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Physical landscape associations with mapped ecosystem values with implications for spatial value transfer: An empirical study from Norway

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ABSTRACT

The identification of spatial associations between perceived ecosystem values and physical landscapes is confronted by a diversity of mapping methods, heterogeneous human populations, and variability in physical landscape classification systems. This study reviews previous research on spatial associations and reports new empirical findings from Norway to describe the potential for spatial "value transfer" methods that extrapolate ecosystem values to other locations. Public participation GIS (PPGIS) survey methods were implemented in two separate study areas in Norway to identify ecosystem values and to analyze their spatial association with land cover data. The ecosystem value associations with land cover were generally consistent with global findings reported elsewhere, with forested areas providing multiple ecosystem "bundles" supporting both recreation-related and provisioning values. Alternative value transfer methods were demonstrated using recreation value to compare actual with predicted distributions using land cover indices derived from value proportions, deviations from expected distribution, and correlation coefficients with ecosystem value bundles. The use of simple ecosystem value percentages located within land cover classes provided the best predictive results for value transfer in this study. The limitations and potential for value transfer methods based on spatial associations between mapped ecosystem values and physical landscape characteristics are discussed.

1. Introduction

Over the last two decades, significant research has focused on identifying and measuring ecosystem services that provide necessary and beneficial services for human well-being (see e.g., Costanza et al., 1997; De Groot et al., 2002; Millennium Ecosystem Assessment (MEA), 2005; Wallace, 2007; Fisher et al., 2009; Kumar, 2010; Haines-Young and Potschin, 2013). Parallel to this research, advances in geospatial technologies and spatially-explicit public participation methods have encouraged experimentation with methods to identify and map the distribution of ecosystem values, especially cultural ecosystem values (Brown and Fagerholm, 2015). The purpose of this paper is to review studies that have examined the relationship between mapped ecosystem values and physical landscape characteristics as a context for reporting empirical research conducted in Norway. The spatial associations found in Norway are used to demonstrate the potential and limitations for inferring ecosystem values from land cover through a process known as spatial value transfer (Troy and Wilson, 2006).

The concept of ecosystem "service" and "value" are often conflated in the literature. The terms are related, but not identical. Ecosystem services are the "benefits people obtain from ecosystems" (MEA, 2005, p. 49) that consist of "the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfil human life" (Daily, 1997, p. 3). Ecosystem values are measures of how important ecosystem services are to people and contain both use and non-use values associated with ecosystems. The participatory mapping of ecosystem values is particularly useful for identifying cultural ecosystem services under the assumption that the values elicited identify spatially-explicit ecosystem properties that contribute to human well-being. Thus, mapped ecosystem values identify the spatial location of ecosystem services.

The ecosystem services and values terminology has been further complicated by participatory mapping studies that have used similar value typologies but with different labels. For example, value typologies have been variously described as *landscape values* (Alessa et al., 2008; Brown, 2005; Zhu et al., 2010), *landscape services* (Fagerholm et al., 2012), forest *values* (Brown and Reed, 2000), *community values* (Raymond et al., 2009), *social values for ecosystem services* (Sherrouse et al., 2011; van Riper et al., 2012), or

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simply *social values* (Bryan et al., 2010). In practice, participatory mapping typologies disproportionately contain values associated with cultural ecosystem services as described in the MEA (2005). The supporting rationale is that of the four major classes of ecosystem services described in the MEA (i.e., provisioning, regulating, supporting, and cultural), the general public has a stronger capacity to identify provisioning and cultural services that are grounded in the experience of living in a region (Brown et al., 2012). Participatory mapping appears ideally suited to identity cultural ecosystem services because mapped values are *relationship* values (Brown and Weber, 2012) that bridge *held* values (what is important to the person) and *assigned* values (landscape features that are important). For consistency, we refer to values that are mapped and linked to spatially-explicit landscape features using participatory methods as *ecosystem values* throughout this article.

The incorporation of cultural ecosystem values into formal ecosystem assessments faces significant barriers including often vague definitions and indefinite relationships between ecosystem structures and functions and human needs and wants (Daniel et al., 2012). Further, individuals perceive social values differently according to their backgrounds, even at homogeneous local scales (Plieninger et al., 2013). Methodological challenges include over-reliance on case study research methods that have low external validity or the ability to extrapolate to other populations, settings, and conditions. Because most cultural ecosystem values are not directly observable in the physical landscape, they require either (1) proxy or indicator measures derived from observed or inferred human behavior, or (2) direct human inquiry about the benefits received. Both approaches involve epistemological assumptions with implications for the internal validity of the values collected. For example, Raudsepp-Hearne et al. (2010) used proxy measures for cultural ecosystem services such as the number of tourist attractions within a given area for tourism benefits and the number of observations of rare species for nature appreciation benefits. Are these valid and accurate proxy measures for the spatial distribution of ecosystem services? Direct methods for assessing cultural ecosystem values often involve spatially-explicit participatory mapping where best practice has yet to coalesce (Brown and Fagerholm, 2015).

In describing physical landscapes, there are also barriers including the availability of spatial data and standardization in collection and reporting. Where physical landscape spatial data does exist, there are often multiple classification systems, collected at multiple scales, at different points in time. While the availability and standardization of spatial data has increased, especially at a national level, the availability of local spatial data is often a limiting factor, especially in data poor developing countries. For example, although land cover is one of the most common spatial data layers for GIS applications, until recently, there was no uniform, global land cover classification system at a spatial resolution useful for analyzing ecosystem values. And while standardization of spatial data is important for interregional or international analyses, standardization can also be a limiting factor through omission of less common, but locally or regionally important physical landscape features.

The continuing quest for identifying universal or at least predictable relationships between ecosystem values and physical landscape characteristics is a natural consequence of methodological barriers, combined with the propensity for science to want to explain and predict relationships from observed phenomena. For example, significant quantitative relationships between ecosystem values and physical landscape features can be used as a method for spatial "value-transfer" where ecosystem values are extrapolated to different regions (Sherrouse et al., 2011) or even countries (Brown and Brabyn, 2012a) in the absence of primary data. The use of value-transfer methods requires confidence in the validity and reliability of the ecosystem value and physical landscape relationships.

1.1. Participatory mapped ecosystem values and physical landscape relationships

There have been multiple empirical studies where ecosystem values have been identified using spatially-explicit mapping methods, commonly referred to as public participation GIS (PPGIS) (NCGIA, 1996a, 1996b; Obermeyer, 1998), participatory GIS (PGIS) (Rambaldi et al., 2006), or volunteered geographic information (VGI) (Goodchild, 2007). All three of these terms describe methods for generating and/or using non-expert spatial information for wide range of applications. As described by Brown and Kyttä (2014), the use of the terms PPGIS and PGIS often reflect the situational context. The term PGIS has been associated with practice in developing countries that emphasize social learning and community engagement, primarily in rural areas, with the resulting maps a potentially useful, but secondary outcome of the process. In contrast, PPGIS has focused on populations in developed countries with an emphasis on the generation of spatial data intended to inform future land use through enhanced public participation methods whose purpose is to improve the quality of land use decisions. The term volunteered geographic information (VGI) describes the harnessing of tools to create, assemble, and disseminate geographic data provided voluntarily by individuals (Goodchild, 2007). PPGIS and PGIS mapping studies often include a volunteer sample or VGI component and ecosystem values have been mapped using methods described as PPGIS/PGIS/VGI (Brown and Fagerholm, 2015).

Research to date on mapped ecosystem values is limited, in part, because participatory mapping is relatively recent with the first mapping study of values occurring in 1998 (Brown, 2005). Of the 30 participatory mapping studies of ecosystem values reviewed by Brown and Fagerholm (2015), less than half analyzed the participatory mapped data for relationships with physical landscape features. Table 1 provides descriptive information for participatory mapping studies where the spatial data were analyzed for association with physical landscape features.

Ecosystem value locations can be mapped with either points or polygons, but with one exception, participatory mapping studies that have assessed relationships with physical landscapes have used points to identify locations. The mapped points are assumed to represent a spatial area of ecosystem value and can be combined with other proximate points to provide a spatial estimate of the ecosystem value area. In contrast, physical landscape data is generally represented as raster or polygon data, with the exception of roads (polylines). The most common physical data that has been analyzed with mapped values is land use/land cover, but other landscape features have included roads, water bodies, landform, elevation, vegetation, built infrastructure, and GIS modeled locations of physical data such as species distributions and carbon storage. The relationships of mapped ecosystem values to administrative boundaries such as protected areas (see e.g., Brown et al., 2014; Palomo et al., 2013; Hausner et al., in press) or municipalities (e.g. Raudsepp-Hearne et al., 2010; Martin-Lopez et al., 2012; Quiroz et al., 2015) have also been analyzed in multiple studies.

Two approaches have emerged in practice for assessing mapped ecosystem values and physical landscape relationships. The SolVES model (http://solves.cr.usgs.gov/) was developed by U.S. Geological survey as a raster-based model that quantifies the relationship between the density of mapped ecosystem values, aggregated into a "value index", and physical landscape metrics such as elevation, slope, distance to roads, and distance to water (Sherrouse et al., 2011). The SolVES model has evolved and now includes Maxent maximum entropy modeling and the option to