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RESEARCH ARTICLE

Spatial patterns of cultural ecosystem services provision in Southern Patagonia

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Abstract
Context Although there is a need to develop a spatially explicit methodological approach that addresses the social importance of cultural ecosystem services for regional planning, few studies have analysed the spatial distribution on the cultural ecosystem services based on social perceptions.
Objective The main objective of this study was to identify cultural ecosystem service hot-spots, and factors that characterize such hot-spots and define the spatial associations between cultural ecosystem services in Southern Patagonia (Argentina).
Methods The study was carried out in Southern Patagonia (243.9 thousand km^2) located between 46° and 55° SL with the Andes mountains on the western fringe and the Atlantic Ocean on the eastern fringe of the study area. The study region has a range of different vegetation types (grasslands, shrub-lands, peat-lands and forests) though the cold arid steppe is the main vegetation type. We used geo-tagged digital images that local people and visitors posted in the Panoramio web platform to identify hot-spots of four cultural ecosystem services (aesthetic value, existence value, recreation and local identity) and relate these hot-spots with social and biophysical landscape features.
Results Aesthetic value was the main cultural service tagged by people, followed by the existence value for biodiversity conservation, followed by local identity and then recreational activity. The spatial distribution of these cultural ecosystem services are

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associated with different social and biophysical characteristics, such as the presence of water bodies, vegetation types, marine and terrestrial fauna, protected areas, urbanization, accessibility and tourism offer. The most important factors are the presence of water in Santa Cruz and tourism offer in Tierra del Fuego.

Conclusions Our results demonstrate that this methodology is useful for assessing cultural ecosystem services at the regional scale, especially in areas with low data availability and field accessibility, such as Southern Patagonia. We also identify new research challenges that can be addressed in cultural ecosystem services research through the use of this method.

Keywords Landscape pictures · Spatial distribution · Social perceptions · Aesthetic value · Existence value · Local identity · Recreation

Introduction

The concept of ecosystem services has recently received increasing attention in scientific and policy contexts because its capacity to bridge the connections between ecosystems and social systems (MEA 2005; Carpenter et al. 2009; Reyers et al. 2013), as well as to integrate ecological, socio-cultural and economic approaches in knowledge building and policy development (e.g. de Groot et al. 2010; Chan et al. 2012). Among the three commonly recognized categories (provisioning, regulating and cultural) (MEA 2005), the cultural ecosystem services have received the least scientific attention (Vihervaara et al. 2010; Crossman et al. 2013), although their human demand will increase in the future in both industrialized (e.g. recreation and experiences in nature) and rural societies (e.g. aspects related to maintenance of its local identity) (Milcu et al. 2013). Cultural ecosystem services are perceived as important for fulfilling basic human and social needs by a broad spectrum of stakeholders in many social-ecological contexts (e.g. Lamarque et al. 2011; Martín-López et al. 2012; Hartel et al. 2014; Oteros-Rozas et al. 2014).

Cultural ecosystem services are defined as the non-material benefits that people gain from ecosystems, through spiritual enrichment, cognitive development, recreation or aesthetic experiences (MEA 2005). Despite the different ways that cultural ecosystem services contribute to the different dimensions of human wellbeing (e.g. materials, health, security, freedom of choice or good social relationships) (Vilardy et al. 2011; Russell et al. 2013), the scientific literature has mostly focused on analysing the contributions of recreational activities to economic welfare (Hernández Morcillo et al. 2013; Milcu et al. 2013), perhaps due to the ease with which an economic valuations can be made of this ecosystem service (Heal 2000). Cultural ecosystem services have rarely been integrated in decision-making because of their intangibility, their complex relationships with biophysical variables and the difficulty of quantifying their multiple and intangible social values (Daniel et al. 2012). Economic valuations of cultural ecosystem services at present are partial and incomplete (Chan et al. 2012). Recently a few studies have analysed the spatial distribution of cultural ecosystem services on the basis of social perceptions and values (e.g. Brown and Raymond 2007; Sherrouse et al. 2011; Fagerholm et al. 2012; Klain and Chan 2012; Plieninger et al. 2013). Most of these studies have been performed at local scale and, therefore, the identification of cultural services hot-spots and associations between the cultural services (e.g. trade-offs and synergies) at regional scales remains understudied. Here, trade-offs and synergies can be understood as positive (e.g. synergy) and negative (e.g. trade-offs) associations between cultural ecosystem services that might result from common underpinning socio-ecological processes or as a response to common pressures (Bennett et al. 2009; Mouchet et al. 2014). Consequently, new methodological approaches are needed to quantify the social importance of cultural ecosystem services that are less reliant on economic metrics, and once these metrics are developed there is a need to analyse the spatial patterns of the cultural ecosystem services at regional scales. Global platforms of geo-tagged digital images, such as the Panoramio (www.panoramio.com), Flickr (www.flickr.com) or Google Earth (earth.google.com) web platforms, can be useful tools to map cultural ecosystem services at regional scales (Casalegno et al. 2013; Nahuelhual et al. 2013; Wood et al. 2013). Furthermore, the majority of the scientific research regarding cultural ecosystem services has been carried out in Europe and North America, while Asia, Africa, and Central and South America remain understudied (Hernández Morcillo et al. 2013; Milcu et al. 2013).

Although the knowledge of cultural ecosystem services is highly relevant for landscape sustainability, i.e. the capacity of landscapes to provide essential ecosystem services that contribute to human well-being in a regional context (Wu 2013), to date only two regional studies have been performed in Europe and South Africa (van Jaarsveld et al. 2005; Vila et al. 2010). In fact, to determine the relationships between landscape patterns, the provision of ecosystem services and the human perception and values of these services has been recognized as one of the challenges in landscape sustainability science (Musacchio 2013; Wu 2013). In this context, there is a need to develop a spatially explicit methodological approach able to map and quantify the social importance of cultural ecosystem services and the spatial associations among the cultural services at regional scale. The objectives of this research were to: (i) identify cultural ecosystem service hot-spots in a sparsely populated region, Southern Patagonia (Argentina), and (ii) identify factors that characterize such hot-spots as well as determine spatial associations between cultural ecosystem services. We specifically aimed to answer the following questions: (i) does the provision of different types of cultural services (e.g. aesthetic values, existence values, recreation and local identity) change across the landscape?; and (ii) which social and biophysical variables best explain the spatial distribution of each cultural ecosystem service, as well as their associations (e.g. synergies and trade-offs)?

Methods

Study area

The study was carried out in Southern Patagonia (46°00′ to 55°03′ SL, 63°47′ to 73°32′ WL), in Santa Cruz (243.9 thousand km^2) and Tierra del Fuego (21.3 thousand km^2) provinces (Argentina). Ice fields and the Andes mountains (N to S direction) define relief and climate in Santa Cruz province, generating a rainfall gradient from W to E. Vegetation types are dominated by the steppe and shrub-lands, where forests occupy a narrow fringe along the base of the mountains. Santa Cruz province has a population density of 1.3 inhabitants km^2 mainly in small towns and cities (n = 12), located on the sea shore or close to the mountains, except for a small town called Gobernador Gregores that is located in the middle of the province. National parks and provincial reserves mainly preserve forest at the foot of the Andes, however, some reserves were created to protect special heritage values (e.g. Bosque Petrificado national park), while others preserve unique biodiversity (e.g. Monte León national park and the Laguna de los Escarchados provincial reserve) (Fig. 1).

In Tierra del Fuego, the Andes Mountains runs from W to E, and also defines the relief and climate of the region, but here there is a major influence of the Antarctica. A rainfall gradient from N to S defines the vegetation types in Tierra del Fuego, with grasslands in the north and forests in the south. This province has a population density of 6.0 inhabitants km^2 mainly located in two cities (97.5 % of the total population), one close to ranching and oil extraction areas, and one close to major tourism area. National parks and provincial reserves mainly preserved the forests, despite another ecological or heritage values (Fig. 2).

Data sampling

The social and biophysical importance of cultural ecosystem service provision in different parts of the territory was measured through the quantification of geo-tagged digital images that local people and visitors posted on the Panoramio web platform, which is populated by an increasing number of users worldwide (Casalegno et al. 2013; Nahuelhual et al. 2013; Wood et al. 2013). Panoramio hosts photos focused on landscapes, natural features and animals in their natural environment (Panoramio 2013). Images that have as their central subject people, machines, vehicles or the interiors of structures, or that depict public events such as fairs or concerts, are usually excluded from the platform. The semantic content of Panoramio and Google Earth photographs has been interpreted to measure the aesthetic value provided by landscapes (Casalegno et al. 2013; Nahuelhual et al. 2013), as well these measurements have been made using the Flickr platform to quantify nature-based tourism and recreational activities (Wood et al. 2013). We further advanced in the cultural services research by interpreted Panoramio photographs to quantify and map the social and biophysical importance of four selected cultural services: (i) aesthetic value, (ii) existence value, (iii) recreation, and (iv) local identity.

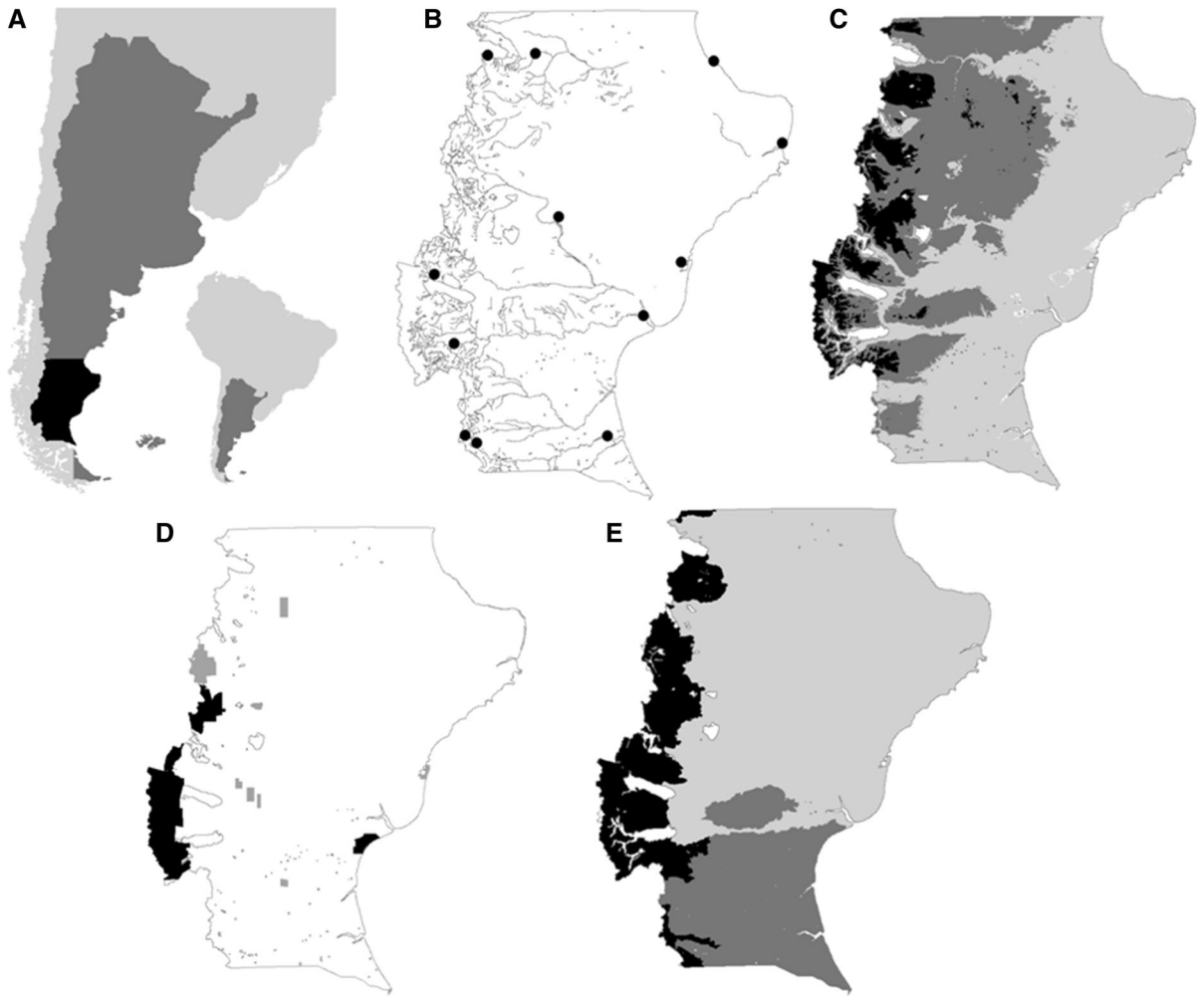

Fig. 1 Characterization of Santa Cruz province: **a** location (*black* Santa Cruz); **b** main cities (*black dots*) and main water bodies (coast, lakes, lagoons and rivers); **c** relief (*grey* 0–400 m.a.s.l., *dark grey* 400–1000 m.a.s.l., *black* >1000 m.a.s.l.); **d** protection areas (*grey* provincial reserves, *black* national parks); and **e** vegetation types (*grey* dry steppe, *dark grey* humid steppe and shrub-lands, *black* alpine vegetation and forests)

Santa Cruz and Tierra del Fuego were studied separately. Different size of sampling windows was defined for each province due to contrasting area: we used windows sizes of 14,600 ha for Santa Cruz and 3100 ha for Tierra del Fuego, resulting in 1668 sampling windows for Santa Cruz and 681 for Tierra del Fuego. Each window was characterized according to social and biophysical characteristics with potential to be determinant on people preferences. Three characteristics were defined in relation with the environment for each window: (i) presence of marine coasts, lakes, lagoons and rivers, (ii) vegetation types (forests, peat-lands, shrub-lands, grasslands, and alpine vegetation), and (iii) existence of national parks and provincial reserves. Two in relation with the human presence: (iv) presence of cities, towns or ranches, and (v) accessibility via quantification of national highways, provincial roads and rough paths (ranch and forest harvesting access roads). Finally, we quantified the (vi) tourism offer, as mass (package tours) and eco-tourism (off-road, adventure, bird watching and sport fishing) (Lacitignola et al. 2007), as it may influence on the possibility to reach different locations.

All photographs that appeared in the Panoramio web platform for each sampling window were

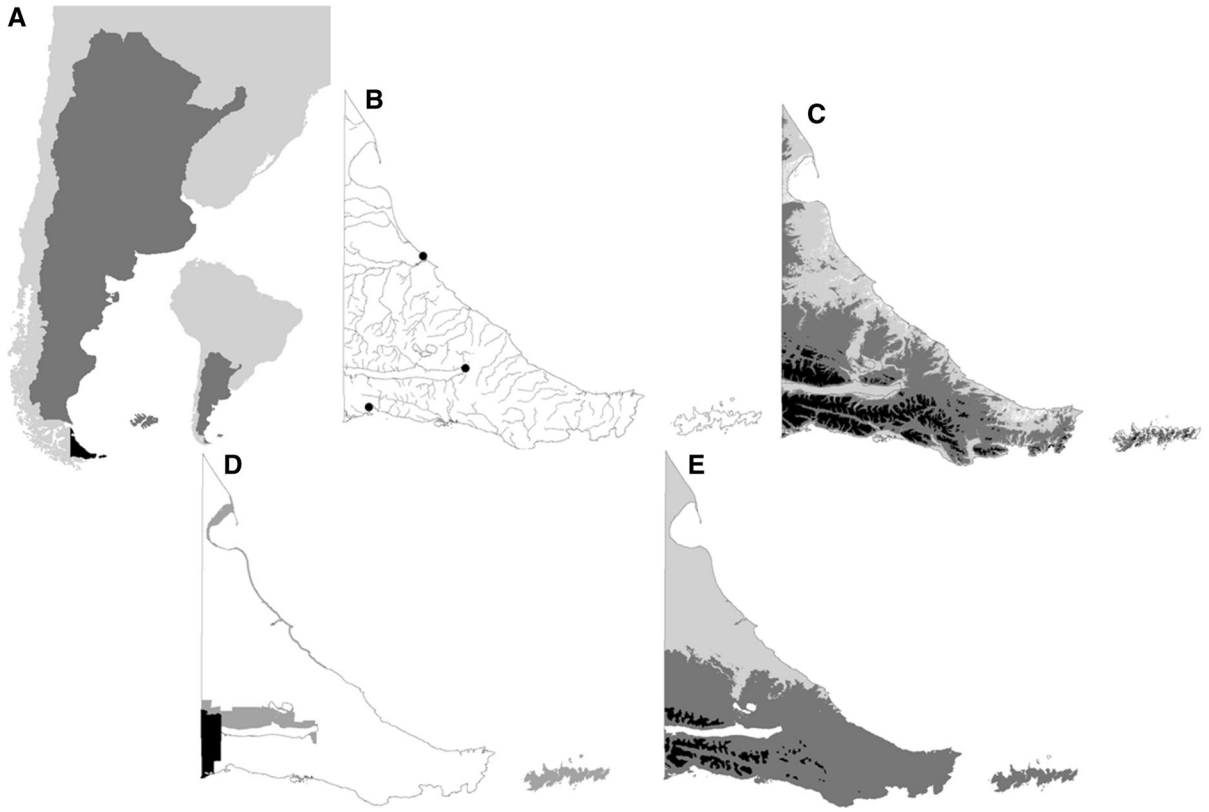

Fig. 2 Characterization of Tierra del Fuego province: **a** location (*black* Tierra del Fuego); **b** cities (*black dots*) and main water bodies (coast, lakes, lagoons and rivers); **c** relief (*grey* 0–100 m.a.s.l., *dark grey* 100–400 m.a.s.l., *black* >400 m.a.s.l.); **d** protection areas (*grey* provincial reserves, *black* national parks); and **e** vegetation types (*grey* grassland and shrub-land steppe, *dark grey Nothofagus* forests, *black* alpine vegetation)

included in the analysis. The photos were classified by two researchers according to the cultural ecosystem services that the photographer try to highlight: (i) aesthetic values, which included natural and urban landscapes; (ii) existence values, which included photos directly related to individual species of flora and fauna, both native and allochthonous; (iii) local identity, which included heritage, folklore, traditions, art and local workers (ranching, forestry, artisanal fishing, mining, and oil extraction); and (iv) recreational activity, which included winter sports, hiking, trekking, climbing, riding, camping, kayaking and sport fishing. We excluded from the analysis those photos that were: (i) geo-tagged incorrectly; (ii) included people or vehicles as the central subject; (iii) were taken in the interiors of structures; (iv) were obtained from planes; (v) taken in the sea and where the coast of mainland was not included.

Data analysis

The number of photos for each cultural service uploaded onto Panoramio was tallied for each analysis window and this data was recorded in a Geographic Information System (GIS). With this data and in order to deal with objective 1, hot-spots for each cultural service were defined by maps of each region (Santa Cruz and Tierra del Fuego). To assess which social and biophysical variables best explained the spatial distribution of each cultural service, and to highlight any synergies or trade-offs that might exist between the various cultural (objective 2) we ran multivariate analyses: (i) detrended correspondence analysis (DCA), and (ii) redundancy analysis (RDA). The number of photos for each cultural ecosystem service in each analysis window was log-transformed prior to each analysis in order to reduce heterocedasticity.

Table 1 Explanatory variables used in each analysis for detrended corresponded analysis (DCA), redundancy analysis (RDA) and logistic regression, and the source of information

Variables	Description	Analysis	Source of information
Mountains	Presence/Absence	Detrended correspondence analysis	Identification in Panoramio photographs by authors
Water bodies and rivers			
Vegetation			
Exotic fauna			
Terrestrial fauna			
Marine fauna			
Flora			
Anthropogenic assets			
Water	**Ordinal (0–4)**	**Redundancy analysis**	Satellite images and GIS layers
Sea-coast	Presence/Absence	Logistic regression	
Lake	Presence/Absence	Logistic regression	
Lagoon	Presence/Absence	Logistic regression	
River	Presence/Absence	Logistic regression	
Vegetation	**Ordinal (1–4)**	**Redundancy analysis**	Satellite images and GIS layers
Forest	Presence/Absence	Logistic regression	
Peat-lands	Presence/Absence	Logistic regression	
Shrub-lands	Presence/Absence	Logistic regression	
Grasslands	Presence/Absence	Logistic regression	
Alpine vegetation	Presence/Absence	Logistic regression	
Protected areas	**Ordinal (0–2)**	**Redundancy analysis**	GIS layers
National Parks	Presence/Absence	Logistic regression	
Provincial reserves	Presence/Absence	Logistic regression	
Urbanization	**Presence/Absence**	**Redundancy analysis**	Satellite images and GIS layers
Cities	Presence/Absence	Logistic regression	
Ranches	Presence/Absence	Logistic regression	
Accessibility	**Ordinal (0–3)**	**Redundancy analysis**	Satellite images and GIS layers
National routes	Presence/Absence	Logistic regression	
Provincial routes	Presence/Absence	Logistic regression	
Rough paths	Presence/Absence	Logistic regression	
Tourism facilities	**Ordinal (0-2)**	**Redundancy analysis**	Local tourism companies
Mass-tourism	Presence/Absence	Logistic regression	
Eco-tourism	Presence/Absence	Logistic regression	

In bold are presented the general biophysical factors

Table 1 presents the list of variables used in each analysis, their description and source.

DCA was conducted to determine the association between cultural ecosystem services and specific social and -biophysical characteristics that appeared in photographs: (i) presence of mountain landscapes due to both regions presented contrasting landscapes with or without this specific characteristic, (ii) presence of water bodies and rivers to analyse the hydrophilia phenomena (Bernáldez 1985), (iii) presence of vegetation to analyse the phytophilia phenomena (Ulrich 1986), (iv) presence of exotic fauna (e.g. beavers, grey foxes, rabbits, and domestic animals as cows, sheeps, dogs and horses), (v) presence of terrestrial native fauna, (vi) presence of marine native fauna, (vii) presence of flora, and (viii) presence of human infrastructure (e.g. cities, towns, ranches or buildings) to analyse the influence of human transformed landscapes. We split the fauna in exotic and native to determine the influence of invasive alien

species that greatly modifies the region which can influence or not over people perception of the ecosystem services (Estévez et al. 2015). DCA was selected because this ordination technique simultaneously analyses sampling units and variables, allowing the examination of interrelationships between them in a single-step analysis (Ludwig and Reynolds 1988). DCA analysis used a data matrix with the quantity of photos of each ES in each sampling window, without down weight for rare variables and with axis rescaling (Manly 1994). In this analysis, sampling windows that have comparable number of photos of each ecosystem services are likely to occur closer in multivariate space (Jongman et al. 1995). We used PC-Ord software for the DCA (McCune and Mefford 1999).

To assess the spatial relationships among cultural ecosystem service (e.g. aesthetic, existence, recreation, local identity), and between ES and the social and biophysical factors identified in GIS layers (e.g. existence of water, vegetation, urbanization, protected areas, accessibility and tourism offer) (Table 1), we performed another RDA. This analysis has been recently suggested as a proper statistical technique for identifying associations between ecosystem services (Mouchet et al. 2014). Due to lack of normality in the data the number of photos determined for each ecosystem service was log transformed prior to analyses. The significance of the explanatory variables in the explanation of the associations between cultural ecosystem services was tested with Monte Carlo permutation test with $=500$ permutations per analysis. The inertia of the factors, which represents the explained variance, was used to identify the most important social and biophysical factors determining the associations between cultural ecosystem services.

Finally, to identify which specific characteristics within the broad categories of social and biophysical factors (e.g. water, vegetation, protected areas, urban settlements, accessibility and tourism offer) determine the level of provision of each cultural ecosystem service, we carried out logistic regressions for both Santa Cruz and Tierra del Fuego. We transformed the four dependent variables (e.g. aesthetic values, existence values, recreation and local identity) into dichotomous variables according to presence or absence of each cultural ecosystem service. The explanatory variables are those presented in Table 1. The identification of relevant social and biophysical characteristics that determine the provision of each cultural ecosystem services were performed by applying stepwise forward model selection, and the model selection was done with the lowest Akaike information criterion (AIC) (Burham and Anderson 2002).

Results

Ecosystem services hot-spots

A total of 13,091 photos were analysed (5549 for Santa Cruz and 7542 for Tierra del Fuego). 5.8 % of the photos from Santa Cruz and 14.8 % of the photos from Tierra del Fuego were excluded from the analyses according to the selection criteria. Aesthetic value was the main cultural service tagged by people (81.6 % in Santa Cruz and 65.4 % in Tierra del Fuego), followed by the existence value (6.3 % in Santa Cruz and 13.0 % in Tierra del Fuego), recreation (3.7 % in Santa Cruz and 5.2 % in Tierra del Fuego), and local identity (2.5 % in Santa Cruz and 1.6 % in Tierra del Fuego) (Table 2). Spatial patterns of ES provision (hot-spots) for aesthetic values, local identity and existence values in both areas presented different patterns (Figs. 3 and 4), due to these services were more spatially clustered in Tierra del Fuego than in Santa Cruz. In this sense, while aesthetic value in Santa Cruz was related to national parks (e.g. Los Glaciares national park or Monte León national park) or cities (e.g. Puerto Deseado), in Tierra del Fuego it was related to mountain areas along the national route between Ushuaia and Tolhuin cities. Contrary, similar distribution was found for recreation services in both regions. The existence value of biodiversity was mostly found for people in Santa Cruz cities (e.g. El Calafate, El Chaltén and Puerto Deseado), while in Tierra del Fuego were found in the national park and excursions offered by mass tourist operators (e.g. Martillo and Los Lobos islands). Local identity was mainly related with cities (e.g. small cities as El Chaltén in Santa Cruz, or large cities in Tierra del Fuego as Ushuaia or Rio Grande), and areas with special cultural interest (e.g. Cueva de las Manos UNESCO World Heritage in Santa Cruz, and two ranches with historical shipwrecks, like San Pablo and Remolino in Tierra de Fuego). Finally, recreation was related to areas with winter sports practices in Tierra del Fuego, and areas of leisure for local inhabitants in Santa Cruz (e.g. El Calafate and Puerto San Julián).

Table 2 Number of average photographs for each sampling window representing the four cultural ecosystem services and the socio-biophysical characteristics identified in the photographs in Santa Cruz and Tierra del Fuego

	Santa Cruz	Tierra del Fuego
Cultural ecosystem services		
Aesthetic value	1.87 (0.41)	7.10 (1.39)
Existence value	0.21 (0.05)	1.44 (0.37)
Recreation	0.12 (0.02)	0.53 (0.12)
Local identity	0.14 (0.03)	0.30 (0.07)
Socio-biophysical characteristics		
Mountains	0.37 (0.21)	0.63 (0.16)
Water bodies and rivers	0.50 (0.11)	2.43 (0.39)
Vegetation	1.00 (0.22)	1.13 (0.21)
Exotic fauna	0.02 (0.01)	0.31 (0.08)
Terrestrial autochthonous fauna	0.07 (0.02)	0.15 (0.04)
Marine autochthonous fauna	0.07 (0.03)	0.56 (0.31)
Flora	0.05 (0.02)	0.42 (0.09)
Anthropogenic assets	0.85 (0.19)	3.10 (0.91)

Standard error is presented between brackets

Relationships between ecosystem services and social and biophysical characteristics

With DCA we could graphically correlate cultural ecosystem services with specific social and biophysical characteristics. In Santa Cruz, axis 1 (eigenvalue 0.3933, length of gradient 3.52) and axis 2 (eigenvalue 0.1704, length of gradient 3.63) presented a total variance of 1.662 (Fig. 5a). Aesthetic value was related with the presence of water, exotic fauna, vegetation communities and mountains; while existence value was closely related to local identity. Both services (existence value and local identity) were associated with the presence of flora, terrestrial autochthonous fauna and human buildings. In Tierra del Fuego, axis 1 (eigenvalue 0.3434, length of gradient 4.26) and axis 2 (eigenvalue 0.1503, length of gradient 3.97) presented a total variance of 1.318 (Fig. 5b). While aesthetic value occupied the centre of the graph, equally influenced by all the studied variables, the existence value was closely related to marine and terrestrial autochthonous fauna and recreation was associated with mountains. Finally, local identity was related to human buildings.

RDA produced a similar pattern to DCA, suggesting that our identification of social and biophysical features in photographs fitted with the information obtained from GIS layers (see Table 1 for information sources). 85.6 % of the variance in Santa Cruz (0.746 of total inertia and pseudo-F = 0.300 with $p < 0.001$) and 80.0 % of the variance in Tierra del Fuego (1.945 of total inertia and pseudo-F = 0.580 with $p < 0.001$) were explained with the two first axes of RDA (Table 3). In Santa Cruz, water, urbanization, protected areas and tourism offer significantly influenced aesthetic value and recreation services (first axis); while urbanization and tourism offer were associated with existence value and local identity (second axis). In Tierra del Fuego, water, urbanization, accessibility and tourism offer significantly influenced aesthetic, existence and recreational values (first axis); while vegetation types, protection areas, accessibility and tourism offer influenced local identity value (second axis). In both cases, there was a clear trade-off between local identity and existence values.

Water types greatly influenced the provision of cultural ecosystem services (Table 4). Aesthetic value presented higher values when pictures were taken close to marine coasts, lakes and rivers in both Santa Cruz and Tierra del Fuego. Similarly, the presence of sea coast, lakes and rivers positively influenced existence values, recreation and local identity in Santa Cruz, while in Tierra del Fuego only sea coast positively determined the provision of existence values and local identity (Table 4). Concerning vegetation, the influence of different vegetation communities differed in the provision of each of cultural ecosystem services. Existence values correlated positively with forests in both research sites. While forest positively influenced existence values in Santa Cruz, the other vegetation communities have a negative influence in the provision of cultural ecosystem

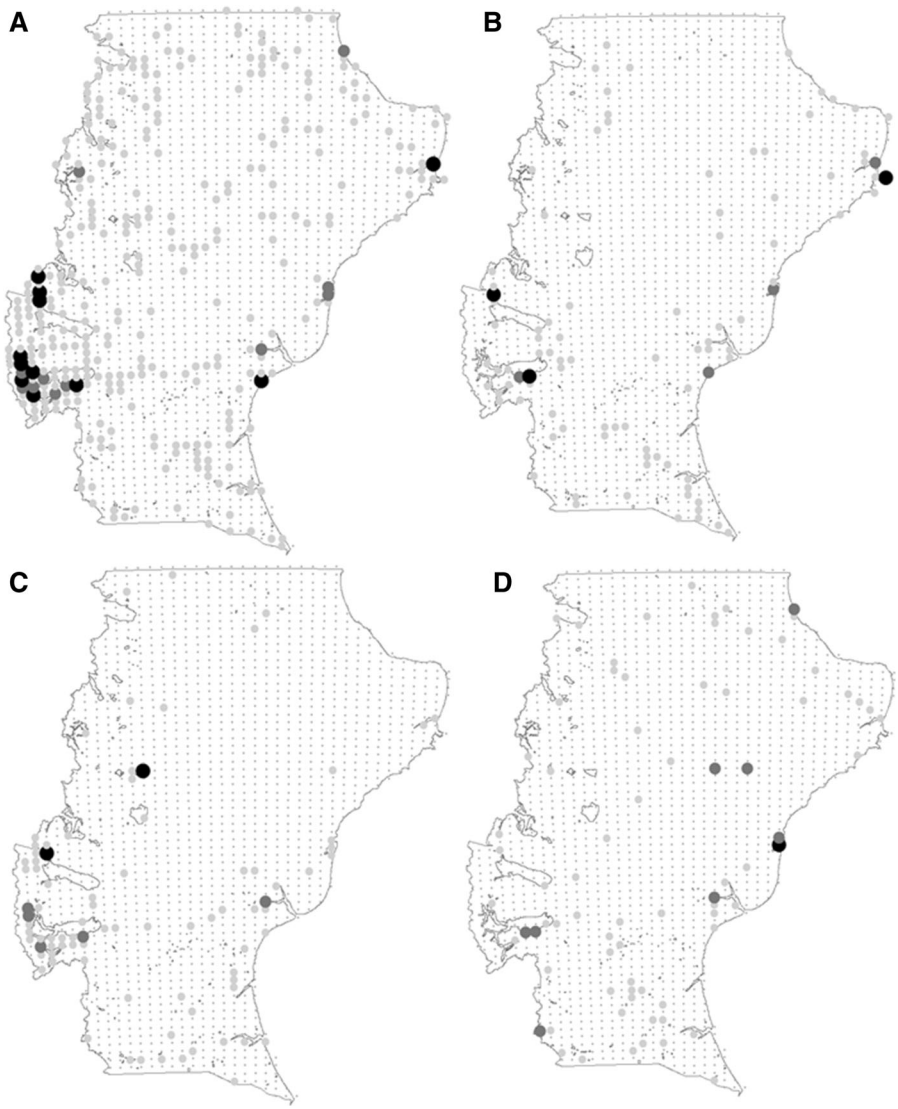

Fig. 3 Santa Cruz province hot-spots of cultural services defined by number of photos for each sampling point: **a** aesthetic value, **b** existence value, **c** local identity, **d** recreation. *Grey dots* represents 1–25 photos.windows^{-1} for **a**, 1–10 photos.windows^{-1} for **b**, and 1–5 photos.windows^{-1} for **c** and **d**; *dark grey dots* represents 26–50 photos.windows^{-1} for **a**, 11–25 photos.windows^{-1} for **b**, and 6–20 photos.windows^{-1} for **c** and **d**; and *black dots* represents >50 photos.windows^{-1} for **a**, >25 photos.windows^{-1} for **b**, and >20 photos.windows^{-1} for **c** and **d**

services: grasslands in aesthetic values and recreation, peat-lands in existence values and local identity, and shrub-lands in existence values (Table 4). In Tierra del Fuego, on the contrary, grasslands and alpine vegetation positively influenced the provision of local identity and recreation, respectively (Table 4).

The existence of protected areas did not have a consistent effect on the associations between cultural ecosystem services (Table 3). In Santa Cruz we did not detect a correlation between the existence of protected areas and the provision of cultural ecosystem services (Table 4). However in Tierra del Fuego the presence of national parks and provincial reserves was positively correlated with the provision of aesthetic values and recreation. Further, protected areas also correlated with existence values in Tierra del Fuego. Similarly, there was no effect between anthropogenic features of the landscape (urban settlements, main roads or tourism offer) and the provision of cultural ecosystem services in Santa Cruz, but anthropogenic features of the landscape were correlated with cultural ecosystem services in Tierra del Fuego, particularly the tourism offer. In fact, both mass tourism and eco-tourism positively affected the supply of all cultural ecosystem services. Finally, while ranches and national routes positively determined the provision of aesthetic and existence values, rough paths positively influenced the provision of local identity (Table 4).

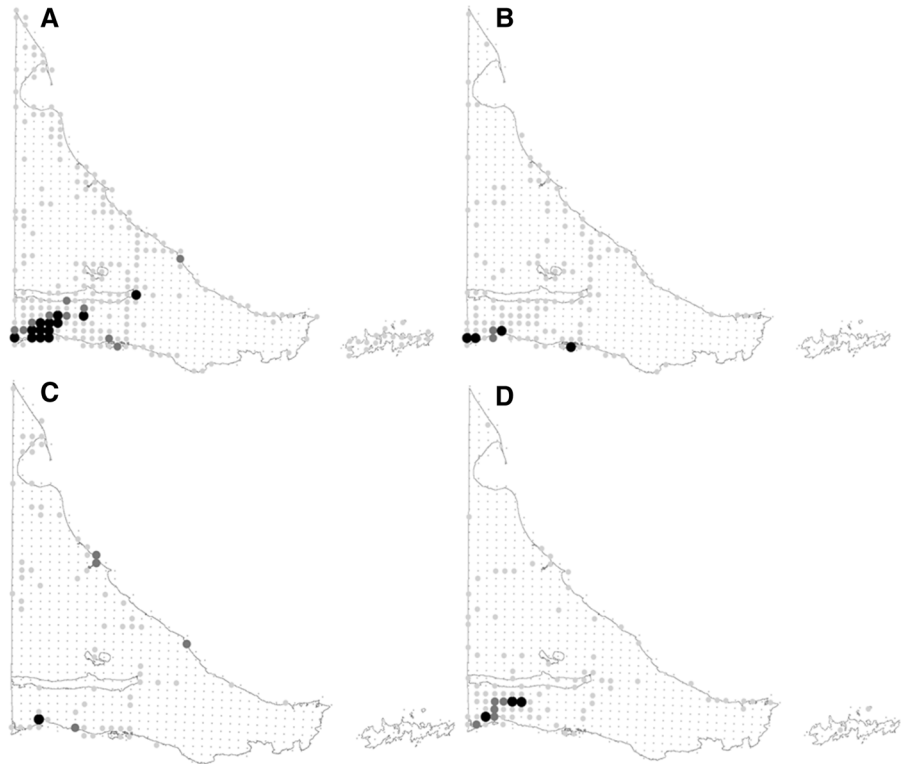

Fig. 4 Tierra del Fuego province hot-spots of cultural services defined by number of photos for each sampling point: **a** aesthetic value, **b** existence value, **c** local identity, **d** recreation. *Grey dots* represents 1–25 photos.windows^{-1} for **a** and **b**, and 1–10 photos.windows^{-1} for **c** and **d**; *dark grey dots* represents 26–50 photos.windows^{-1} for **a** and **b**, and 11–25 photos.windows^{-1} for **c** and **d**; and *black dots* represents >50 photos.windows^{-1} for **a** and **b**, and >25 photos.windows^{-1} for **c** and **d**

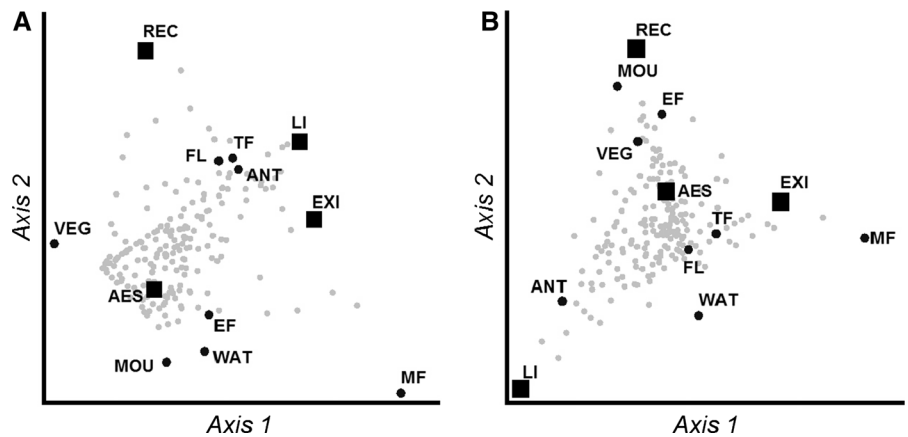

Fig. 5 Detrended correspondence analysis of cultural ecosystem services photographed and the associated socio-biophysical characteristics in Santa Cruz province (**a**) and Tierra del Fuego (**b**). Ecosystem services (*squared dots*): *AES* aesthetic value, *EXI* existence value, *LI* local identity, *REC* recreation. Biophysical characteristics (*circular dots*): *MOU* mountain landscapes, *WAT* water bodies and rivers, *VEG* vegetation communities, *EF* allochthonous fauna, *TF* terrestrial fauna, *MF* marine fauna, *FL* flora, *ANT* cities, towns, ranches or human buildings

Table 3 Factor loadings derived from the redundancy analysis (RDA) conducted for Santa Cruz and Tierra del Fuego study areas, showing the relationships between socio-biophysical characteristics and cultural ecosystem services photographed

	Santa Cruz		Tierra del Fuego	
	F1	F2	F1	F2
Socio-biophysical factors				
Water	0.199**	−0.016	0.290**	0.048
Vegetation	0.130	0.102	0.098	−0.150**
Protected areas	0.401**	0.131	0.111	0.106**
Urbanization	0.193**	−0.211**	0.420**	0.027
Accessibility	0.139	−0.115	0.280**	0.130**
Tourism offer	0.306**	−0.044**	0.617**	0.003**
Cultural ecosystem services				
Aesthetic value	2.619**	0.129	2.948**	0.113
Existence value	0.675	−0.230**	1.803**	−0.147
Recreation	0.595**	0.019	0.903**	−0.221
Local identity	0.461	−0.422**	0.626	0.210**
RDA statistics				
Eigenvalue	*0.413*	*0.078*	*0.846*	*0.139*
Variance (%)	*72.04*	*13.568*	*68.69*	*11.31*
% accumulated	*72.04*	*85.611*	*68.69*	*80.00*

Variables codification based on the number of types of each variable presented in the sampling windows. Water: sea coasts, lakes, lagoons or rivers (0–4). Vegetation: forest, peat-lands, shrub-lands or grasslands (1–4). Protected areas: national parks or provincial nature reserves (0–2). Urbanization: presence or absence (0–1). Accessibility: national routes, provincial routes or rough paths (0–3). Tourism offer: mass-tourism or eco-tourism (0–2)

Italic values indicate $p < 0.001$

** $p \leq 0.05$

Discussion

Contributions of social media data to cultural ecosystem services assessment

The difficulties of measuring cultural ecosystem services at regional scales (Hernández Morcillo et al. 2013) have hindered scientific progress towards understanding both the social demand and the social and biophysical factors that affect provision of cultural ES. Here, we demonstrate that using image data from social media platforms can help to identify places where people enjoy cultural ecosystem services. This study contributes to current literature on mapping cultural ecosystem services at regional scales (Casalegno et al. 2013; Nahuelhual et al. 2013; Wood et al. 2013) by assessing simultaneously four different cultural services (e.g. aesthetic value, existence value, recreation and local identity). Also, it was possible to identify which social and biophysical features are associated with the provision of the cultural ES and allows assessment of spatial trade-offs and synergies (Table 3). Furthermore, the technique used here allows for the identification of cultural ecosystem service hotspots in areas with little baseline information, e.g. Southern Patagonia in Argentina (Figs. 3 and 4). In addition, with this technique it was possible to determine which social and biophysical factors correlate with the provision of cultural ecosystem services. It may be possible to identify plausible future scenarios for cultural ecosystem services provision on the basis of changes in land-use, accessibility, changes in tourism enterprise, and infrastructure and management of protected areas. Finally, these social media platforms can be seen as a kind of citizen science for understanding spatial patterns and underlying drivers of cultural ecosystem services because these pictures are voluntarily uploaded. In this sense, they allow us to monitor the conditions and trends of cultural ecosystem services in the medium- and long-term.

In spite of these strengths remarked above, this method may be biased on the basis of who is taking

Table 4 Standard coefficients of the logistic regression models for identify which specific socio-biophysical features determine the presence of cultural ecosystem services in Santa Cruz and Tierra del Fuego

	Santa Cruz				Tierra del Fuego			
	Aesthetic value	Existence value	Recreation	Local identity	Aesthetic value	Existence value	Recreation	Local identity
Water								
Sea-coast	0.113***	0.199***	0.163***	0.138***	0.455***	0.189**		0.215**
Lake	0.242***	0.178***	0.244***	0.134**	0.312***			
Lagoon								
River	0.172***	0.194***	0.373***	0.257***	0.150*			
Vegetation								
Forest		0.160**				0.381***		
Peat-lands		−0.127*		−0.121				
Shrub-lands		−0.216**						
Grasslands	−0.195***		−0.185***					0.229*
Alpine vegetation							0.345***	
PA								
National parks					0.262***	0.295***	0.126*	
Provincial reserves					0.170**		0.139*	
Urban								
Cities								
Ranches					0.595***	0.310***		
Access								
National routes					0.206*	0.161*		
Provincial routes							−0.166*	
Rough paths								0.431***
Tourism								
Mass-tourism					0.515***	0.493***	0.246***	0.295***
Eco-tourism					0.318***	0.575***	0.288***	0.330***
Log-likelihood	1514.03	663.21	567.38	588.52	527.32	399.56	403.86	335.48
AIC	1524.03	677.21	577.38	599.53	547.32	415.56	417.87	347.48
Chi squared (Wald)	142.44***	65.24***	98.86***	31.17***	182.05***	139.27***	80.64***	80.11***
% of correct predictions	81.06	94.42	94.78	95.44	83.99	87.81	89.28	89.87

PA protected areas, *AIC* akaike information criteria

*** $p \leq 0.001$; ** $p \leq 0.01$; * $p \leq 0.05$

digital photographs and uploading them to Panoramio (Wood et al. 2013). This entails that those stakeholders without access to technology, either internet or digital cameras, are not represented in the sampled population and, therefore, their preferences towards cultural services are not registered. Although it has been previously demonstrated that social preferences towards cultural ecosystem services vary among stakeholder groups (Martín-López et al. 2009; Castro et al. 2011; Higuera et al. 2013; Zagarola et al. 2014), the current method aims to represent only the views and preferences of some stakeholders. Consequently, the representativeness of this method in terms of sampled population is less than other techniques used

for assessing cultural ecosystem services, such as interviews or questionnaires, although its spatial representativeness is broader as it can uncover the cultural services preferences in remote areas and at the regional scale. Probably, integration of data collected using different techniques and at different spatial scales (interviews and questionnaires at local scale and social media at regional scales) will be needed to develop a more complete understanding of the cultural ecosystem services. Besides their complementarity in terms of spatial scales, it is important to point out that the communication channel for collecting data is different: verbal language in interviews or questionnaires and pictures in social media. Here, photographs offer an innovative tool for assessing certain cultural ecosystem services that are quite challenging to appraise through verbal language, such as aesthetic and existence values. The use of photo-questionnaires as a way to determine the social importance of cultural ecosystem services has been recently applied (García-Llorente et al. 2012; López-Santiago et al. 2014; Milcu et al. 2014). Finally, the potential bias triggered by interviewers (Bateman et al. 2002) while collecting data through questionnaires and interviews certainly disappears with this method as people voluntarily upload photographs to social media platforms. However, to appraise the importance of cultural ecosystem services through the number of uploaded photographs entails an inherent bias related with the interpretation of pictures by researchers and with the capacity to photograph certain cultural services. For example, to identify sacred areas in pictures by researchers or to photograph traditions is quite challenging.

Social and biophysical factors determining the provision of cultural ecosystem services in Patagonia

Hot-spots in Southern Patagonia changed according to the particular cultural ecosystem service and the social and biophysical landscape characteristics that underpin their provision. In fact, to give a step forward on understanding the provision of cultural ecosystem services by demonstrating their linkages with ecological aspects and with social and biophysical landscape components is relevant in ecosystem services research because cultural services are the most influenced by the social-ecological context (Daniel et al. 2012). Concerning the effect of the presence of water bodies on cultural ecosystem services, our results are consistent with previous studies as there is a positive effect of water on aesthetic values (Bernáldez 1985; García-Llorente et al. 2012) and recreation (e.g. fishing, sailing and canoeing) (Termansen et al. 2004; Abildtrup et al. 2013). However, this study advances the knowledge regarding the effect of water bodies on cultural ecosystem services by demonstrating a differential effect. Although lakes and marine coasts have a positive effect on aesthetic and existence values, they also positively influenced recreation and local identity in Santa Cruz whereas in Tierra del Fuego water bodies local identity was the only cultural ES associated with water (coastline) (Table 4). While rivers are also positively associated with all cultural ecosystem services in Santa Cruz, they only influenced aesthetic values in Tierra del Fuego (Table 4). This can be explained because Santa Cruz is drier than Tierra del Fuego and thus water, because of its scarcity is critical to quality of life in the sub region.

The positive effect of vegetation on social preferences towards cultural services can be interpreted as an expression of phytophilia (Ulrich 1986; García-Llorente et al. 2012; López-Santiago et al. 2014), which is the phenomenon of people generally preferring green and forested views over arid landscapes (DeLucio and Múgica 1994). The phytophilia phenomena has an influence in Patagonia as forests are important in determining the enjoyment of existence values in both regions and alpine vegetation determines recreation activities in Tierra del Fuego (Table 4). It is also remarkable that grasslands positively influenced local identity in Tierra del Fuego because many of the human activities were related to ranching (Table 4).

The presence of specific anthropogenic assets also explained the provision of cultural services (Table 3). Several studies have shown that respondents identified some cultural ecosystem services closely related with anthropogenic landscapes (Lamarque et al. 2011; Casado-Arzuaga et al. 2013). In regions where humans are scarce such as Southern Patagonia, visitors appreciate signs of civilization. Indeed, ranches were positively associated with aesthetic values in Tierra del Fuego (Table 4). Southern Patagonia is visited by a large number of tourists, although, only eco- and mass-tourism offer influence the provision of all cultural ecosystem services in Tierra del Fuego (Table 4). While mass-tourism is determined mainly

by accommodation and entertainment facilities, ecotourism is defined as responsible travel to areas with relatively high degree of natural values, which might sustain biodiversity and wellbeing of local people (Lacitignola et al. 2007). In addition, the accessibility in Tierra del Fuego is crucial for the cultural services (Tables 3 and 4). In our study, many areas still remain unknown and remote due to the lack of access (e.g. inland of the eastern part of Tierra del Fuego) and therefore people are not able to perceive the cultural services of those remote areas. As previously mentioned, the influence of accessibility highlights the relevance of socio-economic and cultural aspects when assessing cultural ecosystem services (Daniel et al. 2012). Previous studies have demonstrated that cultural ecosystem services are correlated with the accessibility to the areas (Abildtrup et al. 2013; Sen et al. 2014; Richards and Friess 2015). Protected areas influenced the perception of cultural ecosystem services in Southern Patagonia (Table 3), being exceptional in Tierra del Fuego as national park and provincial reserves positively influenced the distribution of aesthetic and existence values (Table 4), and probably for this reason, during the last years, governments created several new provincial reserves in Patagonia.

The provision of cultural ecosystem services in Santa Cruz and Tierra del Fuego presented some similarities, but generally showed different relationships with the landscape social and biophysical characteristics. In both provinces, aesthetic values were related to the natural ecosystems, where fauna and flora can be easily accessed. However in Santa Cruz, it was also related to water bodies and mountains because people preferred those landscapes in comparison with the dry steppe (Fig. 5). As it was expected, the existence value was related to flora and terrestrial fauna in Santa Cruz, while in Tierra del Fuego it was related to terrestrial and marine fauna. This study also pointed out the fact that, in contrast to previous studies (e.g. Raymond et al. 2009; Martín-López et al. 2012; Casado-Arzuaga et al. 2013), people perceived more important the aesthetic values than existence value or recreation service. However, this result could be related with the particularities of Patagonia landscapes. In fact, aesthetic value has been recently found as the only relevant cultural service for local communities and environmental professionals in Patagonia (Zagarola et al. 2014). The fact that recreation service was mostly important in mountain areas of Tierra del Fuego and that local identity was the cultural services least valued is also consistent with Zagarola et al. (2014).

Concluding remarks

To assess cultural ecosystem services and to determine how landscape features determine their provision at regional scales are still one of the remaining scientific questions in ecosystem services research (Hernández Morcillo et al. 2013; Milcu et al. 2013) and landscape sustainability science (Musacchio 2013; Wu 2013). The innovative methodology presented in this study has allowed us to identify hot-spots for different cultural ecosystem services (Figs. 3 and 4), the spatial trade-offs and synergies among them (Table 3) and the social and biophysical features of landscapes that determine their provision (Fig. 5). Therefore, this study seeks to draw attention in both scientific communities, i.e. ecosystem services and landscape sustainability by addressing three of their challenges: (i) to explore the cultural dimension of landscapes and ecosystem services (Musacchio 2013), (ii) to understand how important are cultural ecosystem services for people (Potschin and Haines-Young 2013) and (iii) to develop and operationalize a novel and innovative method (Wu 2013), which is able to uncover the social importance of cultural ecosystem services at regional scale.

Although this methodology has limitations related to the availability of uploaded photographs in social media platforms, it has several strengths for cultural ecosystem services assessment. Among its advantages, it offers complementary information to traditional assessment tools (e.g. questionnaires and interviews) which use visual language as a communication channel. In this way, it offers the opportunity to asses certain cultural ecosystem services that are challenging to appraise with oral language, such as aesthetic values. Further, as this method is based on the pictures people upload to social media platforms, it can be seen as a type of citizen science able to advance knowledge in cultural ecosystem services and contribute to landscape planning. First, as this technique can be simultaneously applied in many places, it allows identification of the key social and biophysical landscape features that provide multiple cultural

ecosystem services. Indeed, the present application of the method has demonstrated that cultural ecosystem services are associated with the presence of water bodies, vegetation types, marine and terrestrial fauna, protected areas, urbanization, accessibility and tourism offer in Southern Patagonia. Second, because people often indicate the exact date when the photo has been taken, it could be used for identifying temporal trade-offs of cultural ecosystem services through the analysis of the historical changes of the social and biophysical landscape features that explain each of the services. Moreover, future research could be able to monitor the trends of social preferences towards cultural ecosystem services. Lastly, by proposing a proper protocol for uploading pictures which incorporate the reasons why people photograph certain landscapes or species, researchers will be able to investigate the motivations and values underpinning the demand of cultural ecosystem services.

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