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Crowdsourcing indicators for cultural ecosystem services: A geographically weighted approach for mountain landscapes

Patrizia Tenerelli[a], Urška Demšar[b], Sandra Luque[a,c,*]

[a] IRSTEA – National Research Institute of Science and Technology for Environment and Agriculture, UR EMGR Mountain Ecosystems Unit, Grenoble, France
[b] University of St Andrews, School of Geography and Geosciences, North Street, KY16 9AJ St Andrews, Scotland, UK
[c] University of St Andrews, School of Biology, St Andrews KY16 9ST, Scotland UK

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ABSTRACT

Integrating cultural dimensions into the ecosystem service framework is essential for appraising non-material benefits stemming from different human–environment interactions. This study investigates how the actual provision of cultural services is distributed across the landscape according to spatially varying relationships. The final aim was to analyse how landscape settings are associated to people's preferences and perceptions related to cultural ecosystem services in mountain landscapes. We demonstrated a spatially explicit method based on geo-tagged images from popular social media to assess revealed preferences. A spatially weighted regression showed that specific variables correspond to prominent drivers of cultural ecosystem services at the local scale. The results of this explanatory approach can be used to integrate the cultural service dimension into land planning by taking into account specific benefiting areas and by setting priorities on the ecosystems and landscape characteristics which affect the service supply. We finally concluded that the use of crowdsourced data allows identifying spatial patterns of cultural ecosystem service preferences and their association with landscape settings.

1. Introduction

The Ecosystem Service (ES) framework offers an opportunity to capture different dimensions of coupled human–environment systems and integrate natural capital management into decision making and environmental governance. One of the impacts of the growing interest about ES concepts is the improved interdisciplinary component among different academic areas and interest groups (Luck et al., 2012). The category of cultural ecosystem services (CES), in particular, requires assessing benefits and values from different perspectives, including socio-ecological (Chan et al., 2012, Daniel et al., 2012), socio-cultural (Chiesura and de Groot, 2003; Martín-López et al., 2012; Oteros-Rozas et al., 2014) and psycho-cultural dimensions (Kumar and Kumar, 2008). CES are defined as the non-material benefits that people obtain from ecosystems (MEA, 2005). Their intangible and subjective dimensions make CES difficult to quantify and integrate into the ES framework (Daniel et al., 2012; Kirchhoff, 2012), which has led to controversial interpretation and valuation (Chan et al., 2012).

The growing demand for CES (Guo et al., 2010) calls for methods to identify and quantify them in order to plan for the provision of such services. The review work from Milcu et al. (2013) pointed out that CES are least studied among ES, but with an increasing number of publications. Moreover quality indicators for assessing CES are still underdeveloped (Maes et al., 2016; La Rosa et al., 2015; Feld et al., 2009). Assessing and valuing CES allows bridging the gap between ecology, landscape research and social science (Chan et al., 2012; Schaich et al., 2010), while promoting a broader perspective of how natural capital contributes to well-being. Cultural ES have also played a role in motivating public support for nature conservation (Daniel et al., 2012; Phillips, 1998). Integrated approaches are thus needed to assess non material benefits across several dimensions derived from CES in order to inform decision-making (Chan et al., 2012) and land planners.

Assessing preferences and benefits of CES is challenging, especially when considering the spatial and temporal dimension. The social demand of CES and nature oriented recreational activities are also fluctuating over space and time (Duffus and Dearden, 1990). Most of the current studies on CES are based on monetary assessment and socio-cultural preferences through interviews or specific

* Corresponding author at: IRSTEA – National Research Institute of Science and Technology for Environment and Agriculture, UR EMGR Mountain Ecosystems Unit, Grenoble 38000, France. Tel.: +44 1334463381.
E-mail addresses: patrizia.tenerelli@irstea.fr (P. Tenerelli), urska.demsar@st-andrews.ac.uk (U. Demšar), sandra.luque@irstea.fr, sl208@st-andrews.ac.uk (S. Luque).

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surveys which are collected on a declarative basis (e.g. Martín-López et al., 2009; Oteros-Rozas et al., 2014; Petrosillo et al., 2007; Vollmer et al., 2015). Revealed preferences for CES are more difficult to capture and spatially referenced data are seldom available. Spatially explicit data on location for nearby CES provision has the potential to reveal specific patterns (Plieninger et al., 2013; Sherrouse et al., 2011; Van Berkel and Verburg, 2014) and improve the quality of CES indicators (Hernández-Morcillo et al., 2013). Furthermore spatially explicit indicators can also have a real positive impact in planning contexts and in local decision level (La Rosa et al., 2015).

Several spatial approaches have already been developed to assess and map CES through participatory approaches and surveys (e.g. Bryan et al., 2010Van Berkel and Verburg, 2014; Klain et al., 2012), biophysical models (e.g. Lautenbach et al., 2011; Paracchini et al., 2014) or the combination of the two (e.g. Casado-Arzuaga et al., 2014; Kienast et al., 2012; Nahuelhual et al., 2013; Sherrouse et al., 2011). Spatially explicit models based on the combination of biophysical and socio-cultural variables demonstrated that physical component of landscape can be associated to CES benefits (Plieninger et al., 2013; Sherrouse et al., 2011; Van Berkel and Verburg, 2014) and community perceptions of landscape values (Alessa et al., 2008).

In recent years, following the development of social networks, user generated contents are providing volunteered geographic information (Goodchild, 2007) in different application fields. The very fast rate of image uploading on photo sharing platform, in particular, offers potential for a new map paradigm (Leberl, 2010) defined by a crowd of observers acting as distributed sensors (Singleton, 2010). According to Heipke (2010) images uploaded to a host website can be considered as geospatial data which are crowd-sourced by “passive mappers”. Those data can be used in mapping tasks after processing and interpretation. Recent studies have used photographs retrieved from online platforms to explore place perception and geographical variability of human patterns (Cao and O'Halloran, 2014; Hollenstein and Purves, 2010; Li et al., 2013). The analysis of community contributed photos can also be used as a complementary technique of interviews or questionnaires to assess preferences of CES, assuming that visitors are attracted by the location where they take photographs. Visitor's photographs have been employed together with interview by previous studies on landscape and nature perception, proving a suitable way to analyse different environmental aspects which may attract visitors (Dorwart et al., 2009; Taylor et al., 1995). The analysis of photoseries from platforms such as Flickr and Panoramio has already been shown to be a suitable proxy for the empirical estimation of visiting frequency (Da Rugna et al., 2012; Kisilevich et al., 2010; Produit et al., 2014; Sun et al., 2013; Wood et al., 2013). More recently online photo libraries have been used to assess CES (Allan et al., 2015; Arkema et al., 2015; Casalegno et al., 2013; Martínez Pastur et al., 2015; Keeler et al., 2015; Nahuelhual et al., 2013; Richards and Friess, 2015; Willemen et al., 2015).

The primary purpose of this study is to analyse the geographic variability in CES and identify the landscape settings which shape the actual provision of CES. We define the landscape settings as the physical and built characteristics underpinning benefits related to cultural values. The actual provision of CES is given by specific benefiting areas where the service potential supply, or theoretical service provision, match the presence of beneficiaries (Bagstad et al., 2014). Revealed preferences and spatially explicit data of actual service provision were acquired from the online photo-sharing platform Flickr. The number of photographs uploaded on Flickr was used as an indicator to assess a spectrum of opportunities for CES provision in the study area. Our final aim is to understand how landscape settings are spatially associated to people's preferences related to CES in mountain landscapes. The results of this assessment finally delivers key information for ecosystem service planning that can help to improve changes at the regional level which directly affect the service delivery.

2. Materials and methods

The methodology followed in the present study is based on spatial analysis and modelling of multiple data sources. We divided the workflow into a database preparation phase, an explanatory data analysis and a final interpretation phase (Fig. 1).

As a first step we created a database of spatially referenced and validated photoseries. We then selected the landscape settings potentially related to the CES. Specific pre-processing operations for harmonizing the data were performed at this stage. The number of uploaded photographs and the landscape settings were used as dependent and explanatory variables, respectively. In the second phase we performed a local analysis of the factors that contribute to CES at different locations. For this, a global Poisson regression model was compared with a local Geographically Weighted Poisson Regression (GWPR) model in order to see if there exists spatial variability in the relationships between landscape settings and CES. The next sections provide a detailed description of each step.

2.1. Study area

Mountain resources represent important challenges for biodiversity, economic development, place-based cultural and human well-being, while being exceptionally fragile and susceptible to rapid shifts and changes (MEA, 2005). Further, mountain ES are therefore addressed by an increasing number of studies (Grêt-Regamey et al., 2012) considering the consequences of historical land-use change (Schirpke et al., 2013; Leadley et al., 2014) and trade- offs (Gonzalez-Redin et al., 2016) for ES provision. The present study addresses CES in the region of ‘Quatre Montagnes’ situated in the north of the Vercors massif, at the border between the northern and the southern French Alps (Fig. 2). This area is located in the Vercors Natural Regional Park (VNRP), covering 12% of the extent of the park (25,000 ha), and is part of the Long Term Ecological Research sites (LTER). The area constitutes an important network for nature conservation and biodiversity, encompassing different protection status, such as Natura 2000 areas and Integral Biological Reserves (IBRs). Forest represents the dominant ecosystem, covering 60% of the landscape; a number of different grasslands habitats also characterise the landscape composition. A variable altitude, ranging from 500 to 2200 m, with very heterogeneous topography, characterises different types of biota.

The spatial heterogeneity, given by the different lithology, geomorphology, land cover and management practice, results in a complex landscape mosaic which affects ecological processes at different scales (Redon et al., 2014a,b). Within this complex mosaic, the presence of a wide range of natural and semi-natural habitats provides a vast range of ecosystem services. Nature oriented tourism, in particular, is one of the CES which represents a main driver of economic development in the Vercors Mountains. Tourism offer in this area has been increasingly diversified and is characterised by high seasonal fluctuation. In particular, local culture and sense of place related to traditional landscapes are important CES in mountain areas (MEA, 2005) such as Quatre Montagne.

The urban and periurban population distributed in the nearby main valleys and the local population of the Quatre Montagnes municipalities −11,865 inhabitants (INSEE, 2007) – are the main beneficiaries of CES in the region. In particular, the urban agglomerate of Grenoble, which is in a distance range of about 20 km, the agglomerate of Lyon and the cities of Saint-Etienne, Annecy,