented in shrublands ($n=4$ studies), *recreation* values were over-represented in mixed forests and shrublands ($n=3$ studies), *biological* values were over-represented in deciduous forests and mixed forests ($n=3$), *economic* values were over-represented in shrublands and developed areas ($n=3$), and *historic* values were over-represented in developed areas ($n=3$). There were inconsistent results between place-based values and needle-leaved evergreen forests. In three studies, place-based values were under-represented in evergreen forests (Sierra Nevada (CA), Coconino (AZ), Deschutes/Ochoco (OR)), but were over-represented in two studies (Mt. Hood (OR) and South Island (NZ)).

The most obvious value/cover relationship is with water bodies where there was a significant spatial association with every value in at least one study. For esthetic and recreation values, there were eight and seven studies with significant associations respectively, while economic value was significant in five studies. One might expect these findings given that seven of the 11 study areas contain coastal areas, and yet, water bodies were also significant for multiple non-coastal studies. Of particular importance is the spatial association between *life sustaining* value and three inland studies (Sierra Nevada (CA), Coconino (AZ), Deschutes/Ochoco (OR)). In these regions where water is relatively scarce, the perceived value of water bodies to sustain life is amplified. Further, *recreation* value had significant association with water bodies in every inland study region ($n=4$). Thus, the importance of water as a cultural and supporting ecosystem service was recognized by all the regional populations.

When the value/cover Z scores were aggregated across the 11 studies (see Fig. 2), the significant results from individual PPGIS studies were reinforced. All place-based values were under-represented in agricultural/cropland (Class 14), permanent snow and ice (Class 220), and closed needle-leaved evergreen forests (Class 70). In contrast, with a few exceptions, place-based values were over-represented in water bodies (Class 210), broad-leaved evergreen or semi-deciduous forests (Class 40), shrublands (Class 130), mixed broad-leaved and evergreen forests (Class 100), and broad-leaved forests (Class 60). Developed areas (Class 190) were also over-represented with most place-based values. Noteworthy are the distributions of perceived *biological* values which are thematically linked with provisioning and supporting ecosystem services, and the distribution of *life sustaining* values which exemplify regulating and supporting ecosystem services. *Biological* values were found disproportionately in broad-leaved evergreen or semi-deciduous forests (Class 40), mixed broad-leaved and evergreen forests (Class 100), shrublands (Class 130), and water bodies (Class 210), while *life sustaining* values were most disproportional in broad-leaved evergreen or semi-deciduous forests (Class 40) and water bodies (Class 210). These disproportionate spatial associations indicate general public awareness of the ecological importance of forests, with or without a deeper understanding of forest ecology.

The Shannon diversity index was calculated within each study area for each land cover class to assess the abundance and evenness of place-based values. The mean, maximum, and minimum Shannon diversity indices of place-based values by land cover class are presented in Fig. 3. The mean diversity indices for the majority of land cover classes are greater than two indicating relatively high place-value diversity. Most place-based values were identified in most land cover classes, thus the differences in the Shannon diversity indices reflect the relative abundance of values found within the land cover classes. The lower diversity indices for developed areas (Class 190), permanent snow and ice (Class 220), and the wetland land cover (Classes 160 and 180) suggest lower place-value diversity. However, statistical inferences for the wetland classes cannot be made given the small sample size.

For land cover classes found in five or more studies, independent samples t-tests were performed to determine if there were significant differences in the Shannon diversity indices. Developed areas (Class 190) were significantly less diverse ($\alpha=.05$) than broad-leaved deciduous forests ($t(10)=2.23$, $p=.04$) and shrublands ($t(15)=2.13$, $p=.03$). Developed areas were also significantly less diverse ($\alpha=.10$) than needle-leaved evergreen forests (Class 70), mixed broad-leaved and needle-leaved forests (Class 100), grassland (Class 140), sparse vegetation (Class 150), and bare areas (Class 200). Land cover areas with permanent snow and ice (Class 220) were significantly less diverse ($\alpha=.10$) than shrublands (Class 130).

Overall, the empirical results indicate significant positive spatial association between place-based values and landscapes containing forests (especially broad-leaved), water, and developed areas, and significant negative spatial association with agricultural croplands and areas of permanent snow and ice.

4. Discussion

This study was the first to examine spatial associations between place-based values that describe social values of ecosystem services and global land cover. The high degree of variability in both human perceptions of landscape value and the diversity of earth's ecosystems provides a high threshold for discovering significant spatial associations. This study used three types of analytical approaches to examine the potential relationships between place-based values and land cover: descriptive crosstabs with frequencies, proportional analysis, and diversity analysis.

Despite the human and landscape variability, significant value/cover spatial associations emerged from the analysis. The axiom that water is fundamental to life on earth was reflected in the proportional results where regional human populations recognize the benefits of water across the full range of place-based values—from *esthetic* and *recreation* value to *life sustaining* and *biological* value. Acre for acre, water provides the most important ecosystem benefits of all global land cover. Similarly, forests of all types provide a full range of ecosystem benefits, especially broad-leaved semi-deciduous and deciduous forests which are disproportionately important relative to their land cover area. The ecosystem services provided by forests extend to non-material human benefits including *spiritual*, *therapeutic*, and *wilderness* values, among others.

Proportional analysis, however, is insufficient to fully explain the association between place-based values and land cover because it can mask basic conclusions derived from simple frequency distributions. The material and non-material ecosystem benefits of needle-leaved evergreen forests were under-represented in the proportional analysis due to the dominance of this particular land cover in several of the studies, and yet, more place-based values in total were identified in needle-leaved evergreen forests than any other land cover (about 22 percent of the total values mapped). Thus, both frequency and proportional analyses appear essential to describe the relationships between place-based values and physical landscapes.

The diversity analysis of values by land cover provides a useful complement to frequency and proportional analyses by indicating

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Table 3
Significant proportional relationships between landscape values and land cover classes. Color indicates significantly fewer (pink/red) or more (green) landscape values in land cover than expected ($Z > 1.96$ or $Z < -1.96$, $p \leq .05$). Blue color indicates inconsistent results where the same value was over- and under-represented in different studies. Wetland classes 160, 170, and 180 (not included below) have no significance.

	Aesthetic	Recreation	Biological	Economic	Life sustaining	Historic	Learning	Intrinsic	Spiritual	Therapeutic	Wilderness	Future
14 - Rainfed croplands (n=4)	(-) Otways (AU) (-) K.I. 2004 (AU) (-) S.I. (NZ) (-) K.I. 2010 (AU)											
20 - Mosaic croplands/ vegetation (n=5)												
30 - Mosaic vegetation/ croplands (n=7)		(+) Otways (AU)		(+) Otways (AU)		(+) Coco (AZ)			(+) Coco (AZ)			
40 - Closed to open broadleaved evergreen or semi-deciduous forest (n=3)	(+) Otways (AU) (-) K.I. 2004 (AU)	(+) Otways (AU)	(+) Otways (AU) (+) K.I. 2004 (AU)	(-) Otways (AU)	(+) Otways (AU) (+) K.I. 2004 (AU)	(+) Otways (AU) (-) K.I. 2004 (AU)	(+) Otways (AU) (+) K.I. 2004 (AU)	(+) Otways (AU)	(+) Otways (AU)	(+) Otways (AU)	(+) Otways (AU) (+) K.I. 2004 (AU) (+) K.I. 2010 (AU)	(+) Otways (AU) (+) K.I. 2004 (AU)
50 - Closed broadleaved deciduous forest (n=4)												
60 - Open broadleaved deciduous forest (n=6)	(+) Otways (AU)	(+) Otways (AU)	(+) Otways (AU) (+) K.I. 2004 (AU) (+) K.I. 2010 (AU)	(+) Otways (AU)	(+) K.I. 2004 (AU)	(+) Otways (AU)	(+) K.I. 2004 (AU)			(+) Otways (AU)	(+) K.I. 2004 (AU) (+) K.I. 2010 (AU)	(+) K.I. 2004 (AU)
70 - Closed needleleaved evergreen forest (n=8)	(-) Sierra (CA) (-) Desch (OR)	(-) Sierra (CA) (+) S.I. (NZ) (-) Desch (OR) (+) MtHood (OR)	(-) Sierra (CA) (+) S.I. (NZ) (-) Desch (OR)	(-) Sierra (CA) (-) Coco (AZ) (-) Desch (OR)	(-) Sierra (CA) (-) Coco (AZ)	(-) Sierra (CA) (-) Coco (AZ) (-) Desch (OR)	(-) Sierra (CA) (-) Coco (AZ) (+) S.I. (NZ)	(-) Sierra (CA) (-) Desch (OR)	(-) Sierra (CA) (-) Coco (AZ) (-) Desch (OR)	(-) Sierra (CA) (-) Desch (OR) (+) MtHood (OR)	(-) Sierra (CA) (+) MtHood (OR)	
90 - Open needleleaved deciduous or evergreen forest (n=3)	(+) Chug 2012 (AK)	(+) Chug 2012 (AK)										
100 - Closed to open mixed broadleaved and needleleaved forest (n=8)	(+) Chug 2012 (AK) (+) Chug 1998 (AK)	(+) S.I. (NZ) (+) Chug 2012 (AK) (+) Chug 1998 (AK)	(+) S.I. (NZ) (+) Chug 2012 (AK) (+) Chug 1998 (AK)		(+) Chug 2012 (AK)	(+) Chug 2012 (AK) (+) Chug 1998 (AK)	(+) Chug 1998 (AK)				(+) S.I. (NZ)	(+) Chug 2012 (AK)
110 - Mosaic Forest-Shrubland/Grassland (n=11)												
120 - Mosaic Grassland/Forest-Shrubland (n=10)		(+) Chug 2012 (AK) (+) Chug 1998 (AK)										
130 - Closed to open shrubland (n=11)	(+) Sierra (CA) (+) Otways (AU) (+) K.I. 2004 (AU) (+) MtHood (OR)	(+) Sierra (CA) (+) Otways (AU) (+) Chug 1998 (AK)	(+) Sierra (CA)	(+) Otways (AU) (+) MtHood (OR) (+) Chug 1998 (AK)	(+) Sierra (CA)	(+) MtHood (OR) (+) Chug 1998 (AK)			(+) MtHood (OR) (+) Chug 1998 (AK)	(+) Otways (AU)		
140 - Closed to open grassland (n=11)	(+) S.I. (NZ)	(+) S.I. (NZ)		(+) Otways (AU) (+) S.I. (NZ)		(+) S.I. (NZ)					(+) S.I. (NZ)	
150 - Sparse vegetation (n=6)	(+) Chug 1998 (AK) (+) Kenai (AK)	(+) Chug 1998 (AK) (+) Kenai (AK)	(+) Chug 1998 (AK) (+) Kenai (AK)	(+) Chug 1998 (AK) (+) Kenai (AK)			(+) Kenai (AK)		(+) Kenai (AK)	(+) Kenai (AK)		(+) Chug 1998 (AK)
190 - Artificial areas (n=6)	(+) Otways (AU)	(+) Otways (AU) (+) K.I. 2004 (AU)	(+) Otways (AU)	(+) Otways (AU) (+) K.I. 2004 (AU) (+) S.I. (NZ)		(+) Otways (AU) (+) K.I. 2004 (AU) (+) S.I. (NZ)	(+) Otways (AU) (+) S.I. (NZ)	(+) Otways (AU)	(+) Otways (AU)	(+) Otways (AU)		
200 - Bare areas (n=7)						(+) Coco (AZ)	(+) Coco (AZ)					
210 - Water bodies (n=11)	(+) Sierra (CA) (+) Otways (AU) (+) K.I. 2004 (AU) (+) S.I. (NZ) (+) Desch (OR) (+) Kenai (AK) (+) K.I. 2010 (AU)	(+) Sierra (CA) (+) Otways (AU) (+) K.I. 2004 (AU) (+) Coco (AZ) (+) S.I. (NZ) (+) Desch (OR) (+) MtHood (OR) (+) K.I. 2010 (AU)	(+) Sierra (CA) (+) Otways (AU) (+) K.I. 2004 (AU) (+) K.I. 2010 (AU)	(+) Otways (AU) (+) Otways (AU) (+) K.I. 2004 (AU) (+) Desch (OR) (+) K.I. 2010 (AU)	(+) Sierra (CA) (+) Coco (AZ) (+) MtHood (OR)	(+) Otways (AU) (+) K.I. 2004 (AU) (+) K.I. 2010 (AU)	(+) K.I. 2004 (AU) (+) K.I. 2010 (AU)	(+) Otways (AU) (+) K.I. 2004 (AU)	(+) K.I. 2004 (AU) (+) K.I. 2010 (AU)	(+) Otways (AU) (+) K.I. 2004 (AU)	(+) Otways (AU) (+) K.I. 2004 (AU) (+) Kenai (AK)	(+) K.I. 2004 (AU)
220 - Permanent snow and ice (n=6)	(-) Chug 2012 (AK) (-) Chug 1998 (AK)	(-) Chug 2012 (-) Chug 1998 (AK)	(-) Chug 1998 (AK)	(-) Chug 1998 (AK)	(-) Chug 1998 (AK)	(-) Chug 1998 (AK)	(-) Chug 1998 (AK)		(-) Chug 1998 (AK)	(-) Chug 1998 (AK)	(-) Chug 2012	(-) Chug 1998 (AK)

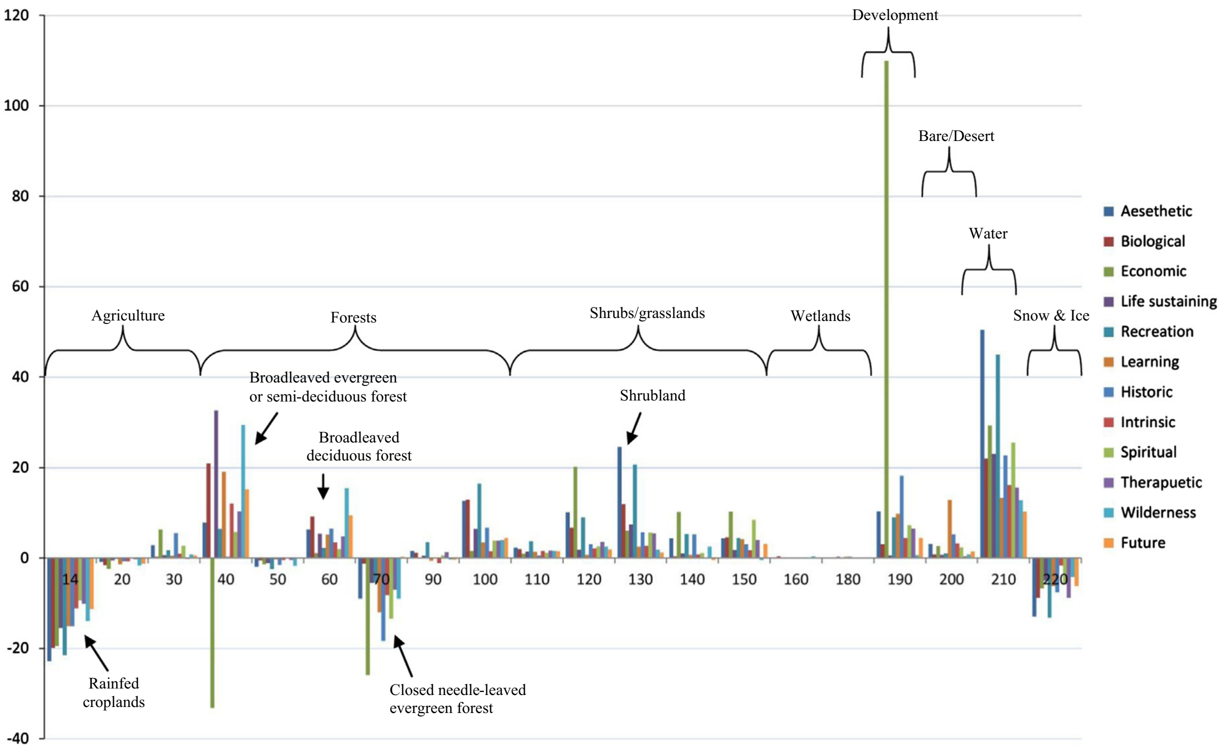

Fig. 2. Summed *Z* scores of place-based values (minimum of 3 studies) by land cover class.

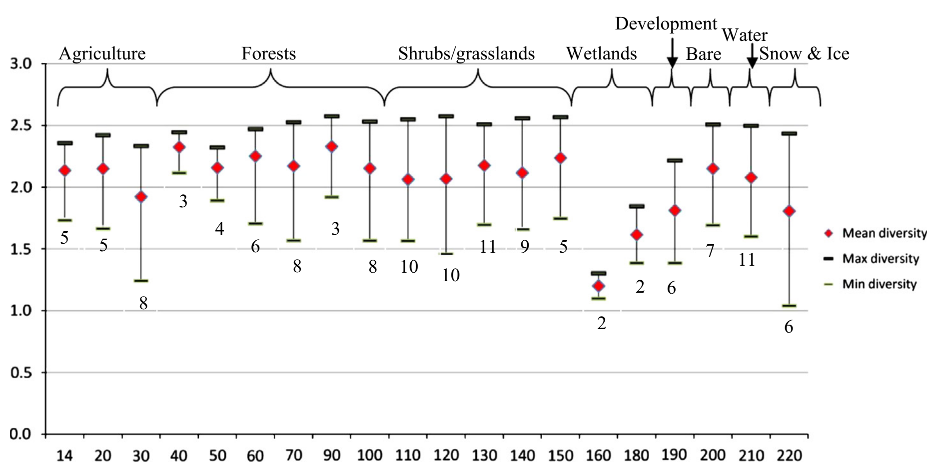

Fig. 3. Mean, maximum, and minimum Shannon diversity indices (vertical axis) of place-based values by land cover class (horizontal axis). The number of studies used to calculate the mean appears below the minimum value.

the potential multi-functionality of various land cover classes. Diversity indices reveal the extent to which the same physical landscape or place provides multiple values that are indicative of ecosystem benefits. The results indicate that most land cover classes provide a relatively high diversity of social values for ecosystem services with the exception of developed areas and permanent snow and ice where value diversity is less. These results reflect the adaptability of the human species across a range of global ecosystems—wherever humans live on earth, they derive ecosystem benefits from both natural and developed landscapes.

4.1. Evaluating social values of ecosystem services

If the social values of ecosystem services are to inform future land use decisions, there must be a mechanism to evaluate different landscapes based on the type and quality of services present to determine their relative importance in providing those services. What criteria should be used to determine the importance of the place-based values that manifest as spatial distributions on the landscape? The monetization of ecosystem services into dollars per "average" hectare provides a commensurate measure for the value of ecosystem services which can guide the prioritization of landscape protection. For example, deGroot et al. (2002) estimated the economic value of global biomes. Based on their analysis, a prudent policy would protect and conserve the highest valued biomes consisting of coral reefs and coastal wetlands. Sutton and Costanza (2002) imputed dollar estimates per hectare to land cover classes that were similar, although not directly comparable with those used in this study. Based on their estimates, permanent wetlands had the highest dollar value per hectare, followed by water bodies, evergreen broadleaved forests, and mixed forests. But the social values of ecosystem services lack

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a singular, commensurate ranking criterion such as dollars per hectare.

In lieu of a single, commensurate evaluation criterion for the social values of ecosystem services, some guidance can be found in ecology where the importance of the spatial distribution of individuals and species can be assessed using measures of abundance (the total number of individual organisms), richness (the total number of different species), and diversity (the number of different species and the evenness of the distribution). These same criteria can be applied to evaluate the importance of different landscapes that provide social values of ecosystem services using spatially delimited areas such as land cover. Value abundance is the total count of placed-based values within an area, value richness is the number of different values present, and value diversity can be calculated using a formula such as Shannon's index.

Two additional evaluation criteria that can be used evaluate the importance of landscapes given the spatial distribution of place-based values: proportionality and density. Value proportionality is determined by comparing the actual proportion of values within a given land cover to the expected proportion as reported in this study. Value density is computed by dividing the number of values found within a given land cover class by the land cover area. The detailed results of place-based value abundance, proportionality, and diversity criteria were presented earlier in this article.

To demonstrate how different evaluation criteria can influence the determination of landscape importance by social values, the 20 land cover classes assessed in this study were ranked in importance according to these criteria and appear in Table 4. The criterion of value richness is not shown because most land cover classes in each study area contained all the values in the values typology and thus this criterion provides little contrast in rank. However, in principle, value richness should be retained as a potential evaluation criterion.

The evaluative criteria rankings reveal that land cover importance would differ significantly depending on the chosen evaluation criterion. Based on abundance, needle-leaved evergreen forest (Class 70) would be considered most important while water bodies (Class 210) would be most important using the proportionality criterion. Developed areas (Class 190) would be most important using the density criterion and needle-leaved deciduous or evergreen forests (Class 90) would be considered most important with the diversity criterion.

Given these disparate evaluation results, one could use multi-criteria techniques (e.g., weighting, ranking) to integrate the evaluation criteria into a single importance metric. However, combining the criteria would still require assumptions about the relative importance of the individual criteria to combine into an overall measure. The purpose here is not to present and defend a particular criterion or combination of criteria for determining the importance of different landscapes in providing social values for ecosystem services. A defensible argument can be advanced for any the evaluation criteria presented herein. Rather, the purpose is to initiate critical discourse on the preferred methods to evaluate the importance of different landscapes where the social values for ecosystem services have been identified and mapped using participatory methods.

An important future research question is the extent to which economic and social valuation methods for ecosystem services yield similar or different results. Do these alternative valuation paradigms provide similar or different information to inform land use decision making? Although not directly comparable, economic values associated with land cover types in the Sutton and Costanza (2002) study most closely track the results of landscape evaluation using the proportionality criterion in this study. One can speculate that the principle of scarcity which underpins economic valuation is also reflected in the proportionality criterion. The one exploratory PPGIS study where a regional population was asked to identify a wide range of ecosystem services operationalized from the MEA (2003) suggests that supporting and regulatory ecosystem services would be under-valued using the abundance criterion of importance (Brown et al., 2012). Economic valuation which relies on expert knowledge has a greater capacity to capture these types of ecosystem services. In contrast, social valuation methods appear to excel in the area of identifying and measuring nonmarket-based cultural services.

If the participatory mapping of the social values of ecosystem services for landscape evaluation is to breach the walls of academia and gain traction within land management and policy decision-making processes, its value in decision support must be demonstrated. Economic valuation of ecosystem services provides an estimate of the economic tradeoffs associated with land development or degradation that can compromise the delivery of ecosystem services (or alternatively, land restoration to enhance ecosystem service delivery). Similarly, the social valuation of ecosystem services provides an estimate of the social tradeoffs, especially in cultural values, that are often lacking in evaluating land use decisions. For now, these social tradeoffs appear in the form of ordinal rankings of relative land cover importance, but with future research, more informative measures can be developed.

Table 4
Rank outcomes of alternative criteria for evaluating the social value of ecosystem services by land cover.

Land cover class (number of studies)	Abundance	Density	Proportionality	Diversity
14 - Rainfed croplands (n=4)	7	19	20	11
20 - Mosaic croplands/vegetation (n=5)	16	11	16	10
30 - Mosaic vegetation/croplands (n=7)	13	9	11	16
40 - Closed to open broadleaved evergreen or semi-deciduous forest (n=3)	2	2	3	2
50 - Closed broadleaved deciduous forest (n=4)	18	8	17	7
60 - Open broadleaved deciduous forest (n=6)	9	4	6	3
70 - Closed needle leaved evergreen forest (n=8)	1	7	19	6
90 - Open needle leaved deciduous or evergreen forest (n=3)	14	17	13	1
100 - Closed to open mixed broadleaved and needle leaved forest (n=8)	3	12	5	8
110 - Mosaic Forest-Shrubland/Grassland (n=11)	15	14	12	15
120 - Mosaic Grassland/Forest-Shrubland (n=10)	6	16	7	14
130 - Closed to open shrubland (n=11)	8	5	4	5
140 - Closed to open grassland (n=11)	10	18	10	12
150 - Sparse vegetation (n=6)	5	13	8	4
160 - Closed to open broadleaved forest regularly flooded (n=2)	20	3	15	20
180 - Closed to open vegetation regularly flooded (n=2)	19	15	14	19
190 - Artificial areas (n=6)	12	1	2	17
200 - Bare areas (n=7)	17	10	9	9
210 - Water bodies (n=11)	4	6	1	13
220 - Permanent snow and ice (n=6)	11	20	18	18

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In the sustainable development triad of environmental, economic, and social consideration, the social acceptability component arguably receives the least attention. Understanding the place-based values of local and regional populations requires significant time and resources to implement for which governments often lack both the capacity and the resolve. This helps explain why the participatory mapping of social values of ecosystem services has been largely an academic pursuit (Brown, 2012).

It is axiomatic that more PPGIS studies to develop larger empirical databases would enhance the external validity of the putative spatial associations described herein, or perhaps, uncover new spatial associations. However, most land use decisions are local and regional in character and it is at this scale where better understanding of the social values of ecosystem services can have the greatest influence over current and future land use. A key area for future research will be to assess the importance of the same regional-scale landscape using both economic and social valuation methods with common spatial land cover classes to more clearly determine the degree of complement, contradiction, or redundancy between the two ecosystem service valuation paradigms. This author asserts that the two valuation paradigms and their associated data collection methods are generally complementary because of their relative strengths and weaknesses in evaluating the full range of ecosystem services. One should not rely exclusively on social valuation methods to evaluate landscape importance where ecosystem services are closely linked to ecological processes and functions because scientists have greater depth of knowledge. Likewise, economic valuation methods are not particularly adept at translating non-material landscape values such as *spiritual* value into surrogate dollar measures that appear socially credible given the diversity of human preferences. Economic and social evaluation methods for ecosystem services appear to be two sides of the same evaluation coin. So we should not be asking “heads or tails”, but whether the coin is of sufficient size to provide information that will actually make a difference.

4.2. Study limitations

This study was the first to examine the spatial associations between placed-based values and global land cover using PPGIS data from multiple studies completed in the U.S., Australia, and New Zealand. The key limitations derive primarily from the geographic scope of the studies, scale and scarcity effects, and the cultural valuation context.

The PPGIS studies included in the analysis were located in temperate and sub-arctic ecoregions and did not include study locations in tropical and sub-tropical areas. It is unknown whether the significant spatial associations found in this study would hold in tropical regions.

Place values are dependent on the scale in which they are mapped. The studies used in this meta-analysis were focused at a regional landscape scale that lacks the spatial resolution to identify some physical landscape features that may contribute to particular place values. For example, spiritual values may be associated with very fine-grain landscape features such as rocks, springs, or mountains. But fine-grained landscape features are not adequately captured in either the participatory mapping methods or the generalized global land cover classes used in the analysis. Another example is the valuation of wetlands. At the resolution of the land cover classification (300 m), significant relationships between values and wetlands were not apparent in this study but significant spatial associations were found using the same PPGIS data set in New Zealand using land cover data with 30 m resolution (Brown and Brabyn, 2012a). The New Zealand study found associations between *life sustaining* value and two wetland classes that were not found at the global scale of this study.

The relative scarcity or abundance of physical landscape features across global locations can also influence place-based valuation. For example, the value of water bodies (*life sustaining* value in the typology) identified by mapping participants is likely influenced by abundance in the study region; scarce water would likely increase its value while abundance would reduce the perceived value relative to other regions.

Finally, the premise of the analysis presented herein is that human values for landscapes are sufficiently embedded in the general human condition to transcend variations in physical settings and culture that influence the place valuation process. And yet, this premise may not hold. The place valuation process is not only influenced by the physical landscape context, but also the cultural context in which the valuation takes place. The regional populations in this study are located in developed countries that may be said to roughly share similar cultures, values, and aspirations. All three countries have achieved a level of affluence where consideration of non-material values of landscapes is not only possible, but has become central to key aspects of the culture. But other cultures are likely to value physical landscape features differently. For example, assessing regional populations in developing countries may reveal spatial associations with landscapes that are perhaps more instrumental or material in character. And such cultural differences may also extend to national identity. There may be place valuation differences between the U.S. and European counties and even between neighboring European countries.

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