Ambio
https://doi.org/10.1007/s13280-019-01268-w

RESEARCH ARTICLE

Using social media images to assess ecosystem services in a remote protected area in the Argentinean Andes

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Received: 10 May 2019 / Revised: 4 September 2019 / Accepted: 19 September 2019

Abstract Social media images are a novel source of data to assess how people view and value the environment. Access to these images is often free, the volume and spread of images is expanding rapidly and hence they are an increasingly valuable source of data complementing and expanding on other data. Recently, coding images has been used to assess sociocultural values relating to ecosystem services including those provided by national parks. To further explore the use of social media images, including for remote environments, we analysed the content of images posted to Flickr by people visiting a national park that contains the highest mountain in the southern hemisphere, Mt. Aconcagua, in Argentina, South America. The saliency of aesthetic landscapes, recreation, social relations and fresh-water provisioning was high across the 334 images posted to Flickr by 104 visitors to the Park, but location mattered. Images from visitors in easily accessible day-use areas were significantly more likely to include content that reflects biodiversity-existence, geology, culture and education services, while the content of images from remote areas was more likely to reflect social relations and fresh-water provision services. Comparisons of the content of images from Mt. Aconcagua with other studies in Europe, South America, Asia, Africa and Australia highlight similarities and differences in people's views of the diversity of locations, but also the benefits and limitations of user-generated social media content when assessing environmental and management issues.

Keywords Aconcagua Provincial Park · Content analysis · Cultural ecosystem services · Flickr · Social media

INTRODUCTION

Nature, including in national parks, provides a myriad of ecosystem services to humans (Costanza et al. 1997; Millennium Ecosystem Assessment 2005). These include provisioning (e.g. fresh water, food, raw material, genetic resources), regulating and maintaining (e.g. climate, water quality, erosion, pollination, soil formation, nutrient cycling, primary productivity, biodiversity) and cultural ecosystem services (e.g. recreation and tourism, aesthetics, education and research, spiritual and religious, and cultural identity) (Millennium Ecosystem Assessment 2005; Stolton and Dudley 2014; Haines-Young and Potschin 2017).

Mountain areas provide many of these services and account for 32% of all protected areas globally (Grêt-Regamey et al. 2012; World Commission on Protected Areas 2019). They are the source of the worlds' major rivers and play a critical role in water cycles by capturing moisture from the air, storing it as snow or ice providing water for agriculture, communities and industries downstream (Hamilton and McMillan 2004; Grêt-Regamey et al. 2012). Mountains are also important centres of biological diversity, providing refuge for many rare and endemic plants and animals, and conserving rich assemblages of species and ecosystems (Hamilton and McMillan 2004). Many contain sites of great cultural, sacred or spiritual significance (Bernbaum 2006) and are often popular tourism and recreation destinations (Debarbieux et al. 2014). Despite this, research on mountain parks, including the ecosystem services they provide and how these are valued by visitors, is sparse, particularly for remote areas where research, monitoring and management is often limited both by resources and capacity (Hamilton and McMillan 2004; Grêt-Regamey et al. 2012).

Published online: 12 October 2019

An increasingly important challenge for the management of mountain parks is assessing how visitors view and value these environments including the ecosystem services they provide (Martinez Pastur et al. 2015; Richards and Friess 2015; Leung et al. 2018; Oteros-Rozas et al. 2018). Previously, data on the views and values of visitors to parks have been collected using surveys, choice experiments, community consultation and focus groups, among others (Newsome et al. 2012; Stolton and Dudley 2014). More recently, data from social media have been used to address important environmental and management questions (Ghermandi and Sinclair 2019), including identifying how visitors view and value natural environments and potential ecosystem services (Oteros-Rozas et al. 2018; Teles da Mota and Pickering 2018; Rosário et al. 2019).

Social media data have been used to assess the relative popularity of different parks (Wood et al. 2013; Tenkanen et al. 2017), as well as spatial and temporal patterns of visitor use (Norman and Pickering 2017; Walden-Schreiner et al. 2018; Norman et al. 2019). Recently, researchers have started using social media data to evaluate how people value natural environments (Calcagni et al. 2019; Ghermandi and Sinclair 2019). Much of this research leverages data from the image-sharing platform Flickr (Calcagni et al. 2019; Ghermandi and Sinclair 2019). For instance, data from Flickr were used to assess spatial patterns of ecosystem services in different landscapes based on where images were taken (Martinez Pastur et al. 2015; Van Zanten et al. 2016; Langemeyer et al. 2018). Studies have also started to analyse the content of image to gauge how people value natural environments (Richards and Friess 2015; Thiagarajah et al. 2015; Angradi et al. 2018; Hausmann et al. 2018), agricultural landscapes in Europe (Oteros-Rozas et al. 2018; Tieskens et al. 2018) and countries (Stephchenkova and Zhan 2013; Richards and Tunçer 2018).

Although analysis of user-generated content from social media is still a novel approach for addressing environmental and management issues (Sherren et al. 2017), it has already provided important insights, particularly in Europe and North America. Yet, research from South America is limited (Calcagni et al. 2019; Ghermandi and Sinclair 2019). The few studies from the region include Martinez Pastur et al. (2015) who conducted a spatial analysis of cultural ecosystem services in southern Patagonia using the text and location of images posted on the image-sharing platform Panoramio. They found that aesthetic, existence, local identity and recreational values were common in text, while locations with water bodies and tourism opportunities were important based on the geolocation of images. Martinez-Harms et al. (2018) used geolocated images from Flickr to assess visitor use (i.e. photo user days) of 65 parks in Chile and compared the results with visitor numbers for 32 of the parks. They assessed the effects of distances and social inequality on visitation rates using the Flickr users' home-location, obtained from users' public-profiles, and local-government socioeconomic data. Results indicated that people from lower socioeconomic areas tended to visit parks closer to them, while people from wealthier areas travelled further. Walden-Schreiner et al. (2018) used geolocated images for Aconcagua Provincial Park, in Argentina, to look at temporal and spatial patterns of use. This paucity of research using social media data in South America also reflects the broader issue of a dearth of research on monitoring and managing park-visitors in the region compared to Europe and North America (Barros et al. 2015a; Pickering et al. 2018a).

To further evaluate how social media data can be used to assess how people view and value natural environments, we analysed user-generated content created by visitors to the highest mountain in the southern hemisphere, Mt. Aconcagua in Argentina. The content of images posted to Flickr by visitors to Aconcagua Provincial Park was used: (1) to assess the relative popularity of different aspects of the Park, and how they relate to ecosystem services, and (2) how the content of the images differs between the easily accessible day-use areas and the more remote areas of the Park that are only accessible to adventure-based tourists. Research has shown that the activities, values and attitudes of day-use visitors to parks can differ from those of adventure-based tourists who access more remote areas, with important implications for management (Buckley 2006; Abbe and Manning 2007; Pierce and Manning 2015). We also compared the results from Aconcagua Provincial Park with those from 12 other locations where the content of images from Flickr has also been used to assess visitor views and values and associated ecosystem services.

MATERIALS AND METHODS

Study area

This study assessed images from Aconcagua Provincial Park (~ 700 km^2), an IUCN Category II protected area in Argentina containing Mt. Aconcagua (6962 m a.s.l.). The Park has high aesthetic, conservation, biodiversity and cultural values and is the major water catchment in the region providing drinking water and irrigation to over one million people. However, monitoring and management of the Park is severely limited by resources and research capacity (Barros et al. 2015a).

As the Park is easily accessible from the international highway linking Mendoza in Argentina, with Santiago in Chile, it is relatively popular with approximately 41 000 visitors during summer (Barros et al. 2015a). Most visitors spend less than a day in the Park (35 000 people), going on short walks or sightseeing in the Horcones Valley. This valley is the main entrance to the Park and has a range of infrastructure including a short public road, carparks, visitor centre, self-guided 2-km circuit trail, paleontological and archaeological sites and a park ranger station with helicopter pad (Barros et al. 2015a; Walden-Schreiner et al. 2018) (Table 1; Fig. 1). In addition, about 6000 people in summer access more remote areas of the Park on multi-day trips, including attempting to summit Mt. Aconcagua (15–20 day trip) (Barros et al. 2015b). During autumn, winter and spring, remote areas of the Park are closed and visitation is limited to the day-use areas of the Horcones Valley, including the visitor centre and short walks. Previous research using geolocated images from Flickr found that most images were taken during summer on trails, at campsites, or at buildings such as the visitor centre, with very few images taken in winter, and they were almost exclusively in the Horcones Valley (Walden-Schreiner et al. 2018).

Content analysis of images

Data were obtained from the popular social media platform Flickr, which has over 65 million users, and over 10 billion publicly available images on the platform (Smith 2018). Flickr's Application Programming Interface (API) and an R script were used to retrieve metadata for publicly available geotagged images taken in the Park between November 2010 and July 2018. Metadata leveraged in this analysis included when the image was taken, when it was uploaded to Flickr, owner ID, number of views, image URL, camera type and geolocation where the image was taken (i.e. longitude and latitude). Data were written to a comma-separated values (csv) file and imported into Excel for analysis.

Before analysing the content of images, the total number of images per visitor were capped. Specifically, the 10 most-viewed images per user were selected. This was done to ensure that results did not over-represent the views and values of prolific posters of images from the Park. Then images were divided into those taken within day-use areas of the Park or the remote areas using ArcGIS (version 10.5) combined with management zonation GIS layers for the Park. Images were also reviewed to ensure they were taken in the Park, that they were still publicly available on Flickr and that they were not duplicates posted by the same visitor. The final 334 geolocated images (Fig. 1) were then viewed online using the image URL from the metadata and their content classified by one person using variables

Table 1 Important natural, cultural, tourism and recreational features within the day-use and remote areas of Aconcagua Provincial Park, Argentina

Feature	Day-use areas	Remote areas
Visitor centre	Permits, toilets and interpretive material	–
Interpretative trail	2 km trail exploring natural and historic features	–
Historic buildings	3 (Puente del Inca Hotel Ruin, Crucified-Christ in Park entry, Hanging Wooden Bridge)	5 (Incas Ruin, Ibañez Refuge, Colombia Refuge Ruin, Hotel Plaza de Mulas, Berlin Refuge)
Lakes	Two lakes (Horcones and Espejo)	Two glacier lakes near Plaza de Mulas Campsite
River	Two rivers (Horcones and Vacas)	Four rivers (Horcones, Horcones Superior, Horcones Inferior, Vacas) with trails next to and crossing the rivers, also glacial feed streams and springs
Glaciers	1 Visible glacier of 6 km^2 from day-use area (Horcones Inferior Glacier)	242 Glaciers, total surface area of 82 km^2
Alpine meadows	10 Meadows. Total surface area of 0.10 km^2	40 Meadows. Total surface area of 0.43 km^2
Distinctive rock formation	Erratic-blocks, coloured-sedimentary formation, fossil shells incrusted in big rock	Coloured-sedimentary formation of Aconcagua west face, landslides, iconic formations that climbers clearly identify and use as meeting/resting points
Campsites and park rangers	Basic-campsite next to car-park and the park rangers station including helicopter and rescue facilities	Seven campsites and three park ranger stations on Horcones route and five campsites and three park ranger stations on Vacas route to summit
Recreation activities and services	Includes trekking, walking, birdwatching, picnic, sightseeing and helicopter use to move rangers and medical emergencies	Trekking and climbing, medical service, rescue patrols, art gallery at 4300 m a.s.l. and helicopters used to move rangers and for medical emergencies
Traditional cultural activities	Muleteers (mule/horse riders)	
Native flora	120 Species	
Native fauna	60 Bird species and 11 mammals including puma, condor (*Vultur gryphus*), zorro colorado (*Lycalopex culpaeus*) and lamas (*Lama guanicoe*)	

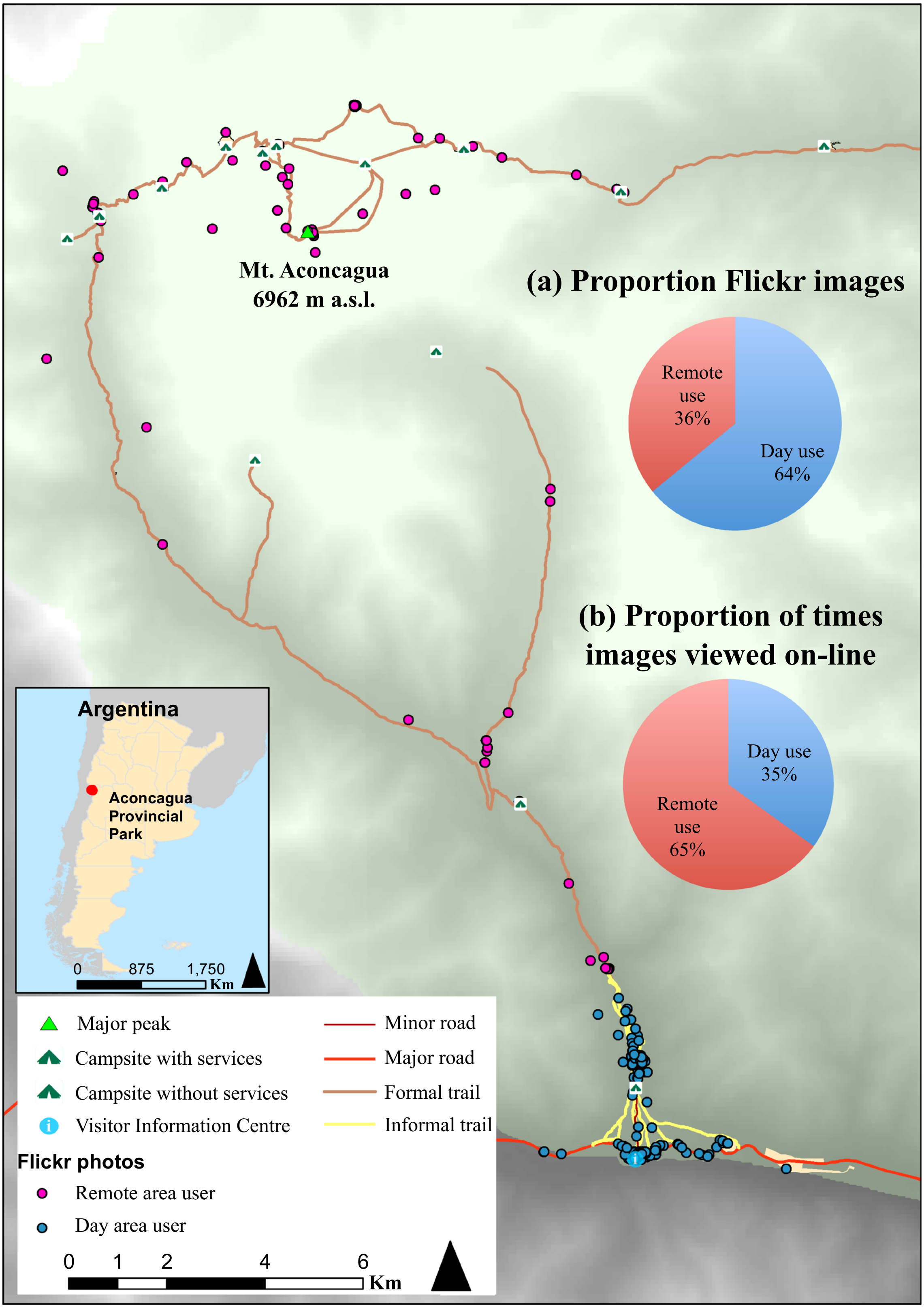

Fig. 1 Aconcagua Provincial Park in Argentina showing location of images from Flickr taken in the day-use area and remote areas of the Park. More images were taken within day-use areas than in remote areas (**a**), but images from remote areas were more popular online (**b**)

reflecting features such as landscapes and geology, number of people, activities, infrastructure, flora and fauna, using a quantitative metonymic approach, where the features or attributes in the image were classified based on their apparent content (Stephchenkova and Zhan 2013; Sherren et al. 2017). Using this approach, it was then possible to statistically compare the content of images taken in the day-use area—Horcones Valley—with those taken in more remote areas of the Park. Each image could represent multiple categories, so an image taken in summer, that included the main summit, glaciers and four hikers on the side of a trail looking at a camera represented nine categories including: summer, aesthetic, mountain range, glacier, people present, number of people, trails, looking at camera and activity (e.g. hiking and resting). Data for specific variables including landscape, snow, storm, sunny, mammals, birds, native flora, mountains, boulder, lake, river, creek, glacier, hotel, railway, mules, walking, horse riding, birdwatching, among others were then combined to calculate the number of images that had content relating to different types of ecosystem services in the Park (Table 2). This was done using criteria/categories from previous studies with similar aims (Martinez Pastur et al. 2015; Richards and Friess 2015; Oteros-Rozas et al. 2018), which were then slightly adjusted to reflect specific aspects of the natural environment of the Park, and hence the types of ecosystem services that it may provide.

To assess relationships among variables, exploratory Categorical Principal Component Analyses (CATPCA) were performed in the statistical software SPSS (version 25). The CATPCA analysis is analogous to Principal Component Analysis (PCA), except that it is suitable for categorical variables (i.e. nominal or ordinal) and non-linear relationships. In CATPCA, variable categories are transformed into numerical values and analysed as conventional linear PCA (Linting, et al. 2007). Differences in the image content from the day-use and remote-use areas of the Park were also statistically tested using χ^2 and ANOVA tests at 95% confidence intervals. Results from Aconcagua Provincial Park were then compared with results from 12 other locations where the content of Flickr images has also been analysed to assess potential ecosystem services using similar methodology.

RESULTS

There were 902 publicly shared geolocated images taken in the Park and posted to Flickr by 111 visitors (Table 3). Of these, most visitors (77%) uploaded less than five images, with half of the visitors uploading only one image. Six visitors uploaded more than 30 images, including 1 person who uploaded 151 images from the Park. After capping the number of images per visitor at 10 and confirming that the content of the images was within the Park, 334 images posted by 104 visitors remained for further coding. On average, these images were viewed 287 times each (SD ± 830) with a total 95 899 views (Table 3). Most of the images were taken in summer (64%), or autumn (21%), with few images in winter (4%) or spring (11%). Those posting the images to Flickr about the Park tended to use dedicated digital cameras (78%), although some (22%) used mobile phones with cameras. The average number of images of the Park per year was 37, with a minimum of 5 taken in 2010 and a maximum of 72 in 2012.

Natural landscapes appeared in many images (62%), including mountains (39%) and glaciers (43%) (Table 4). In contrast, there were few images of specific plants,

Table 2 The types of ecosystem services relating to the specific types of content of images on Flickr taken in Aconcagua Provincial Park, Argentina

Ecosystem service	Definition	Examples in Aconcagua
Aesthetic	Sites of particular beauty	Natural landscapes
Existence/biodiversity	The intrinsic value of nature and biodiversity. Belief that all species are worth protecting regardless of their utility	Fauna and flora, alpine meadows
Provision: geological		Distinctive/iconic rock formations
Provision: fresh water		Snow on ground, rivers, lakes, alpine meadows, glaciers
Culture and heritage	Sites relevant to local history and culture	Historic buildings, historic railways, folk-muleteers, mules
Recreation	Outdoor recreational activities	Activities: trekking, walking, birdwatching, sightseeing, camping, climbing
	Tourism and recreational infrastructure	Infrastructure: visitor centre, trails, campsites, tents, refuges
Education	Sites that widen the knowledge about plants and animal species	Information signs, visitor centre, interpretative trails
Social relations	Sites serving as meeting points with people/ friends	Hotel Plaza de Mulas, Campsites, visitor centre, tents, refuge and selfies and group photos

Table 3 Number of geotagged images taken in Aconcagua Provincial Park, Argentina and uploaded to Flickr between November 2010 and July 2018. To avoid bias, images were capped at a maximum of 10 per visitor

	Total	Analysed	Day-use	Remote	Summer	Autumn	Winter	Spring
Number of images	902	334	214 (64%)	120 (36%)	214 (64%)	69 (21%)	14 (4%)	37 (11%)
Number of visitors[a]	111	104	79 (76%)	33 (32%)	60 (58%)	28 (27%)	10 (10%)	16 (15%)
Total views	216 066	95 899	33 535	62 364	79 458	7670	2201	6570
Average views per image (min–max)	240 (0–6399)	287 (0–6399)	157	520	371	111	157	178
Average images per visitor	8	3	3	4	4	2	1	2

[a]Percentages and number of visitors when divided into categories can add up to over 100% and sum up to over 104 as some visitors posted images from both day-use and remote areas of the Park and took images in different seasons

animals or buildings and cultural features such as the visitor centre, park entrances, or ranger facilities. Ecosystem services associated with the content of the images included aesthetic (87%), fresh-water provisioning (65%) and recreation and tourism activities (64%). Although the Park is known for high biodiversity and significant cultural and geological values, images with content related to biodiversity (20%), cultural heritage (11%) and iconic geological features (11%) were not common (Table 4).

There were differences in the content of images between the day-use and remote areas of the Park (Table 4; Figs. 2, 3), reflecting variation in the locations and how they are valued by visitors (Table 1). For instance, images in the day-use areas were more likely to include content relating to biodiversity-existence, geology and education ecosystem services (Fig. 3). They were also more likely to focus on features such as the single peak of Mt. Aconcagua, historical structures, recreational trails and activities including walking and birdwatching. In contrast, images from remote areas were more likely to contain content relating to social relations and fresh-water provisioning ecosystem services (Fig. 3). For example, images were more likely to show mountain ranges, glaciers, rivers, campsites, tents and people looking directly at the camera (Table 4).

DISCUSSION

Images from Aconcagua Provincial Park posted on Flickr represent many of the places, objects and experiences valued by visitors and reflected what some visitors share publicly. This study adds to the emerging literature about how images and texts from social media expand the types of data available to assess visitors' views and values of natural environments, including in parks. This includes how image content can relate to potential ecosystem services (Calcagni et al. 2019; Ghermandi and Sinclair 2019), especially for regions where other data-sources are limited (Barros et al. 2015a; Pickering et al. 2018a).

Differences in visitors' views and content relating to ecosystem services in Aconcagua Provincial Park

The differences between the images taken in Aconcagua Provincial Park within day-use and remote areas are likely to reflect differences in what can be seen in these areas, what can be visualized/interpreted from the content of the images and potential differences in what visitors to the two areas value. Other studies have also found spatial differences in potential ecosystem services based on image content analysis (Stephchenkova and Zhan 2013; Richards and Friess 2015; Oteros-Rozas et al. 2018; Richards and Tunçer 2018; Clemente et al. 2019).

Although services, including recreation, were equally important in both day-use and remote areas of Aconcagua, the types of recreation activities differed. Walking was more common in day-use areas and camping was only captured in images from remote areas. Interestingly, some other activities were rarely shown in images including climbing, despite many visitors to remote areas attempting to summit Mt. Aconcagua. Some features were location specific. For example, education services were represented by images of historic buildings, the visitor centre, interpretive trails, the main summit view point, and other interpretive signs, and these features were nearly entirely restricted to the day-use areas.

There were few images from Aconcagua Provincial Park of animals in either the day-use or remote areas. The few animal images were of introduced mammals, specifically mules and hares. The absence of native mammals in images may be because guanaco (*Lama guanicoe*), zorro colorado (*Lycalopex culpaeus*), puma and other species avoid areas used by visitors (Barros et al. 2015b). Furthermore, although the Park has over 90 species of birds, there were very few images of the iconic Andean condor or other large birds, probably due to the difficulties in photographing them. Where there were images of birds, they were mostly small birds that nest on the ground, close to campsites.

Table 4 Results of the content analysis including potential ecosystem services represented in images taken by visitors to Aconcagua Provincial Park, Argentina. Clear = χ^2 test could not be applied, due to small numbers in one of the cells, but differences between day-use and remote-use areas were clear

Content of images	Total $n = 334$	Day-use area $n = 214$	Remote area $n = 120$	χ^2 Tests
Ecosystem services related to the content of images				
Aesthetic	289 (87%)	188 (88%)	101 (84%)	0.895, $p = 0.344$
Biodiversity-existence	68 (20%)	53 (25%)	15 (13%)	7.135, $p = 0.005$
Provision geology (rock formations)	37 (11%)	33 (15%)	4 (3%)	Clear
Provision fresh water	217 (65%)	137 (64%)	80 (67%)	0.237, $p = 0.626$
Culture and heritage	37 (11%)	23 (11%)	14 (12%)	0.066, $p = 0.797$
Recreation	215 (64%)	137 (64%)	78 (65%)	0.032, $p = 0.857$
Education	102 (31%)	97 (45%)	5 (4%)	Clear
Social relations	148 (44%)	74 (35%)	74 (62%)	22.861, $p < 0.001$
Detailed features in images				
Landscape	280	181	99	0.245, $p = 0.364$
Mountain (singular)	131	97 (45%)	34 (28%)	9.314, $p = 0.002$
Mountain range	145	83 (39%)	62 (52%)	5.193, $p = 0.015$
Fauna	26	16	10	
Mules and hares	9	5	4	
Birds	17	11	6	
Flora (only natives shown)	6	6	0	
Sources of fresh water	196	128	68	0.314, $p = 0.328$
River	15	9	6	
Creek	3	3	0	
Lake/lagoon	48	45	3	
Glacier	142	80 (37%)	62 (61%)	6.418, $p = 0.008$
Meadow	42	37	5	
Snow on ground	45	16	29	18.372, $p < 0.001$
Infrastructure and facilities				
Hotel Base Camp Mulas	2		2	
Railway	13	13		
Historic building	15	13	2	
Visitor centre	5	5		
Carpark	3	3		
Park entry	6	6		
Trails	101	91	10	42.605, $p < 0.001$
Durazno Bridge	1	1		
Aconcagua view point	22	22		
Summit-from-summit	0			
Campsites	18	0	18	Clear
Tents	32	0	32	Clear
Mountain refuges	7	0	7	
Helicopter	2	1	1	
Park rangers	2	1	1	
Recreational activities				
Trekking	52	47	5	Clear
Walking/hiking	32	32	0	Clear
Horse riding	3	2	1	
Photography	7	5	2	
Birdwatching	3	3	0	
Sightseeing	18	6	12	Clear

Table 4 continued

Content of images	Total n = 334	Day-use area n = 214	Remote area n = 120	χ^2 Tests
Yoga/stretching	3	1	2	
Camping	23	0	23	Clear
Posing	59	30	29	5.444, p = 0.015
People				
Selfie	6	3	3	
Group looking at camera	18	8	10	3.184, p = 0.065
Group walking off camera	50	28	22	1.664, p = 0.130
Portrait looking at camera	35	19	16	1.627, p = 0.138
Portrait looking away	12	7	5	0.178, p = 0.444
Number people in focus				
#1	61	33	28	ANOVA F = 0.718, p = 0.399
#2	20	13	7	
#3	6	2	4	
#4	7	4	3	
#5	2	1	1	
Number in background				
#1	50	22	28	ANOVA F = 1.284, p = 0.187
#2	26	15	11	
#3	10	6	4	
#4	7	4	3	

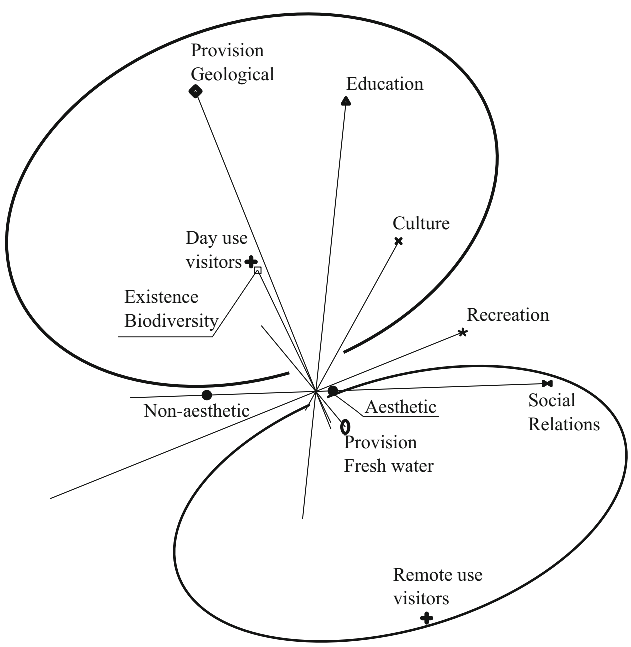

Fig. 2 Distribution of potential ecosystem services relating to the content of the 334 images taken by visitors in the day-use and remote areas of Aconcagua Provincial Park, Argentina based on the results of Categorical Principal Component Analysis. Variable projections represent the relationship among them with those close together positively related and variables at 90° angle not related to each other. Cronbach's α = 0.752 and total variance explained 37%

There was a greater emphasis on images showing social relations in remote areas, despite far fewer people accessing these areas. It is possible that adventure tourists may focus on people in their images as they want to capture a shared experience in remote locations, where adventure tourists are often motivated by connectedness in extreme conditions as part of transformative experiences (Buckley 2006).

Comparison among studies using social media to assess potential ecosystem services

The content of Flickr images has been used to evaluate how people view and value nature in Africa, Europe, Asia, Australia and North and South America (Calcagni et al. 2019; Ghermandi and Sinclair 2019). This includes studies at a range of spatial scales from as small as 1.4 km^2 for areas of mangroves in Singapore to the whole country of Peru, and covers a range of landforms and land uses such as mountains, coastal areas, savannahs, agricultural and urban areas (Table 5).

Among the studies, there was variation in how data were obtained and coded. For instance, some studies retrieved image-metadata based on keywords within the image tags while others retrieved images located within defined polygons based on the geolocation of the images (Table 5). In

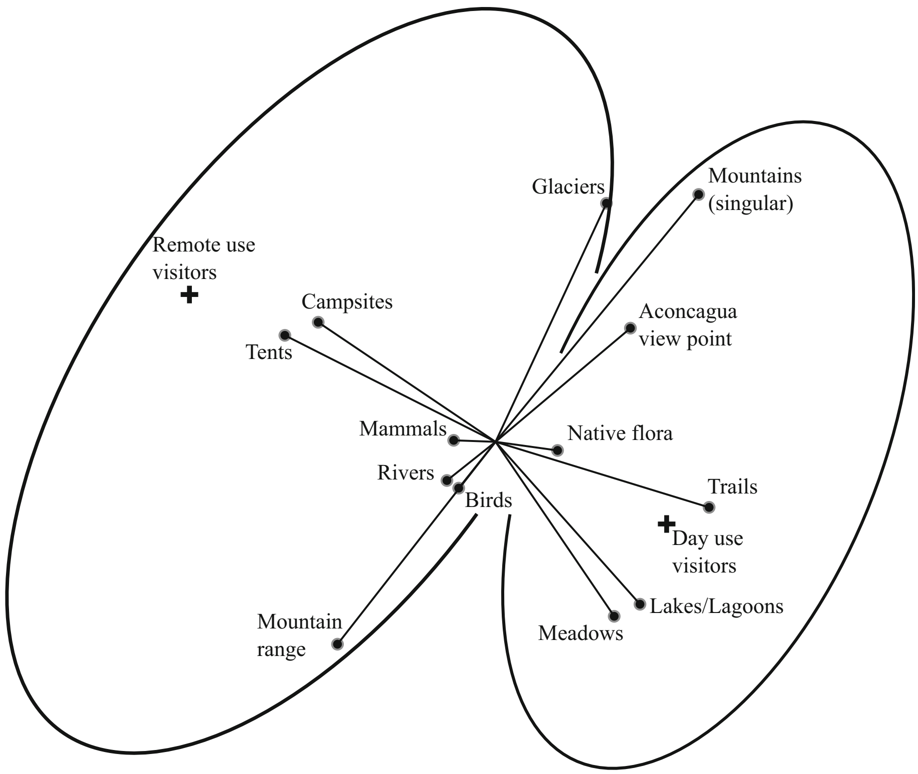

Fig. 3 Features seen among 334 images taken in day-use and remote areas of Aconcagua Provincial Park based on the results of Categorical Principal Component Analysis. Variables' projections represent the relationship among them with those close together positively related and variables at 90° angle not related to each other. Cronbach's α = 0.836 and total variance explained 34%

some studies, images were only assigned to single categories, while in others single images could represent multiple categories. Most studies coded images manually, except Richards and Tunçer (2018) who used machine learning. In some cases, it was not possible to directly equate the categories used in the different studies due to differences in definitions, coding and locations. However, preliminary comparisons could be made relating to the frequency and types of values associated with ecosystems services represented in social media images from different landscapes.

Landscapes were common both in the content of images among locations and in coding categories within studies (Table 5). In several cases, landscapes were treated as equivalent to aesthetic values including in this study, Clemente et al. (2019), Richards and Tunçer (2018) and Pickering et al. (in press) (Table 5). Landscape features, such as mountains, lakes or oceans, were popular in images despite often accounting for a small proportion of the total area of the location. For instance, in Aconcagua Provincial Park, glaciers and lakes were popular in the images (42% and 14%, respectively) even though they account for only 15% of the Park's land area. This is also the case for the peak of Mt. Aconcagua, which was common in images (39%) although it represents a relatively small area and it can only be seen from a few places in the Park.

The presence of people in images reflects differences in visitors' values and perceptions of the places they visit (Stephchenkova and Zhan 2013). In more remote protected areas where few people live, most images show fellow tourists, and hence the presence of people in images is equivalent to tourism activities (e.g. Aconcagua Provincial Park, Kosciuszko National Park, Kruger National Park). The dominance of images of tourists in these parks varies and can be quite low even though visitors may be sharing places with hundreds of others such as in Kosciuszko National Park (Pickering et al. in press) (Table 5). In urban areas, images of people may still predominantly represent recreation (e.g. Spit, Gold Coast), but they can also show locals engaged in day-to-day activities (e.g. Peru). In some cases, images of locals may represent cultural values reflecting apparent difference in ideas, customs or social behaviour with those of tourists (Stephchenkova and Zhan 2013). In some studies, images were coded to indicate if people were looking at the camera and hence could be recognized (e.g. Aconcagua, Spit, Kosciusko, Kruger). This may reflect people's personal history, where seeing a person in a place is important. Although authors included 'selfies' in most image classifications, there were few if any selfies in most studies (e.g. Aconcagua, Spit, Kosciusko). Such images may be more common on other social media

Table 5 Summary of the results of research across 13 locations where the content of Flickr images was used to assess the views and values of visitors and how image content relates to potential cultural ecosystem services and other features of the locations. NR = not recorded or not relevant to the location. NA = not available, as the categories used in the research were defined in such a way that the value could not be extracted from the paper. Where a paper used images from several platforms (Stephchenkova and Zhan 2013; Hausmann et al. 2018; Oteros-Rozas et al. 2018), only the data from Flickr images were included here. Agri = agriculture. Approximate "∼" as in the paper no exact values are given but a bar-figure represents them

	This study	Stephchenkova and Zhan (2013)	Pickering et al. (2018b)	Pickering et al. (in press)	Richards and Friess (2015)	Richards and Tunçer (2018)	Hausmann et al. (2018)	Clemente et al. (2019)	Oteros-Rozas et al. (2018)				
Location	Aconcagua Provincial Park	Peru	The Spit Gold Coast	Kosciuszko Alpine Area	Four mangrove sites	Singapore	Kruger National Park	Sudoeste Alentejano and Costa Vicentina Natural Park	Lake Peipsi	Lesvos	Madrid	Uppland	Obersimmental
Landform/land use	Mountain	Variable	Coastal	Mountain	Coastal	Mostly urban	Savannah	Coastal	Agri.	Agri.	Agri.	Agri. and urban	Alpine pasture
Size of area (km^2)	700	1.3 million	2	200	1.4	722	19 485	605	162	86	183	47	334
Country	Argentina	Peru	Australia	Australia	Singapore	Singapore	South Africa	Portugal	Estonia	Greece	Spain	Sweden	Switzerland
Data collected	Geodata	Text	Text	Geodata	Geodata	Geodata	Geodata	Geodata	Geodata for all five sites				
Number of images	334	500	493	656	762	23048	4597	1378	22	28	200	15	200
Number of categories	79	20	70	69	7	7	57	6	25				
More than one category per image?	Yes	Yes	Yes	Yes	No	No	Yes	No	Yes for all five sites				
Landscape (aesthetic) (%)	87	NR	NA	50.4	20.5		14.4	∼ 60	NA	NA	NA	NA	NA
Rock formations (%)	11	NR	NR	30	NR	NR	NR	∼ 25	18.2	24.1	40	4	56
Water bodies (%)	65	NR	82.7	11.4	NR	NR	NR	∼ 28	59.1	82.8	20	22.6	24
Plant and/or animal (biodiversity-existence) (%)	20	18.2	18.6	13.9	35.3	23.6	84.5	∼ 19	NA	NA	NA	NA	NA
People (%)	36	30.6	45	29	NA	8.5	NA	NR	9.1	3.5	13.3	21.1	18.5
Culture/heritage/history (%)	11	47.6	NA	1.2	0.3	NA	0.3	∼ 5	18.2	17.2	20	24.1	4
Recreation, tourism and sports activities (%)	27	12.8	58	32	13.6	3.2	5	∼ 25	40.9	41.4	26.7	44.7	32.5
Recreation and tourism facilities (%)	56	4.2	NA	42	9.4	NA	1.6	NR					

Table 5 continued

	This study	Stephchenkova and Zhan (2013)	Pickering et al. (2018b)	Pickering et al. (in press)	Richards and Friess (2015)	Richards and Tunçer (2018)	Hausmann et al. (2018)	Clemente et al. (2019)	Oteros-Rozas et al. (2018)				
Location	Aconcagua Provincial Park	Peru	The Spit Gold Coast	Kosciuszko Alpine Area	Four mangrove sites	Singapore	Kruger National Park	Sudoeste Alentejano and Costa Vicentina Natural Park	Lake Peipsi	Lesvos	Madrid	Uppland	Obersimmental
Education/research (%)	31				10.8		NR	~ 1					
Social (%)	44						NA	NA	50	17.2	20	30.2	6
Spiritual (%)	NR	NR	NR		NR	NR	NR	~ 2	13.6	3.5	6.7	20.1	2

platforms such as Facebook, Instagram and Snapchat where images are more likely to be directly shared within social groups or used to market popular identities.

For recreation and tourism activities there are obvious differences among locations. Interestingly, the frequency with which an activity is shown in images does not always match reality, with some types of activities more common in images than in reality, or missing entirely from images (Pickering et al. 2018b). For instance, there were few if any images within the visitors centre at Aconcagua Provincial Park despite its popularity with tourists, while for the Spit, Gold Coast, of the 35 recreation activities known to occur on the Spit, many were not seen in any images (Pickering et al. 2018b).

Some studies separate recreation into activities and facilities, such as in Aconcagua, Spit, Mt. Kosciuszko and Peru, while others may have recorded activities and facilities separately to start with, but then combined them when calculating overall human activities/tourism (Hausmann et al. 2018). A wide range of different types of facilities were recorded across the different studies including accommodation (i.e. hotels, huts, tents), transport (i.e. trolley cars, tour boats, trails, boardwalk) and others (i.e. viewpoints, visitor centres, information boards, surf lifesaving structures, pools, toilets) (this study, Stephchenkova and Zhan 2013; Richards and Friess 2015; Pickering et al. 2018b; and Pickering et al. in press). Culture, heritage and history services were coded in several studies, but they represent different contents including different types of historical buildings, ruins, monuments, monasteries, fortresses and/or burial sites. Sometimes, historical services was combined with cultural services when there were images of people engaged in cultural and other activities reflecting their way of life.

Most studies assessed if images included animals and plants (Table 5). This was considered to reflect existence values, or nature appreciation in some studies. The frequency with which images presented specific plants and animals varied among locations ranging from 14% for the Kosciuszko Alpine Area in Australia to 84.5% in images from Kruger National Park in South Africa. A diversity of animals was shown within and among locations, but most often they were larger mammals or birds, while images of small mammals, reptiles, amphibians or arthropods were rare (Table 5).

The frequency of images showing animals partly depends on how easy it is to capture an image of the animal and this is affected by the size of the animal and its behaviour (Castley et al. 2013). For example, bigger herd mammals active during the day are easier to photograph than smaller, solitary and/or nocturnal species (Castley et al. 2013). For Flickr and other social media platforms, the frequency of different types of animals in images is affected by the preferences of those posting and sharing images and reflect the animals ‘value’ in a specific context (Willemen et al. 2015; Hausmann et al. 2018). For instance, images from protected areas can often include iconic species such as elephants and lions in South Africa (Hausmann et al. 2018) or llama, alpaca and condors in Peru (Stephchenkova and Zhan 2013). They may also show animals that are integral to tourism such as mules in Aconcagua. In agricultural and urban areas, images may include domesticated as well as native animals (Stephchenkova and Zhan 2013; Oteros-Rozas et al. 2018). This could include recreation images such as dogs being taken on walks (Spit, Gold Coast), or reflecting the nature of landscapes such as images of livestock (Oteros-Rozas et al. 2018). Individual plants tend to be uncommon in images in contrast to broad vegetation types (e.g. forests, mangroves, lawns, pastures). As with animals they can have different meaning, such as native plants in protected areas (Aconcagua, Kosciuszko), compared to agricultural landscapes which may represent traditional land uses (Oteros-Rozas et al. 2018).

Many ecosystem services would be hard to capture in images and/or are difficult to code and categorize. This remains an important limitation of the method. This limitation applies particularly to supporting ecosystem services such as soil formation, nutrient cycling, primary productivity, genetic resources, pollination, wellbeing and cultural services such as peace. It is also possible that visitors do not know about these types of values, or do not value them even if they know about them. There may also be issues due to a disconnect between the 'gaze' of the person taking and posting the image and that of the coder (Stephchenkova and Zhan 2013).

An obvious example is spiritual values that are hard to code when it is not associated with specific content such as objects (e.g. churches, temples, monuments) or activities (e.g. religious ceremonies, people in prayer). Many locations embody spiritual values beyond those including sacred landscapes, mountains and rivers, caves and individual trees or where people have a sense of attachment to specific places (Oteros-Rozas et al. 2018; Wartmann and Purves 2018). In some cases, there can also be overlaps between spiritual, cultural and historical services wherein the same object, such as a tomb or temple, which may reflect culture to some people and spiritual values to others. In coding the content of images, we and other researchers have used a metonymic interpretation of images that reflect specific 'norms' of interpretation, while Flickr-users taking and sharing images may 'see' the images from a metaphoric perspective ascribing meaning not apparent to the coder (Stephchenkova and Zhan 2013).

Management implications

Social media as a mean of communication is increasingly popular with people sharing news and experiences, as well as using social media to gain information about places and plan their trips (Miller et al. 2019). This provides managers with opportunities to reach a broader audience, communicating their purpose, functions and opportunities to local residents and tourists. Protected areas managers and tourism agencies can use the knowledge gained through the analysis of user-generated content, including images and text, to better understand Cultural Ecosystem Services demands and preferences (Wolff et al. 2015). At a finer scale, managers can also better understand where and what visitors look for and share within parks helping to tailor education programs and their own social media posts. For instance, in Aconcagua Provincial Park, managers could use information from the Flickr images to encourage more responsible environmental behaviours and safety measures to current, virtual and future visitors (Miller et al. 2019).

Benefits and limitations

Content analysis of social media images enables the rapid assessment of some visitors' perceptions of landscapes. Data from social media can be collected remotely, quickly and cheaply, and provides both spatial and temporal data about visitor use, views and values (Calcagni et al. 2019; Ghermandi and Sinclair 2019). This information is hard to obtain even in easily accessed and well-funded protected areas and is extremely limited for more remote parks and locations. The types of values and preferences reflected in the content of images can match those reported in surveys of visitors (Hausmann et al. 2018).

There are, however, limitations that need to be considered. Only a very small proportion of people visiting parks post images to Flickr (Hausmann et al. 2018), with Flickr and other social media sites dominated by younger, wealthier and more highly educated people (Smith and Anderson 2018). Hence, images on Flickr only represent the 'views' and/or 'interests' of some visitors to parks and the content can be dominated by frequent users of the platforms. They may not show some types of popular activities (this study and Pickering et al. 2018b) but over-represent novel experiences and activities (Calcagni et al. 2019; Ghermandi and Sinclair 2019). There are also important social factors shaping what people post on social media (Oeldorf-Hirsch and Sundar 2016), with variation in content among platforms, users and places (Angradi et al. 2018; Hausmann et al. 2018). As highlighted above, there can also be differences in what is 'seen' by researchers coding images versus their meaning to those posting images (Stephchenkova and Zhan 2013).

CONCLUSIONS

Researchers are starting to evaluate benefits and limitations of social media for managers, practitioners and natural resource professionals. This includes how social media such as Flickr images can be used to better understand the ways people relate to natural environments including the services they provide. But more research is required including comparing platforms, locations and between social media and more traditional methods. What is clear is that user-generated content is increasing in volume and variety with more people posting it from a diversity of places to different platforms where this content itself is shaping and influencing not only visitation to parks, but the ways people value the natural environment.

Acknowledgements We thank Ruben Massarelli and Dirección de Recursos Naturales Renovables, Mendoza for providing the visitor statistic data and GIS layers for Aconcagua Provincial Park and we thank Dr. Charles Lawson for his valuable inputs made to this manuscript. We also thank CONICET-Argentina for their support through the funded Short-Internship-Program (Pasantias Breves en el Exterior) and Griffith University for the Visiting-Fellow Position that made this collaborative-article possible. We also thank the funding provided by The Scientific and Technological Research Fund (FONCYT, PICT 2015-1455 and PICT 2017-1869).

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Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

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