



# Demand and supply of cultural ecosystem services: Use of geotagged photos to map the aesthetic value of landscapes in Hokkaido



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## ABSTRACT

We proposed a mapping method for landscape aesthetic demand and potential supply area based on viewsheds, which is a direct method that provides robust results. Moreover, we mapped the aesthetic value of Hokkaido as a case study in Asia.

The Aichi Biodiversity Target refers to the importance of ecosystem service (ES) mapping methodologies. However, ES mapping in policy and practice has rarely been reported. Robust, reliable indicators are required. Recently, studies estimating aesthetic value have used geotagged photos on social networking services instead of survey results of user preferences. The methods used in these studies were cost effective and provided spatially explicit results. However, these methods used the photography positions. Using the photographed sites is a more direct method to estimate the aesthetic demand.

Therefore, we used geotagged photos on Flickr and viewsheds from each photography position to identify the photographed sites. The demand area was estimated using the viewshed. The potential supply area was estimated using MaxEnt. The demand and potential supply areas were concentrated in natural parks. Comparing the demand and potential supply areas indicates areas with potential supply despite their low demand in forest, farmland, and natural parks. This method will contribute to CES research and decision-making.

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## 1. Introduction

Various scales of decision-making require the measurement and visualization of the value of ecosystem services (ES), which is not included in the market price (MEA, 2005; TEEB, 2010; WBCSD, 2010). The value of cultural ecosystem services (CES) is particularly difficult to measure, both physically and monetarily, because such values are intangible and subjective (MEA, 2005). However, researchers and practitioners know that some CESs contribute to human well-being (Milcu et al., 2013). CES also motivates environmental action compared with other ESs (Hirons et al., 2016). Many CES studies have been conducted in Europe and North and Central America. In Asia, many CES studies have been carried out in China but not in Japan (Hernández-Morcillo et al., 2013; Wolff et al., 2015). There are many CES studies on recreation, ecotourism, and the aesthetic value of landscapes because of their strong economic relevance and relative ease of estimation (Hernández-Morcillo et al., 2013; Milcu et al., 2013).

Travel and tourism accounted for 9.8% (US\$7.2 trillion) of global GDP in 2015, and this contribution is expected to increase to 10.8% (US\$11 trillion) by 2026 (WTTC, 2016). Growth will mostly come from nature-based tourism (Balmford et al., 2009); thus, the potential economic value is high. The aesthetic value of landscapes is the pleasure derived from natural beauty (TEEB, 2010). Aesthetic value is an especially important factor in recreation (Daniel et al., 2012), and is strongly related to market price. For example, residential price is affected by the amount of ocean or lake views (Benson et al., 1998; Crossman et al., 2013a). Mapping CES values provides important points of view for the development of conservation plans and for land-use management. The economic evaluation framework in the TEEB (2008) interim report states that quantification and mapping of ES values are necessary. However, only 18% of mapping studies have mapped CESs, far fewer than those that map regulating services (46%) and provisioning services (30%) (Crossman et al., 2013b). The Aichi Biodiversity Target refers to the importance of ES mapping methodologies (CBD Secretariat, 2011). Much CES mapping has reflected people's preferences and has used methods including an empirical method, a participatory approach, and a monetary valuation (Wolff et al., 2015). The empirical method evaluates CES based on questionnaire surveys

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or interviews that reflect people's preferences or the value of sites (Casado-Arzuaga et al., 2013; de Vries et al., 2007; Sherrouse et al., 2011; van Zanten et al., 2016b). The participatory approach, which is based on expert knowledge or preferences of specific users (Kenter, 2016; Palomo et al., 2013; Scolozzi et al., 2014), is spatially explicit and has high estimation accuracy in site-specific studies (Wolff et al., 2015). Therefore, the empirical method is more appropriate than the participatory approach for evaluating CES over a large area (Wolff et al., 2015). Monetary valuation estimates the monetary value of CES using concepts such as willingness to pay (Häyhä et al., 2015; Kenter, 2016; Nahuelhual et al., 2014). These methods have been used frequently in combination in many studies (Kenter, 2016).

Mapping the aesthetic value of landscapes reflects people's preferences in the same way as the other CESs. It has been mainly based on the results of questionnaire surveys (Casado-Arzuaga et al., 2013; Peña et al., 2015) or interviews on preferences (van Zanten et al., 2016b) gained by empirical methods, and by participatory approaches combined with environmental factors that represent attractiveness such as naturalness (Crossman et al., 2013a; de Vries et al., 2007). However, such surveys are often costly and time-consuming. One study used an Internet survey to improve the survey efficiency (Peña et al., 2015), but the preparation of the questionnaire itself remains a time-consuming process.

In recent years, the widespread use of mobile devices has led to the development of social networking services (SNS), through which text messages and photos of food, landscapes, portraits, and so on are shared on the Internet. Geotagged photos are also increasingly shared, and many of these can be collected from wide areas. SNS data uploaded by users provides user preferences and experiences, and thereby contributes to improving the empirical method. In studies related to the aesthetic value, Casalegno et al. (2013) showed the effectiveness of geotagged photos in estimating the aesthetic value on a regional scale and van Zanten et al. (2016a) demonstrated it at a continental scale. Richards and Friess (2015) demonstrated the rapidness and cost effectiveness of using geotagged photos. Martínez Pastur et al. (2016) showed that classified tags of geotagged photos and their positions can be used to map some CES values such as aesthetic and recreation values. However, many studies have also highlighted the shortcomings of SNS data. The bias of the user group was one of the big concerns (Guerrero et al., 2016; Tenerelli et al., 2016). Therefore, the points of usage of SNS data have been reported (Crampton et al., 2013), and demographic studies have also been conducted to clarify the bias of SNS data (García-Palomares et al., 2015; Wood et al., 2013).

The use of ES mapping applications in policy and practice have rarely been reported. Robust, reliable indicators and shared understanding of ES values are needed (Wolff et al., 2015). The methods of estimating aesthetic value with geotagged photos have used the photography positions not the photographed sites. Therefore, they have usually used density of users who uploaded photos in a grid and models, such as the general linear model, to estimate the aesthetic value. However, using photographed sites is a more method direct than using photography positions and should provide robust results.

We improved the empirical method that uses geotagged photos to estimate the aesthetic value for use in policy and in practice. Mapping both the demand and supply potential of ESs also helps to understand the current state of ES. First, we developed a method to estimate aesthetic demand and potential supply area based on viewsheds and MaxEnt, which provided robust results. Second, we applied the method to Hokkaido, the northernmost island of Japan, to assess the current aesthetic value of the landscapes as a case study in Asia.

## 2. Materials and methods

### 2.1. Study area

Our study area, which was used to develop a method for mapping aesthetic value, was Hokkaido, Japan (43° 31' N, 142° 40' E) (Fig. S1). The area is about 7.8 million ha, and its population in 2010 was 5.5 million (Statistics Bureau Ministry of Internal Affairs and Communications, 2016). The annual average temperature was about 9.8 °C in 2010 (Statistics Bureau Ministry of Internal Affairs and Communications, 2016). The area includes rich natural resources and 23 natural parks. Many tourists utilize the resort areas in Hokkaido to enjoy natural features such as wetlands, lakes, and snow. Moreover, Hokkaido is also a famous agricultural area in Japan and has rice paddies, corn fields, wheat fields, and dairy farms. The number of tourists in 2014 was 7.2 million, comprising 21.3% from overseas and 78.7% from domestic areas (Hokkaido Bureau of Tourism, Department of Economic Affairs, 2015).

### 2.2. Mapping method

We developed a method for mapping the aesthetic value of landscapes in terms of demand and potential supply, by using geotagged photos on Flickr as preference data for aesthetics. Flickr was launched in 2004 and has been operated by Yahoo, Inc. since 2005. As of August 2011, Flickr hosted approximately 6 billion uploaded photos (Flickr, 2011). Wood et al. (2013) reported that the number of Flickr users uploading photos has a positive correlation with the annual number of tourists, and thus this number can be used as a proxy for visitation. To confirm Flickr data characteristics in the studied area, we compared the number of tourists to each municipality between 2010 and 2014 (Hokkaido Bureau of Tourism, Department of Economic Affairs, 2015) with the number of Flickr users who uploaded photos in the same municipality for the same period. This comparison revealed a positive correlation on a log–log scale ( $R^2 = 0.61$ ,  $p < 0.001$ ).

### 2.3. Developing photo datasets

Flickr provides an Application Programming Interface (API) (Flickr, 2016) that allows photos to be searched based on metadata such as photo ID, user ID, Where On Earth Identifier (WOEID) that identifies the location, coordinates, title, tags, date, and positional accuracy. We created three datasets using this API (Table S1). Recently, photos taken with mobile phones are being increasingly uploaded to the Flickr database (Flickr, 2015). The accuracy of GPS in mobile phones is almost within 10 m (Zandbergen and Barbeau, 2011), and mobile phones use has increased since around 2010. We were able to download statistics of visitors to the study area up to 2014. We collected metadata from geotagged photos taken from 2010 to 2014 to confirm the relation between the number of Flickr photos and visitors. We created a first dataset (the Filter 1 dataset) containing geotagged photos uploaded during this time with street-level positional accuracy (provided positional accuracy level by Flickr  $\geq 12$  (Flickr, 2016)) and taken within 500 m of the coastline in the study area (WOEID = 7153351). This dataset has 136,023 geotagged photos including coastal area photos taken from boats. Filter 1 dataset photos included landscape photos and all other types of photos such as portraits with food and monuments. Therefore, we extracted only landscape photos using the “landscape” keyword. A sample of extracted photos is shown in Fig. S2. By this filter, portraits containing landscapes were removed.

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