Science of the Total Environment 636 (2018) 1128–1138

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Inequality in access to cultural ecosystem services from protected areas in the Chilean biodiversity hotspot

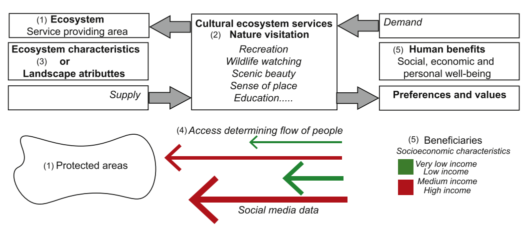
Maria Jose Martinez-Harms [a,b,*], Brett A. Bryan [c], Spencer A. Wood [d,e], David M. Fisher [e], Elizabeth Law [a,b], Jonathan R. Rhodes [b,f], Cynnamon Dobbs [g], Duan Biggs [b,h,i], Kerrie A. Wilson [a,b]

[a] *School of Biological Sciences, The University of Queensland, St. Lucia, QLD 4072, Australia*
[b] *ARC Centre of Excellence for Environmental Decisions, The University of Queensland, St. Lucia, QLD 4072, Australia*
[c] *Centre for Integrative Ecology, School of Life and Environmental Sciences, Deakin University, Melbourne Burwood Campus, 221 Burwood Hwy, Burwood, Vic 3125, Australia*
[d] *School of Environmental and Forest Sciences, University of Washington, Seattle, WA, USA*
[e] *Woods Institute for the Environment, Stanford University, Stanford, CA, USA*
[f] *School of Earth and Environmental Sciences, The University of Queensland, Saint Lucia, Queensland 4072, Australia*
[g] *Departamento de Medio Ambiente y Ecosistemas, Facultad de Agronomía e Ingeniería Forestal, Pontificia Universidad Católica de Chile, Santiago, Chile*
[h] *Environmental Futures Research Institute, Griffith University, Nathan, Queensland 4111, Australia*
[i] *Department of Conservation Ecology and Entomology, Stellenbosch University, Private Bag X1, Matieland 7602, South Africa*

HIGHLIGHTS

- We quantified inequality in access to protected areas CES in a Chilean biodiversity hotspot.
- We developed a proxy for protected areas CES using visitation data from social media.
- Inequality in accessibility to CES from protected areas was very high.
- Conservation planning is needed to reduce inequality in access to protected areas CES.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 26 September 2017
Received in revised form 12 April 2018
Accepted 25 April 2018
Available online 3 May 2018

Editor: D. Barcelo

Keywords:
Inequality
Geotagged photographs
Protected areas
Nature visitation
Human benefits
Social preferences

ABSTRACT

Experiences with nature through visits to protected areas provide important cultural ecosystem services that have the potential to strengthen pro-environmental attitudes and behavior. Understanding accessibility to protected areas and likely preferences for enjoying the benefits of nature visits are key factors in identifying ways to reduce inequality in access and inform the planning and management for future protected areas. We develop, at a regional scale, a novel social media database of visits to public protected areas in part of the Chilean biodiversity hotspot using geotagged photographs and assess the inequality of access using the home locations of the visitors and socio-economic data. We find that 20% of the population of the region make 87% of the visits to protected areas. The larger, more biodiverse protected areas were the most visited and provided most cultural ecosystem services. Wealthier people tend to travel further to visit protected areas while people with lower incomes tend to visit protected areas that are closer to home. By providing information on the current spatial flows of people to protected areas, we demonstrate the need to expand the protected area network, especially in lower income areas, to reduce inequality in access to the benefits from cultural ecosystem services provided by nature to people.

* Corresponding author at: Departamento de Ecologia, Facultad de Ciencias Biologicas, Pontificia Universidad Católica de Chile, Chile.
E-mail addresses: maria.martinezharms@uq.net.au, (M.J. Martinez-Harms), b.bryan@deakin.edu.au, (B.A. Bryan), woodsp@stanford.edu, (S.A. Wood), davefisher@stanford.edu, (D.M. Fisher), e.law@uq.edu.au, (E. Law), j.rhodes@uq.edu.au, (J.R. Rhodes), d.biggs@griffith.edu.au, (D. Biggs), k.wilson2@uq.edu.au (K.A. Wilson).

https://doi.org/10.1016/j.scitotenv.2018.04.353
0048-9697/

1. Introduction

The creation of protected areas is an essential management strategy for conserving biodiversity (Gray et al., 2016) and for providing ecosystem services to society (Pullin et al., 2013). Examples of these services include the provision of clean water to downstream users (Stolton and Dudley, 2003), reducing flooding events (Bubeck et al., 2013), ensuring climate change adaptation and mitigation (Fisichelli et al., 2015; Melillo et al., 2016), and especially the provision of cultural ecosystem services (Willemen et al., 2015). Cultural ecosystem services are the diverse range of non-tangible benefits people receive from natural ecosystems (Daniel et al., 2012) including opportunities to enjoy natural settings, watch wildlife and participate in nature-based recreation, as well as supporting cultural identity and spiritual inspiration (Chan et al., 2012; Milcu et al., 2013; Satz et al., 2013). They can contribute to human wellbeing by enhancing physical and psychological welfare (Chan et al., 2012; Milcu et al., 2013; Satz et al., 2013; Shanahan et al., 2016). The benefits of nature visitation are directly experienced and intuitively appreciated, and they have the potential to motivate and sustain public support for nature conservation (Allan et al., 2015; Daniel et al., 2012).

When assessing the provision of ecosystem services, the spatial distribution of the benefits and whether everyone has equal access to them are crucial considerations (Booth et al., 2010; Shanahan et al., 2014). A thorough assessment is particularly relevant in the context of nature visitation and its role in people's wellbeing. Contrary to provisioning or regulating services which can be supplied by distant service-providing areas, the supply of cultural ecosystem services is mostly localized with people needing to physically visit ecosystems to access to the services. Some sectors of society potentially enjoy greater access to the benefits of protected areas as they have private transportation or a higher disposable income (Shanahan et al., 2014; Shores et al., 2007). Inequality refers to the evenness of the distribution of goods and services across society, so when there is inequality divisions exist that favor or create opportunities for only a portion of society (Schuppert and Wallimann-Helmer, 2015). The effects of inequality on economic development, education, health, and social stability have been well documented across a wide variety of geographical contexts (Agostini and Brown, 2007; Dockemdorff et al., 2000; Parry, 1997; Stierli et al., 2014; Vásquez et al., 2013). However, the effects of inequality in relation to access to protected areas and the cultural ecosystem services they provide have to date only been explored in the “Global North” and for limited geographical extents (Heagney et al., 2015; Shanahan et al., 2014; Wolch et al., 2014). For example, Booth et al. (2010) reported inequality of access to nature recreation in several protected areas in the United Kingdom and identified negative effects on human welfare on those sections of the population with low accessibility with repercussions on the extent of support for conservation in society.

Social media offers high-resolution spatial and temporal data on visitation patterns across broad geographic extents, and it can also be used to infer the socioeconomic characteristics of visitors and visitor preferences (Hausmann et al., 2017; Keeler et al., 2015; Sessions et al., 2016; van Zanten et al., 2016). On social media platforms such as Flickr, for example, users share geo-located photographs that contain the location where the image was taken. This information can be used to quantify people's visits to unpopulated areas and provide insights into preferences for particular landscape attributes (Casalegno et al., 2013; Martinez Pastur et al., 2015; Richards and Friess, 2015; Willemen et al., 2015). This allows assessments of the attractiveness of popular tourist sites (Bassolas et al., 2016) and the exploration of the habits and preferences of recreational visitors of protected areas (Hausmann et al., 2017; Sessions et al., 2016). Social media data are thus a potential source of information to deliver cost-effective assessments of nature visitation benefits over regional areas as a proxy for the provision of cultural ecosystem services (Hausmann et al., 2018; Heikinheimo et al., 2017; Keeler et al., 2015; Richards and Friess, 2015; Sessions et al., 2016; Wood et al., 2013).

Previous research has revealed spatial patterns of cultural ecosystem service use (Paracchini et al., 2014; van Zanten et al., 2016) and has suggested that social media data could be used to increase understanding on the spatio-temporal patterns of values related to biodiversity conservation of different stakeholder groups (Di Minin et al., 2015). However, the distribution of ecosystem services among different communities is still to be assessed using these data. The inequality of access to cultural ecosystem services provided by protected areas has not been assessed. Via nature visitation, cultural ecosystem services are directly enjoyed and intuitively appreciated having the potential to strengthen pro-environmental attitudes and behavior. Given the importance of the benefits from accessing nature for social welfare, this is a critical gap in environmental knowledge, particularly in regions where social inequality has profound welfare and health implications.

In this study we address this knowledge gap by assessing inequality in the accessibility of cultural ecosystem services provided by protected areas in a Chilean biodiversity hotspot. We explore key factors that influence visitation patterns and identify the landscape attributes preferred by visitors to the protected areas. We test the hypothesis that inequality in access to cultural ecosystem services from protected areas is prevalent among municipalities and this inequality is driven by the socio-economic characteristics of the municipalities. Our results provide important insights into the spatial inequality in accessibility of nature visitation benefits and cultural ecosystem services from protected areas among municipalities in the region. This information can be used to inform the planning and management of protected areas to reduce inequality of access to cultural ecosystem services in the future.

1.1. Conceptual framework

Our conceptual framework (Fig. 1) links ecosystems as service providing areas, cultural ecosystem services, and human well-being as supply and demand sides in human–environmental systems (adapted from (Burkhard et al., 2012; Cord et al., 2017)). Protected areas (Fig. 1(1)) represent natural or semi-natural ecosystems underpinning the supply of cultural ecosystem services. The supply (Fig. 1) refers to those biophysical mechanisms such as ecosystem characteristics or landscape attributes (Fig. 1(2)) that underpin the potential delivery of cultural ecosystem services (Fig. 1(3)). Ecosystem services are defined as the benefits provided by ecosystems that influence human well-being and to which people attach value and preferences. Cultural ecosystem services (Fig. 1(3)) are one of three categories of ecosystem services (TEEB, 2010) and include the intangible benefits that emerge from interactions between humans and nature (Chan et al., 2012). The delivery and realization of cultural ecosystem services from protected areas depend on the movement and flow of people to these areas. The accessibility to protected areas will determine the flow of people to protected areas and if the demand is met (Fig. 1(4)). The demand refers to the level of ecosystem services provision required by people driven by human needs, preferences and values (Cord et al., 2017). The change in human well-being that results after an ecosystem service is delivered and used by society are the human benefits (Fig. 1(5)). In this case study, we assume that the population of the study region, which has different socioeconomic characteristics, are the potential beneficiaries (Fig. 1(5)) of the cultural ecosystem services provided by protected areas. We assessed the inequality in access to cultural ecosystem services from protected areas among municipalities and explore which socio-economic variables are driving the way people access cultural ecosystem services from protected areas in the region.

2. Methods

2.1. Study area

The study region covers part of the Chilean biodiversity hotspot (Arroyo et al., 2004), between the Valparaíso region (32°02′S) and

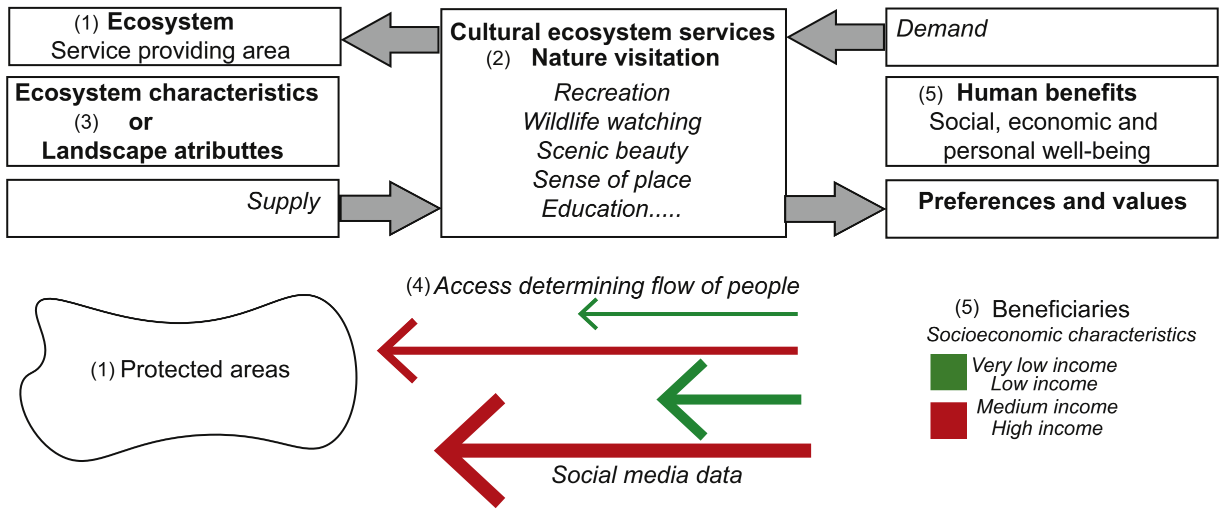


Fig. 1. Conceptual framework linking ecosystems as service providing areas, cultural ecosystem services and human benefits as supply and demand sides in human–environmental systems (adapted from (Burkhard et al., 2012; Cord et al., 2017)). The green and red arrows represent the potential forms of access of the population in the region to the protected areas that we predict will vary according to their socioeconomic characteristics (the thick of the arrow represent population size and the length of the arrow represent the distance travelled along the road network). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Araucania region (39°48′S) (see Appendix Fig. A1). The study region encompasses approximately 148,000 km2, with elevation ranging from 0 to 6500 m. This region is characterized by a Mediterranean climate in the north and temperate climate in the south with mean daily maximum temperatures from 20 °C in summer to 8 °C in winter and with an annual precipitation varying from 250 mm to 700 mm increasing with altitude and latitude (Luebert and Pliscoff, 2006). This region holds the greatest plant richness and endemism in Chile (Bannister et al., 2012) and the most populated areas (Miranda et al., 2017). The public protected area system preserves samples of pristine natural environments, and cultural and scenic elements, allowing education, research, and recreation only when it is compatible with conservation (Law 18,362).The protected areas cover 4% of the Chilean biodiversity hotspot and comprises 65 protected areas including natural monuments (IUCN category III), national parks (IUCN category II), national reserves, and natural sanctuaries (IUCN category IV).

2.2. Protected area visitation

We developed a proxy for visitation rates to protected areas using publicly available geotagged photographs (Sessions et al., 2016; Wood et al., 2013). We used data from images stored on the Flickr photo-sharing website (www.flickr.com). Flickr is a popular image-hosting website for users to share and embed personal photographs. These freely-available data have been used previously as a source of information on when and where people recreate and their preferences for certain types of ecosystems (Hausmann et al., 2018; Keeler et al., 2015; Wood et al., 2013). We used the InVEST Software Suite (Sharp et al., 2016) to gather the image metadata and to calculate the average annual photo-user-days (PUD) for each of the 65 protected areas in the Chilean biodiversity hotspot, based on Flickr photos taken from 2005 to 2014. The annual PUD is the total number of unique photographer-date combinations taken within a specified geographic boundary (Keeler et al., 2015; Wood et al., 2013). If an individual took multiple photos at the same protected area on the same day, that would equate to a single photo-user-day (Wood et al., 2013).

To validate our photo-visitation method for obtaining data on visitation patterns, we acquired data from the National Corporation of Forestry of the Chilean government (http://www.conaf.cl/parques-nacionales/parques-de-chile/). Annual visitor numbers from 2007 were available for 32 of the 65 protected areas within the region. We calculated the average number of visits to each of the 32 protected areas over an eight-year period (2007 to 2014) and compared it to the average annual PUD based on photos from the same time series. We calculated the degree of correlation between visitation data and the PUD proxy data.

2.3. Location and socio-economic characteristics of visitors

To explore the inequality in access to protected areas we obtained information on the home location of visitors within our photo-visitation database. Many Flickr users have a publicly available user profile where they self-report their current home location (Wood et al., 2013). In our study region, 50% of Flickr users shared their home location. Home locations are reported on profiles as place names, and we translated these to geographic coordinates using the Twofishes geocoder (www.twofishes.net). Twofishes is a geocoder software that turns a human-readable location, into latitude and longitude coordinates and have been used in previous studies for similar purposes (Sessions et al., 2016; Wood et al., 2013). For the Flickr users who did not report their home location in their profile, we used a *k*-means clustering algorithm to estimate each user's home location based on the location of all geotagged photographs they had ever shared publicly on *Flickr*. We associated home locations with municipalities (i.e. communes or local government areas) with a spatial intersection of the home location points and the municipality administrative boundaries (boundaries from www.gadm.org). PUDs associated with home locations outside of the study area were excluded from the analysis. We aggregated the PUD visitation data at the municipality level to provide an estimate of the number of visitors to protected areas arising from each municipality.

The socioeconomic characteristics of each municipality were then quantified. The municipality is the smallest administrative unit for which socioeconomic data is collected via the National Socioeconomic Characterization Survey undertaken by the Chilean Ministry of Planning and made freely available to the public (Ministerio Desarrollo Social, 2013). The survey had gathered information on 66,725 households (218,491 individuals) every two years since 1985 from across the major administrative divisions of the country, which involved 15 regions, 54 provinces, and 324 municipalities. The sample sizes at the regional level are noted in the supplementary information (Appendix B, Table B1). The survey provided information on income, education, work, health, housing conditions, and life satisfaction for these households.

We then quantified the inequality of visitation to protected areas for the municipalities of the study region using the Gini coefficient which is commonly used as a measure of inequality of wealth (Wolff, 1992). It measures the difference between a perfectly equitable distribution of resources and the actual distribution of resources and has been applied in assessing many types of inequality (Barr et al., 2011; Damgaard and Weiner, 2000; Halpern et al., 2013; Tulloch et al., 2016). A Gini coefficient of 0 equates to perfect equality and 1 equates to maximal inequality (Gurney et al., 2015). We calculated the Gini coefficient based on the *Lorenz Curve* using the formula defined by Damgaard and Weiner (2000). The Gini coefficient was calculated from the unordered data of the protected area visitation rate (x_i) from the n municipalities (i.e. PUD visits divided by total population of each commune) calculated as the mean of the difference between every possible pair of data (i,j), divided by the mean size μ:

$$G = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n}|x_i - x_j|}{2n^2\mu} \tag{1}$$

All data processing was conducted in *R* (R Core Team, 2012) using the package *ineq* (Zeileis, 2014).

2.4. Mapping cultural ecosystem services demand

We developed a proxy metric of cultural ecosystem service provision for each protected area i, calculated as the total distance travelled to visit it (Eq. (2)). Distance travelled is a proxy for the financial and time costs required to visit protected areas (Ala-Hulkko et al., 2016) and therefore provides an indication of the benefits received from visiting each area. We estimated distance travelled as the distance between the recorded visitor home location within the photo-visitation database and the protected areas they visited. Distance was calculated as the least cost path using the Origin-Destination matrix under the Network Analyst extension in ArcGIS 10.3 (ESRI, 2011) based on the road network data derived from the OpenStreetMap for Chile (OSM, 2016). The total distance travelled to each protected area summed over all photo-user-day records provides an ideal revealed-preference metric for estimating the relative provision of cultural ecosystem services from each protected area. This metric of demand for cultural ecosystem services can then be mapped for all protected areas.

$$CES_i = \sum_{k}^{M} Distance_{ik} \tag{2}$$

CES_i: Index of cultural ecosystem services provision for each protected area i. $Distance_{ik}$: Road distance travelled to protected area i and the home location for each photo-user-day (PUD) k.

We validated the use of the total distance travelled to visit each protected area as a measure of cultural ecosystem services by assessing the relationships with other factors previously associated with the provision of these services including protected area size, biodiversity, and aesthetic amenity. In the study region the size of the 65 protected areas varies from 0.003 to 785 km^2, with 27 protected areas smaller than 10 km^2. Smaller protected areas have been shown to attract fewer people in comparison with large areas (Balmford et al., 2011). Biodiversity was represented by endemic plant richness (Pliscoff et al., 2014) and the number of ecosystems represented (Luebert and Pliscoff, 2006) (Appendix C, Fig. C1). Aesthetic amenity was measured by the proportional coverage of forest and water bodies within each protected area (CONAF-CONAMA-BIRF, 2014). We applied simple and multiple linear regression analysis using the t-test and F-test respectively and assessed the goodness-of-fit of the relationship between the cultural ecosystem services CES_i of the protected areas (response variable) and these landscape attributes (predictor variables). Data processing was conducted in R (R Core Team, 2012) and plotted using the package ggplot2.

Cultural ecosystem services demand was positively related to the size of protected areas (Fig. 2a), the endemic plant richness (Fig. 2b), and the number of ecosystems represented (Fig. 7c). The multiple regression model including these three explanatory variables together explained a significant amount of the variance in visits (Multiple $R^2 = 0.39$, $p < 0.0001$, $F = 11$, $DF = 52$) but, similar to results from a simpler model that included just the size of the protected areas ($R^2 = 0.37$). We did not find a significant relationship between protected areas and the aesthetic quality of protected areas, measured as the cover of forests and water.

2.5. Quantifying accessibility to cultural ecosystem services

We then developed a spatial layer quantifying a relative index of accessibility of each municipality to the cultural ecosystem services provided by all protected areas in the study area. This metric was calculated for each municipality j as the cultural ecosystem services of each protected area i divided by the distance between the municipality and the protected area, summed over all protected areas, all multiplied by the average income of the municipality. Where a municipality is located closer to more protected areas which provide greater cultural ecosystem services benefits then the accessibility index is higher, particularly if the income of the municipality is also high. Conversely, those municipalities that are located further from the higher cultural service-producing protected areas have lower accessibility to the cultural services provided by Chile's protected areas, particularly if they have lower incomes.

$$Accessibility_j = \left(\sum_{i}^{N} \frac{CES_i}{Distance_{ij}}\right) * Income_j \tag{3}$$

$Accessibility_j$: Accessibility of each municipality j to all protected areas in the Chilean biodiversity hotspot. $Distance_{ij}$: Distance (km) via the road network from each protected area i to each municipality j. $Income_j$: Average annual income per capita of each municipality j.

The first term in the accessibility equation above quantifies the geographic component of accessibility for each municipality. In calculating the geographic component, for each protected area the indicator of cultural ecosystem services provision is divided by the travel distance from the municipality centroid. When summed over all protected areas this provides an aggregate metric of geographic accessibility for each municipality. Where a municipality is closer to more protected areas which provide greater cultural ecosystem services benefits, the geographic accessibility of the municipality is greater.

The geographic component of each municipality was then multiplied by a socioeconomic component to calculate the overall accessibility of each municipality. The socioeconomic component was represented by the average income per capita (Chilean pesos earned per year per person) for each municipality drawn from the National Socioeconomic Characterization Survey (Ministerio Desarrollo Social, 2013). Greater disposable income available to individuals increases accessibility as it reflects the greater personal financial resources available to visit protected areas as individuals have more capacity to spend money on transportation, travel, and recreation.

We validated the use of income as a socioeconomic component of accessibility by testing the association between the average municipality income and the propensity to visit protected areas. However, to reduce the potential confounding effect of people travelling further simply because they live further away, we tested the relationship between average income of each municipality and the distance from each municipality centroid to all protected areas and found a weak negative relationship between these variables (Spearman correlation $rho = -0.2$). Hence, on average, wealthier municipalities tend to be located

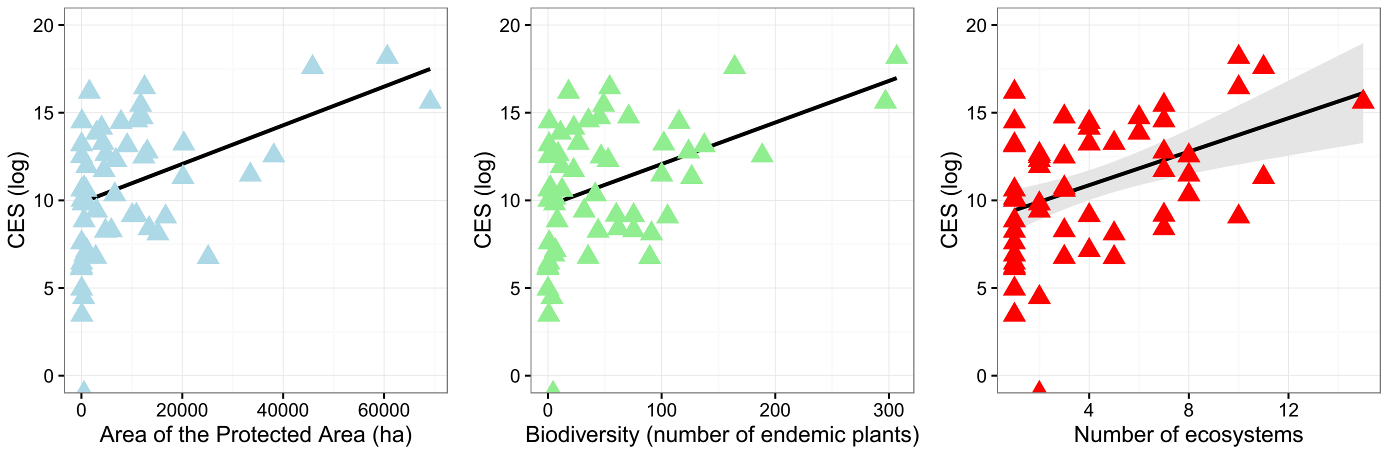


Fig. 2. Landscape attributes of the protected areas influencing cultural ecosystem services demand, (a) area of the protected area, (b) number of endemic plants, and (c) number of ecosystems represented in the protected areas. All variables on the y axis are plotted on a log scale.

closer to protected areas overall and all else equal should travel less far than poorer municipalities to visit them. However, we found a positive and significant relationship ($R^2 = 0.48$, $p < 0.0001$, $F = 130.2$, $DF = 160$) between average income and the distance travelled to the protected area system, weighted by the number of photo-user-days for each municipality (Fig. 3). Thus, people from municipalities with a higher average income tended to visit protected areas more often and travel further, whereas individuals from municipalities with a lower average income visited protected areas closer to home (Fig.3). This provided a strong justification for the use of income as a socioeconomic component of accessibility.

We also tested if other socioeconomic characteristics of municipalities were related to visits to protected areas, including gender, rural/urban, education, health, and car ownership to reduce any other confounding effects. We did not find significant associations between any other single socioeconomic variable (gender, rural/urban, education, private health, and car ownership) and the number of visits to protected areas.

3. Results

3.1. Protected areas visitation

We found that the majority (56 out of 65) of the protected areas in the Chilean biodiversity hotspot had been photographed by Flickr users from 2005 to 2014 (Appendix D). In these protected areas, the PUDs ranged from 1 to 425 (Fig. 4), with 60% of protected areas having PUD values of <50. Conguillio, Villarrica, Huerquehue, and La Campana National Parks are the most visited protected areas according to this metric, along with the Acantilados Federico Santa Maria and Peninsula de Hualpen National Monuments (Fig. 4). We found a strong relationship between empirical visitation data and the PUD proxy (*Spearman* correlation *rho* = 0.74).

3.2. Distribution of access to protected areas

We determined the home locations of 3816 visitors who shared Flickr images and identified 2944 of these visitors with home locations in Chile. We present visitor's home locations for four protected areas as specific examples (Fig. 5). The home locations were distributed among 162 of the 324 municipalities of Chile.

The inequality of visitation to protected areas was high (Fig. 4, Gini coefficient = 0.79). Our results show that 20% of the population makes for 87% of the visits to protected areas in the region (Fig. 6).

3.3. Mapping social accessibility to cultural ecosystem services benefits

The accessibility of the municipalities to cultural ecosystem services provided by protected areas varies spatially according the proximity to higher CES-providing protected areas (Fig. 7b) and the income of the

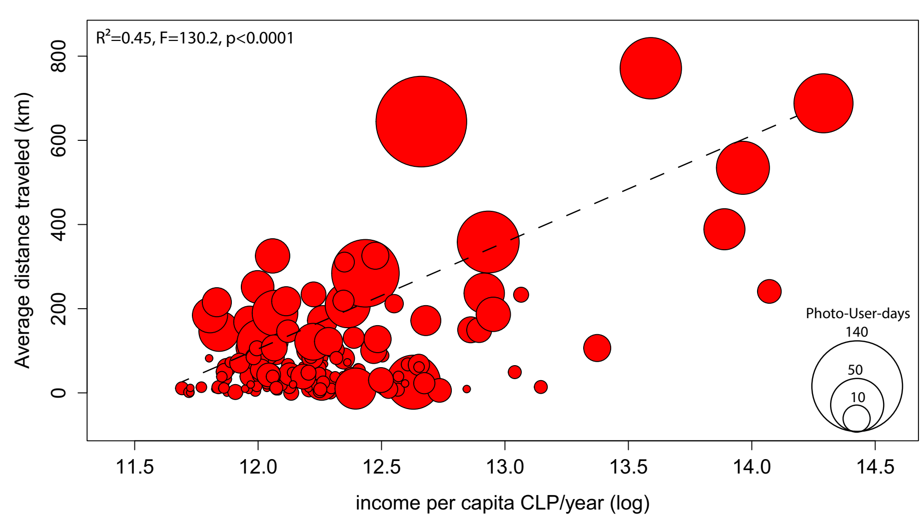


Fig. 3. Total distance travelled per municipality against average income per capita in Chilean pesos, weighted by the total annual photo-user-days.

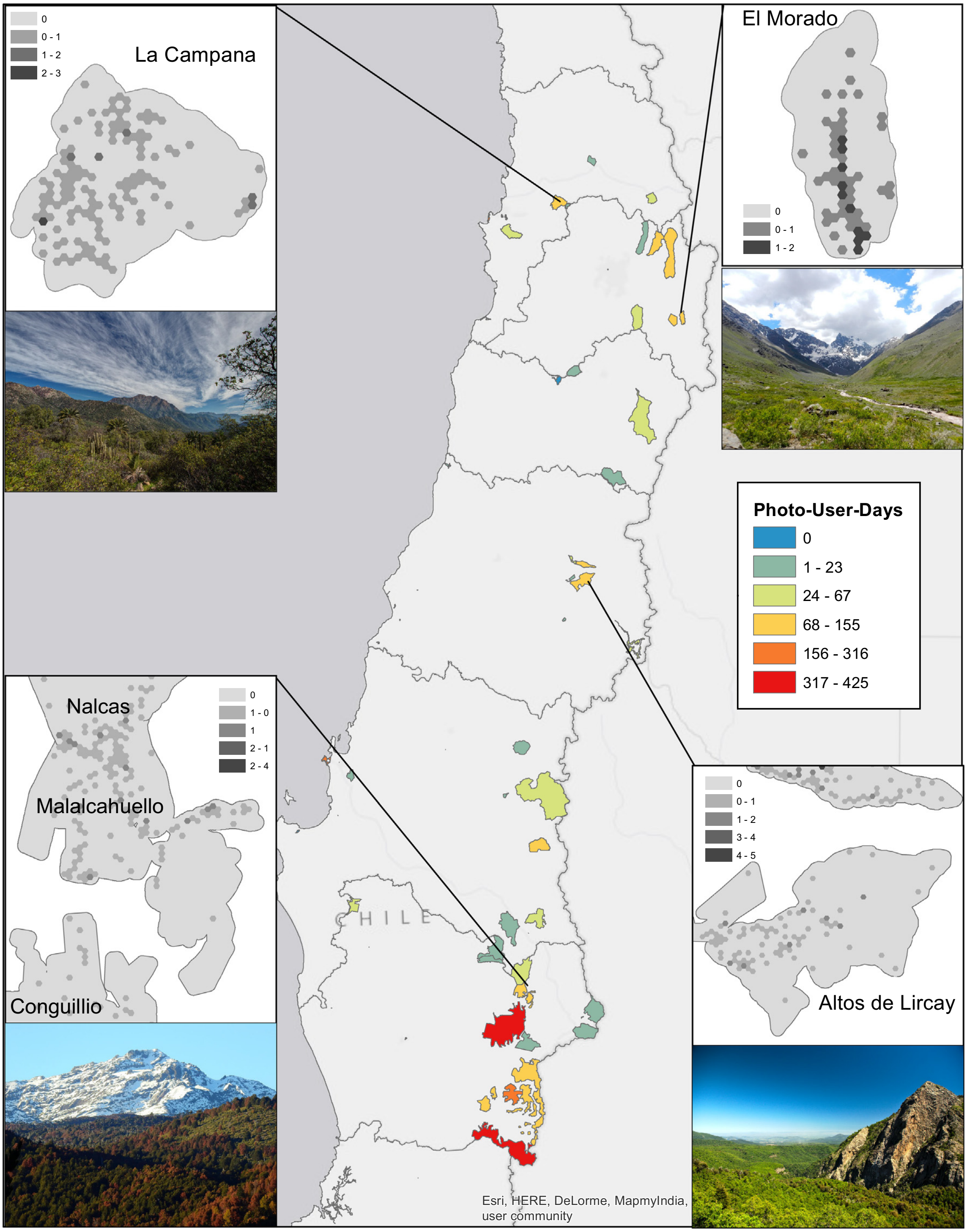


Fig. 4. Total annual photo-user-days (PUD) for the 65 protected areas of the Chilean biodiversity hotspot, with a close-up view for four protected areas (displayed at a 500 m grid resolution).

commune (Fig. 7a). The municipalities in the northern administrative regions (regions V, RM, VI and VII) have the lowest accessibility, measured as the average distance from the commune to all protected areas (Fig. 7d). For example, 90% of the Valparaiso region (region V in Fig. 7d) has low or very low accessibility. The accessibility of the municipalities to the protected area system increases in the southern regions where the municipalities are closer to the protected areas (because there is a greater area protected) and the protected areas are also more popular. For example, in the most southern region of Araucania (region XI in Fig. 7 and d), 40% of the region has high and very high accessibility to the protected area system.

4. Discussion

Using a novel database of visitation to protected areas for the Chilean biodiversity hotspot we reveal that access to protected areas is very unequal with the majority of visits to protected areas arising from a small proportion of municipalities. The distance travelled to protected areas is

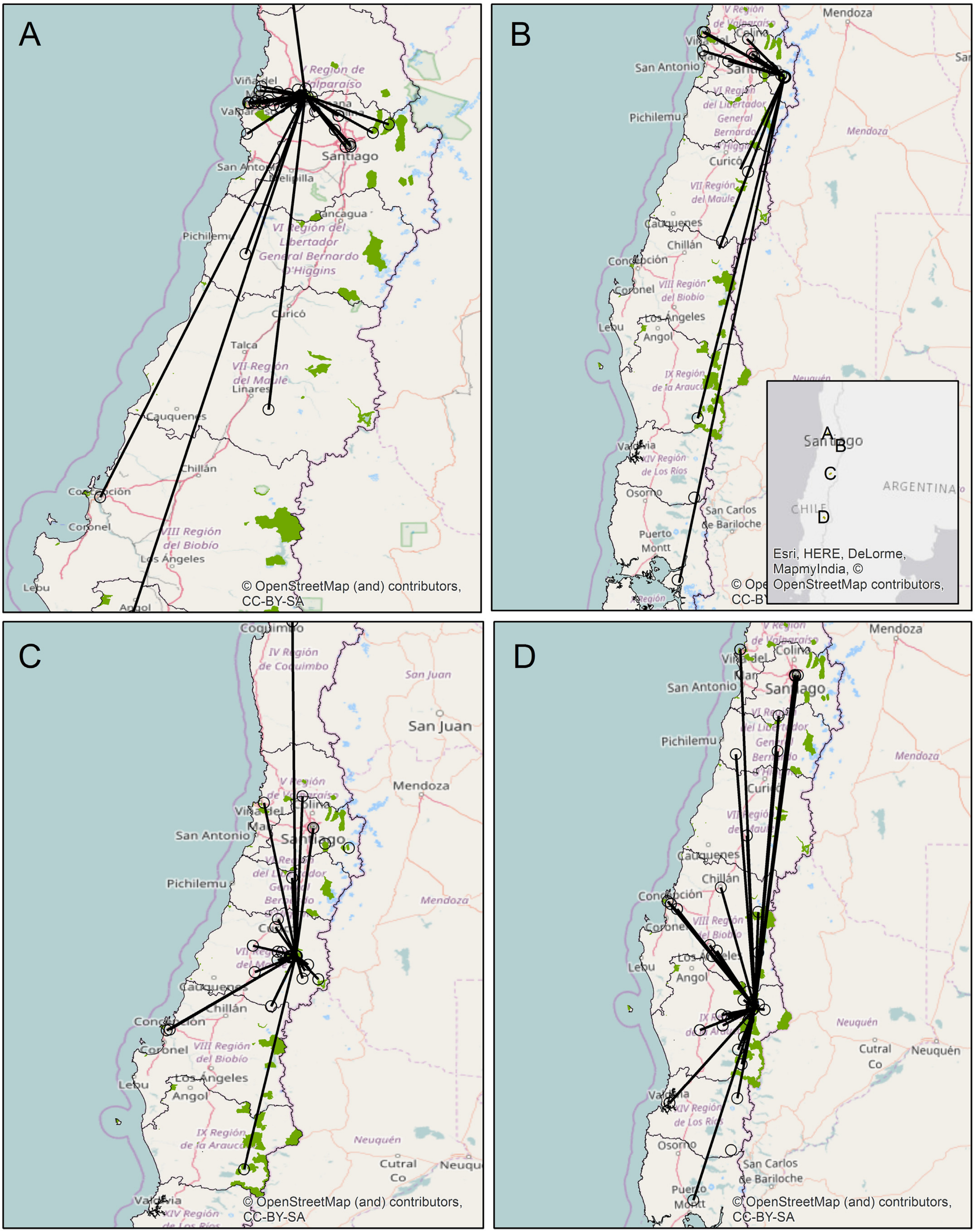


Fig. 5. Examples of the distribution of visitors' home locations for four protected areas in the Chilean biodiversity hotspot: A. National Park La Campana, B. Natural Monument El Morado, C. Natural Reserve Altos de Lircay and D. Natural Reserve Malalcahuello.

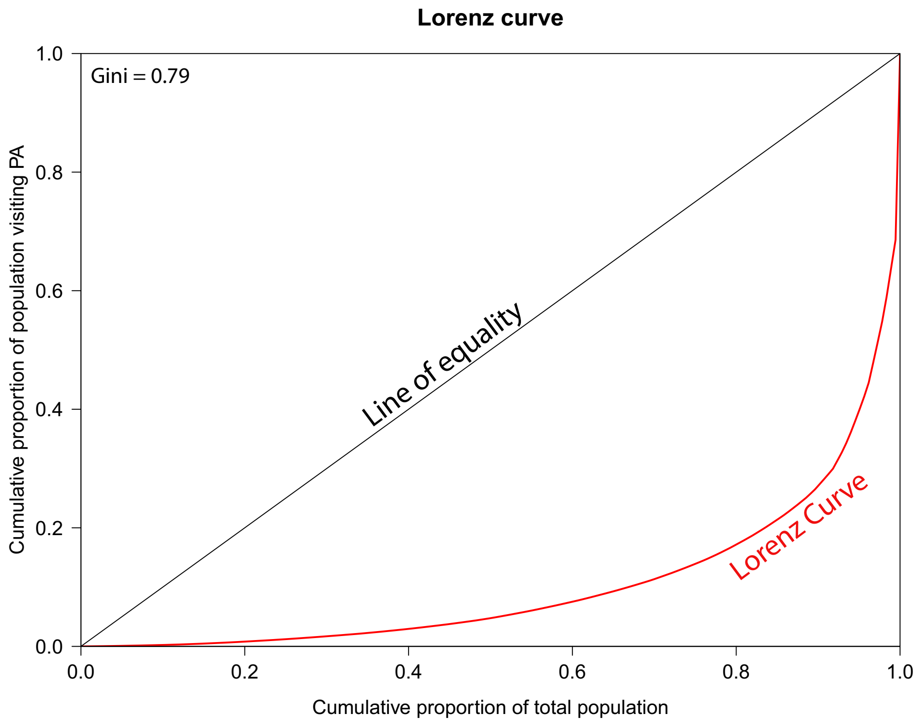


Fig. 6. Lorenz curve for the cumulative proportion of population visiting protected areas in the Chilean biodiversity hotspot region of Chile based on the photo-visitation database (annual photo-user-days standardized by the population size of each commune).

positively related to the average income of the municipalities where the visitors reside. Individuals from wealthier municipalities tend to travel further to visit protected areas while people from poorer municipalities visit protected areas that are closer to their home locations. The accessibility map shows that access is particularly limited in the northern portion of the study region where there is a smaller area protected overall (Fig.7b). This is the first time in Latin America that the inequality of visitation to protected areas has been assessed and the first time that the distribution of nature visitation benefits has been appraised across such a large geographic extent.

Previous studies have addressed the distribution of protected areas using distance analysis and census data (Ala-Hulkko et al., 2016; Lindsey et al., 2001; Nicholls and Shafer, 2001) and assessed how access to nature varies across different socioeconomic groups (Shanahan et al., 2014). Most studies have used direct surveys within protected areas (Ament et al., 2016; Booth et al., 2010). Our results are consistent with previous studies suggesting that the lowest income earners have more-limited access to protected areas (Booth et al., 2010; Lindsey et al., 2001; Shanahan et al., 2014). Our study advances previous efforts by providing the first comprehensive regional assessment of equality of the distribution of benefits from cultural ecosystem services provided by visiting nature. The collection of data extracted from social media capturing social values, experiences and observations in natural and semi-natural ecosystems can open new avenues to further understand the realization of cultural ecosystem services by people (Maes et al., 2018). The advantage of using social media data to study the inequality of access to protected areas, compared to more traditional techniques such as social surveys, is that social media allows us to capture dynamic landscape-scale processes across large geographic extents (van Zanten et al., 2016). However, it must be acknowledged that social media data may exhibit bias resulting from the volunteered and unstructured nature of its data which is selected through an emotional process rather than from a rational synthesis (Wang et al., 2018).

Chile has the highest income inequality of any Organization for Economic Co-operation and Development (OECD) country, and one of the highest levels of income inequality in Latin America (OECD, 2015; Pizzolitto, 2005). An unequal distribution of nature visitation benefits could have important implications for the wellbeing of the Chilean population. There is evidence that knowing and experiencing nature makes people happier and healthier (Bratman et al., 2012; Burns, 2005; Russell et al., 2013). For example, being in nature relieves stress (Van Den Berg et al., 2007), improves physical health (McCurdy et al., 2010; Ulrich, 1984) and makes people more productive and creative (Maller et al., 2006). A hypothesis termed "biophilia" asserts the existence of a biologically based, inherent human need to affiliate with nature (Kellert and Wilson, 1995). The lack of experiences and interactions with nature affects peoples' physical and emotional wellbeing (Bratman et al., 2012; Keniger et al., 2013; Russell et al., 2013) and prevents people from developing connections to nature, which can lead to negative attitudes towards nature (Louv, 2008). There is a need to improve access to protected areas in the Chilean biodiversity hotspot to minimize the level of disconnection with nature and associated negative impacts on human welfare (Gurney et al., 2015; Klein et al., 2015).

In the Chilean biodiversity hotspot, the size of the protected areas and their biodiversity are positively influencing visitation and demand for cultural ecosystem services from the protected areas. Specifically, the larger protected areas located in the southern part of the region are the most popular and are subject to the greatest demand. However, these areas are distant from the main urban settlements in which most of the country's population is concentrated. As the study region has a very low percentage of public land and contains some of the smallest protected areas of the country and the world (Kuempel et al., 2016), these findings call attention to the need to expand the current protected area system and improve the equality in access to cultural ecosystem services.

Information on visitation rates to protected areas is limited and sparse (Balmford et al., 2015). Given the scarcity of data on visits to protected areas, we used all available regional level data. However, our models explained only part of the variance (i.e. 45% and 39% of the variance of visitation patterns were explained by the socioeconomic

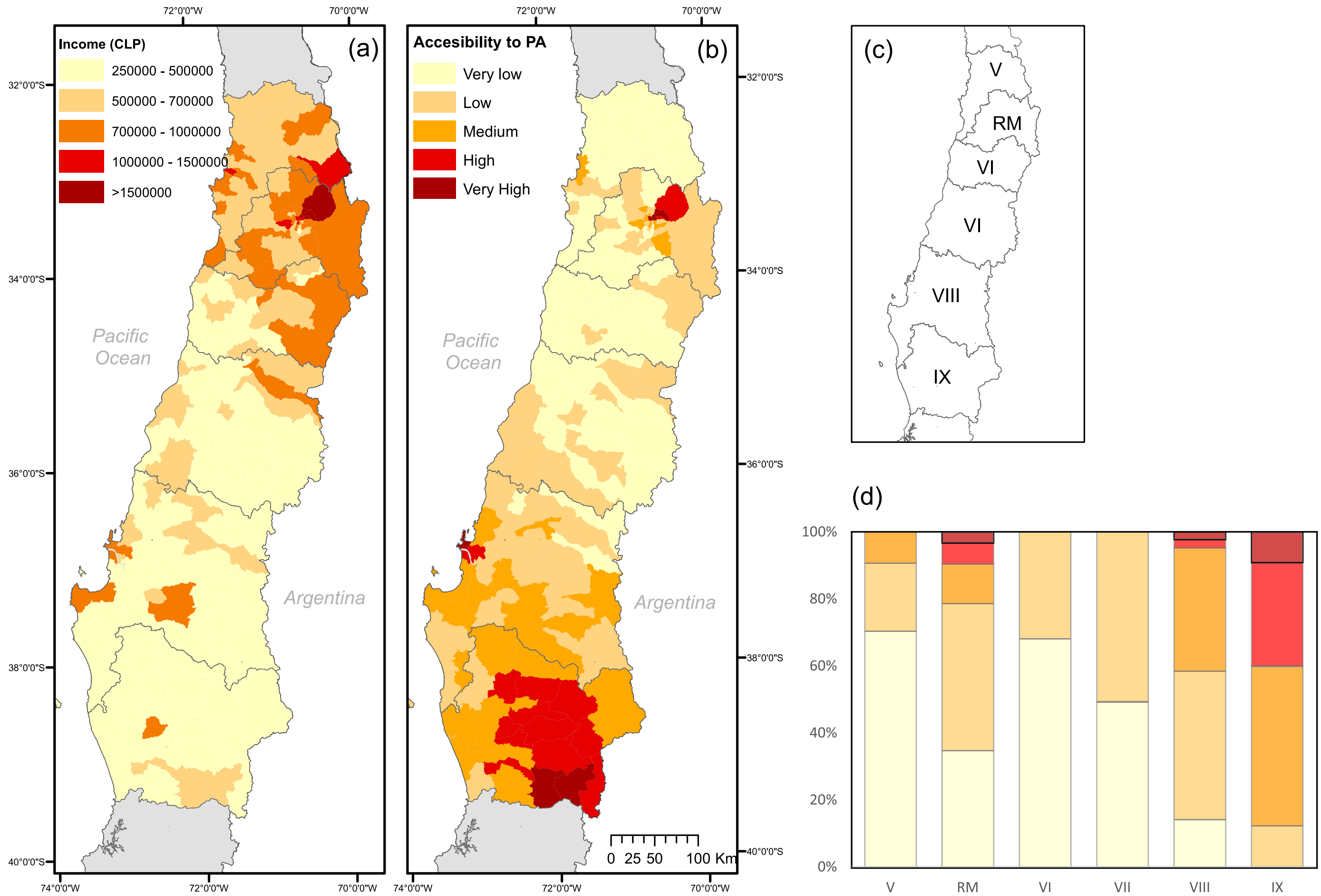


Fig. 7. (a) Income of the municipalities, (b) accessibility of municipalities to the cultural ecosystem services provided by the protected area system, (c) map depicting the administrative regions of the study area and (d) a bar graph representing the administrative regions of the Chilean biodiversity hotspot from north to south and the percentage of area in each accessibility category.

and landscape attribute variables respectively). Variables such as infrastructure inside protected areas (Pullin et al., 2013), transport options to protected areas (Chile boasts an extensive public transportation network (Spenceley et al., 2015)), biophysical attributes such as climate and elevation, and sociodemographic characteristics at the individual level such as age, gender and education (Booth et al., 2010) could also influence visitation patterns. We were unable to identify clear relationships between nature recreation and the other socioeconomic variables collated in the national survey such as education, car ownership, and health. Other limiting factors affecting the visitation of protected areas are related to the fact that people in Chile prefer to visit coastal areas for their cultural ecosystem services such as quietness and scenery of the coast (De Juan et al., 2017). The public protected area system covers a small portion of the study region and is largely biased towards the southern and higher elevation areas of the Andean range (Durán et al., 2013). We highlight the need to expand the protected area network to bring the cultural ecosystem services of protected areas closer to people (and especially those with lower income) to obtain greater benefits for human wellbeing.

The use of social-media to estimate visits to protected areas has limitations that warrant consideration. In this case the content of the photo was not interpreted, so the photos do not necessarily represent the exact cultural ecosystem services provided in a protected area. Another limitation is that the InVEST recreation model focuses on just one social media platform and Flickr users may not be representative of the full spectrum of beneficiaries of cultural services from protected areas. For example, these results might be biased towards younger or wealthier segments of the population. Including other platforms such as *Instagram* or *Panoramio*, as done by recent studies (Hausmann et al., 2018; van Zanten et al., 2016) might help address this limitation in the future. Another limitation when calculating the home location of visitors is that there is a possibility of error from users misreporting their home locations which brings uncertainty to this analysis. In our analysis, the socioeconomic characteristics of visitors was assigned to the characteristics of the whole commune which can also cause bias in our results. In our analysis, we have not considered private protected areas because empirical information available regarding number of visits to these areas was not available which impedes its validation with the photo-visitation approach. However, the effect is likely to be very small as private reserves constitute only a small percentage of the total protected areas in the study area. In addition, access to private land by the public is restricted which does little to improve access to the cultural ecosystem services provided by these areas.

Despite these challenges, social media data has proven to be very useful for capturing aspects of ecosystem service demand, not just supply (Cord et al., 2017). Moreover the creative combination of multiple data sources such as social media data, satellite products and various types of other socio-economic and environmental information (including household surveys, population, biodiversity data etc.) is the key to further understanding the use of cultural ecosystem services by people. Our case study demonstrates the suitability of social media data for estimating visits to protected areas as we found that geotagged photographs uploaded to Flickr were strongly correlated to empirical visitation to protected areas demonstrating that the photo-visitation method is a good indicator of protected area visitation rates in the study region. To further study social preferences for cultural ecosystem services a next step would be to interpret the photographs and the types of cultural ecosystem services represented in the pictures (Martinez Pastur et al., 2015). Also, initiatives that encourage visitors to contribute images while visiting protected areas and to report more information about their socioeconomic background and social preferences could facilitate cost-effective future studies of recreational behavior and at larger scales (van Zanten et al., 2016).

As well as expanding the coverage of public protected areas, private landholders could also provide biodiversity conservation and public access for nature recreation through voluntary or incentivized programs. The forestry and agriculture sectors own a substantial proportion of natural land in the more populated areas of the Chilean biodiversity hotspot (Zorondo-Rodríguez et al., 2014). Vineyards have expanded rapidly in Central Chile (Castañeda et al., 2015), and the wine industry is interested in environmentally-friendly practices, setting aside native forest for conservation, and ecotourism (Merelender et al., 2014). The forestry industry, through engagement with the Forest Stewardship Council certification program, is also setting aside an important amount of native forest for conservation, especially in the Nahuelbuta coastal range (Pauchard et al., 2007). However, our study also shows the preference of people, and particularly wealthier populations, to seek the benefits of nature from larger, more biodiverse parks, which are located further from populated areas. Thus, while these initiatives on private land could help improve equitable access to nature recreation opportunities, they are unlikely to be able to provide the full nature visitation benefits of "wilderness" in larger, more biodiverse public protected areas. Further, the preference that we observe for biodiverse areas suggests that sustainable tourism and management strategies, which focus on maintaining and enhancing biodiversity, will be important.

Our case study has important policy implications in providing information on the distribution and spatial flows of people to protected areas. Conservation of natural ecosystems, cultural ecosystem services and the delivery of recreational benefits are explicit objectives of the Chilean protected area system policy (Chilean Government, 1984). Maintaining the equitable distribution of nature recreation benefits alongside a representative sample of biodiversity are key goals of a sustainable network of protected areas in Chile. Nonetheless, the current protected areas system fails to conserve a representative sample of biodiversity (Luebert and Becerra, 1998; Pliscoff and Fuentes-Castillo, 2011) and our study provides empirical evidence that the access to protected areas available to the Chilean population is unequal. This information is key to informing the planning and management of future protected areas to improve equitable of access.

Acknowledgments

MMH is supported by the Ministry of Education from the Chilean Government fellowship and the Australian Research Council Centre of Excellence for Environmental Decisions scholarship. MMH is also supported by the University of Queensland – Commonwealth Scientific and Industrial Research Organization (CSIRO) Integrative Natural Resource Management Postgraduate Fellowship. BAB was supported by CSIRO Agriculture and Food, and Land and Water. KAW was supported by the Australian Research Council Future Fellowship (FT100100413) and the Australian Research Council Centre of Excellence for Environmental Decisions (CE11001000104), funded by the Australian Government. This work was supported by the National Socio-Environmental Synthesis Center (SESYNC) under funding received from the National Science Foundation DBI-1052875.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.scitotenv.2018.04.353.

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