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Spatial and Temporal Patterns of Visitation in the Annapurna Conservation Area, Nepal: Insights from Geolocated Social Media Images

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Mountain protected areas are popular tourism destinations. Those managing such landscapes and activities require data on when and where people go, but obtaining such information is difficult for large and often remote areas, particularly when resources are limited. We illustrate how geolocated images posted on social media could be used to assess tourism by analyzing geolocated images taken in the Annapurna Conservation Area in Nepal and posted to the image-sharing platform Flickr. Data from 577 visitors covering 3 major periods—pre-2007 (limited roads and Maoist insurgency), 2008–2014 (post-insurgency and better roads), and 2015–2020 (post-blizzard and earthquake)—and 4 meteorological seasons were analyzed. We found monthly patterns based on photo user days correlated with recent official visitor data. When finer resolution mapping of photo-user-hour data was visualized using heatmaps, seasonal and spatial patterns were apparent. Visitors mainly stayed on trails, roads, or in villages, with few images off trails, at high elevations, or from the remote north, while visitation was greater and more dispersed in spring and autumn compared to summer and winter. The results highlight the concentrated nature of visitation and hence opportunities to promote new destinations, events, and activities, particularly in summer and winter. They also show how roads and trails have expanded the use of the area. Although beneficial, social media has limitations, as few visitors post to social media, platforms vary in popularity and access to data, and there are increasing ethical and privacy issues with data from social media that need to be considered.

Keywords: *Flickr; mountain tourism; Nepal; protected area management; visitor monitoring.*

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Introduction

Mountains cover just over 30% of the global land surface (Sayre et al 2018), and, as hotspots of biological, geological, and cultural diversity (Foggin 2016), they provide a variety of ecosystem services (WCPA 2020). However, they are rapidly changing, due in part to shifting patterns of agriculture, tourism, and climate (Geneletti and Dawa 2009; WCPA 2020). To protect these environments, many mountains are conserved, with 17% of mountains outside of Antarctica designated as protected areas, accounting for 32.4% of the world's terrestrial protected areas (WCPA 2020). Some of these protected areas are also popular tourism destinations for hiking, trekking, mountaineering, rock climbing, mountain biking, horseback riding, skiing, rafting, sightseeing, bird watching, and cultural interactions, among other activities (Upreti et al 2013; Pastur et al 2016), with approximately 15–20% of global tourism taking place in mountain areas (Richins et al 2016).

To ensure positive experiences for visitors while protecting the natural and cultural values of the areas, local land managers, governments, nongovernmental organizations, and tourism operators need information on who travels where and when in these protected areas (Newsome et al 2012; Eagles 2014; Leung et al 2018). Such data are useful for those directly responsible for the destination because they can provide insights not only into visitor hotspots and hence where more commercial opportunities are available, but also into where additional facilities relating to access (roads and trails), infrastructure (accommodation, food outlets, toilets, and waste disposal), safety, and information as well as recreation activities and attractions could be required (Cessford and Muhar 2003; Spenceley et al 2021). Such information is also important when assessing carrying capacities of tourism hotspots (Cessford and Muhar 2003) and minimizing negative impacts of tourism on ecosystems (Newsome et al 2012; Worboys et al 2015; Pickering et al 2018; Spenceley et al 2021). At a broader scale, such data are important for tourism policy, planning, and marketing strategies (Ziesler and Pettebone 2018; Spenceley et al 2021).

Data on tourism in protected areas can be obtained using a range of methods, such as direct observations, surveys, interviews, track counters, licensing, ticket sales, permits, and indirect observations (eg cameras, satellite images; Veal 2018; Spenceley et al 2021), as well as newer methods such as geographic information system (GIS) tracking and Public

Participatory GIS (Beeco and Brown 2013). However, collecting detailed data on temporal and spatial patterns of use in large remote mountain protected areas is challenging, particularly when resources are very limited, as is the case in many developing countries (Newsome et al 2012; Beeco and Brown 2013). More recently, researchers have started to explore how geolocation data associated with social media images could be used to assess patterns in tourism in natural areas including some mountain protected areas (Teles da Mota and Pickering 2020; Wilkins et al 2021). This includes studies looking at global patterns of park visitation (Levin et al 2015) as well as individual parks or clusters of mountain parks in various European countries (eg Heikinheimo et al 2017; Barros, Moya-Gómez, and Gutiérrez 2019; Sinclair et al 2020a,b), Australia (Walden-Schreiner, Rossi, et al 2018; Pickering et al 2020), the United States (Sessions et al 2016; Walden-Schreiner, Leung, and Tateosian 2018), Argentina (Walden-Schreiner, Rossi, et al 2018; Rossi et al 2019), and Southeast Asia (Khan 2019; Kim et al 2019), among other locations. Much of this, and other nature-based tourism research harnessing social media, accessed data from the platform Flickr (https://www.flickr.com/), which is popular for sharing images of nature, including those taken by park visitors of their trips (Ghermandi and Sinclair 2019; Teles da Mota and Pickering 2020; Wilkins et al 2021). Flickr data have been used to compare seasonal effects on visitation between remote and easily accessible areas and the use of different types of infrastructure, such as trails (Walden-Schreiner, Rossi, et al 2018; Rossi et al 2019; Pickering et al 2020), and to evaluate recreational ecosystem services (Sinclair et al 2020b).

Contributing to this still novel approach, we used a case study to examine visitation patterns in the Annapurna Conservation Area (ACA) in Nepal. Resources are highly constrained in Nepal, as they are in many other developing countries (Nepal Government 2020b) with tourism monitoring mostly limited to registration records from entry points (Nepal Government 2020a) and issues with data accuracy and coverage (Sigdel 2020). For instance, for ACA, managers were recording visitors registering at entrances and the number of permits issued (Sigdel 2020); this was occasionally supplemented by surveys of visitor satisfaction or carrying capacity (Baral et al 2012; Joshi and Dahal 2019). Although collecting more comprehensive visitor data is recommended, an online tracking system that was planned has been delayed because of the impacts of the COVID-19 pandemic on tourism (Himalayan News Service 2020; Sigdel 2020). Further, this would not provide information about past visitation. We used metadata from Flickr images taken in ACA to compare how visitation varied seasonally and spatially across the whole of ACA during 3 major periods where there was increasing access (roads, trails) but also social disruption (political instability, natural disasters). This research contributes to the limited literature on the use of social media data in visitor monitoring in developing countries, including over time and space. Implications for the management of this large, protected area conserving some of the highest mountains in the world are outlined, as well as how social media data could assist in assessing tourism more generally when resources for monitoring are highly constrained.

Methods

Study area

The ACA (28.8205°N, 84.0167°E) is an IUCN (International Union for Conservation of Nature) category VI protected area (Figure 1). It was established in 1986 with the Ghandruk village as a pilot project and now covers 5 districts: Manang, Mustang, Kaski, Myagdi, and Lamjung. It includes major high-elevation peaks with heights ranging from 790–8091 m and is the largest protected area (7629 km^2) in Nepal (NTNC 2020). It is collaboratively managed by the Annapurna Conservation Area Project (ACAP), a subsidiary of the National Trust for Nature Conservation (NTNC), with local communities, and a focus is on environmental protection, sustainable tourism, and development (NTNC 2020).

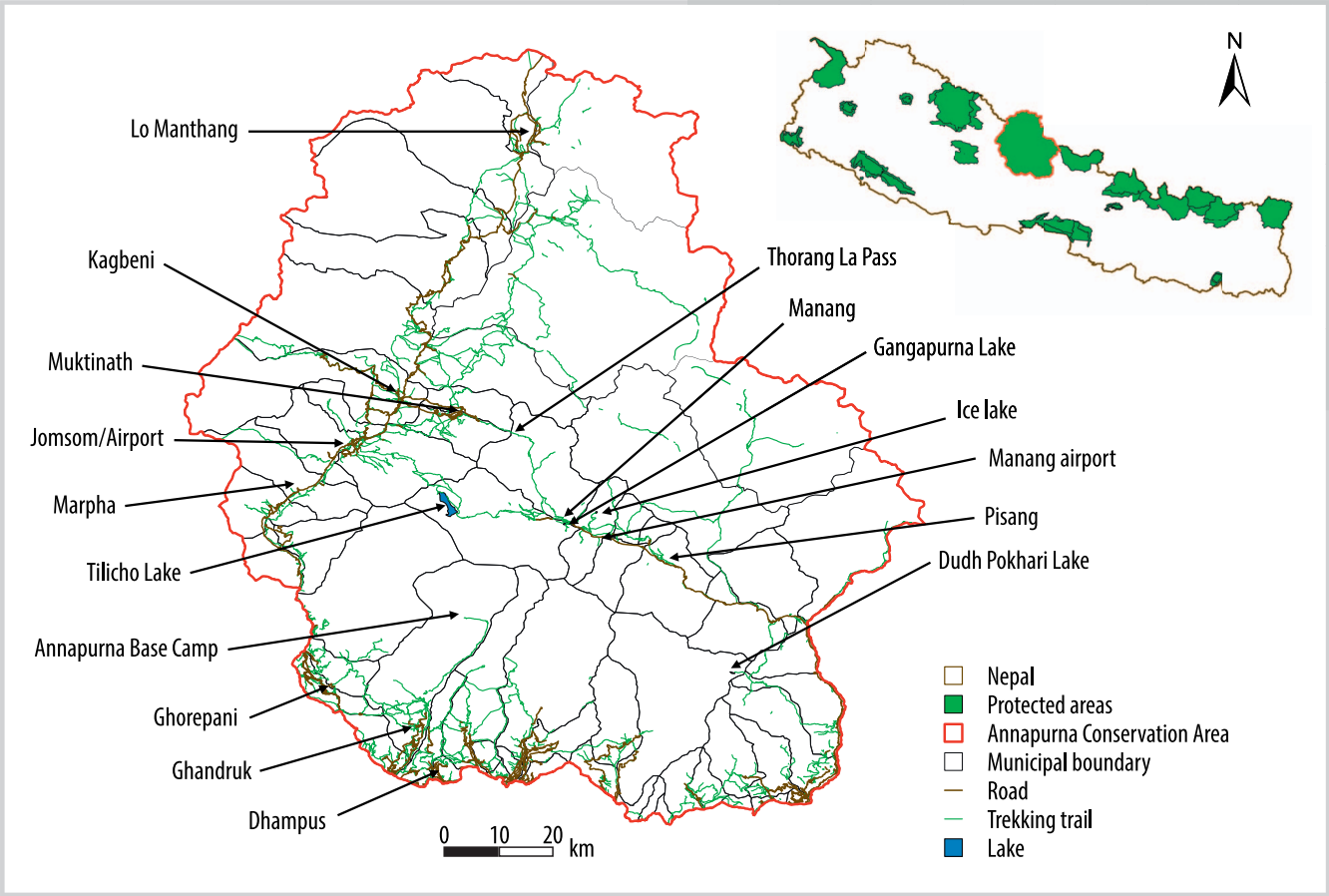
ACA extends from subtropical lowlands to temperate forests in the south and high alpine peaks and trans-Himalayan cold deserts in the north, with temperatures dropping to –10°C in winter (December to February) and rising to 30°C in summer (June to August; Khadka 2020). Autumn (September to November) and spring (March to May) have the best weather and, as a result, are the most popular times for tourism (Khadka 2020). ACA has high biodiversity, internationally renowned peaks over 7000 m, and well-known trekking routes such as the Annapurna Circuit trail (NTNC 2020). The Gurung, Magar, Thakali, Manange, and Loba ethnic people live in the area, along with Brahmins and Chhetris, resulting in diverse ethnic cultures, languages, and religious values, as well as Buddhist monasteries and Hindu temples (Prajapati et al 2020). As a result, ACA is listed as one of the world's top 10 tourism destinations (Lonely Planet 2020) with more than 100,000 domestic and international visitors annually before the COVID-19 pandemic (Nepal Government 2020a).

In the last 20 years, various events have reduced tourism in ACA, including the Maoist insurgency up to 2006 (Baral 2014), a major blizzard in late 2014, the devastating earthquake in early 2015 (Skach 2016), and then, in 2020, the COVID-19 pandemic and associated lockdowns. In contrast, access and movement within ACA has improved with the construction of roads on the western side that opened to traffic in 2007 (Lama and Job 2014) and roads to Manang and Lo Manthang to the Nepal–China border that opened in 2014 (Skach 2016). In addition, there has been ongoing construction of new trails since 2011 (Ruiter and Rai 2019).

Data collection

Metadata for images on Flickr taken in ACA were obtained using an application programming interface (https://www.flickr.com/services/api) and the statistical program R Studio (version 1.3.1093). Data for all images taken within 1927 grids measuring 0.2° horizontal spacing covering ACA that were taken up to July 2020 were downloaded from Flickr, with fewer than 0.83% of images taken before the official launch of Flickr in 2004. Data for each image included the user's Flickr identifying number, their home location (if provided), where (latitude and longitude) and when (date and time) the image was taken, the text of titles, tags, and description of the image, the number of times it was viewed by others on Flickr, and the image URL. As commonly done in these types of studies (Sinclair et al 2018; Wilkins et al 2021), we used

FIGURE 1 The Annapurna Conservation Area including roads, trekking trails, and some of the main tourism sites.



one image per user per day (photo user day, PUD) when comparing images with visitation data to minimize biases from people posting multiple images from the same place and time. We selected the most viewed images to assess preferred popular destinations within ACA. We also used one image per person per hour (photo user hour, PUH) to examine finer scale temporal and spatial tourism patterns. To identify where images were taken in ACA and which features they were associated with, the protected area layers for Nepal were obtained from the Protected Area Planet website (UNEP-WCMC and IUCN 2020), while GIS layers showing roads, trails, and other natural features, such as lakes, were obtained from OpenStreetMap (https://www.openstreetmap.org) and processed in the QGIS open-source geographic information system (version 3.10, A Coruna).

Data analysis

To assess whether temporal patterns based on Flickr images reflect official data, PUD from 2016 to mid-2020 were compared with monthly entry data for ACA from 2016 to 2019 (Nepal Government 2020a), using a Spearman rank correlation coefficient. To analyze finer resolution temporal and spatial patterns of use, Flickr PUH data were compared for the following: (1) 3 major periods, pre-2007 (period of Maoist insurgency and limited roads), 2008–2014 (post-insurgency and increased roads), and 2015–2020 (post-devastating blizzard and earthquake), (2) 4 meteorological seasons, (3) on and off trails and roads, and (4) at different elevations in ACA. The spatial distribution of images was visualized using kernel density heatmaps as the number of images per square kilometer in QGIS. Kernel density is a statistical method to detect patterns in point values from low to high including clusters of high values (Kalinic and Krisp 2018). To calculate the distance of images from roads and trails, a near distance analysis was done in QGIS using the "NNJoin" plugin for the 3 periods and 4 seasons. The elevation where images were taken was obtained in QGIS using the "Point Sampling Tool" and was compared among the 3 periods and 4 seasons using χ^2 tests in Microsoft Excel 2010.

Results

There were 25,955 images taken in ACA posted to Flickr by 577 people, representing 2631 visitor days (PUD) and 7434 visitor hours (PUH; Table 1). As is common with social media image data, a few people (10) posted many images (>100), while most (471) posted fewer than 20. Based on the home location data provided by 239 people, the images reflect visitation from at least 46 countries, including the United Kingdom (32 people), United States (31), Germany (16), France (14), Australia (13), Canada (8), Russia (8), Spain (8), China (6), and India (3). Only 14 people (5.9%) posting images from ACA to Flickr indicated they were from Nepal, and hence the images are likely to predominately represent international tourism rather than how Nepalese use the area.

TABLE 1 Number and percentage of geolocated images from the Annapurna Conservation Area posted to Flickr including among seasons and for 3 periods in the history of the Area.

Time period	Season images taken					PUH[a] (*n*)	χ^2 (*P* value)[b]	Cramer's *V*
	Winter (%)	Spring (%)	Summer (%)	Autumn (%)	Total (%)			
Pre-2007	0.6	0.9	0.3	3.3	5.1	378	63.487 (<0.001)	0.410
2008–2014	6.1	15.3	3.6	27.4	52.4	3895	70.992 (<0.001)	0.135
2015–2020	4.5	17.7	4.7	15.6	42.5	3161	144.582 (<0.001)	0.214
Total (%)	11.2	33.9	8.6	46.3	100.0		279.095 (<0.001)	0.137
Total (*n*)	837	2522	639	3436		7434		

[a]PUH, photo user hours.
[b]*P* values are from χ^2 statistics comparing values among seasons.

When do people visit?

There were slight seasonal patterns in ACA visitation based on Flickr images ($\chi^2 = 279.095$, $P < 0.001$, Cramer's $V = 0.137$), with autumn and, more recently, spring the most popular (Figure 2A). Monthly patterns in PUD data were correlated with official statistics for the same period (Spearman rank correlation $\rho = 0.61$, $P < 0.05$; Figure 2B). Although there were few images before 2007, more recently

FIGURE 2 Temporal variation in when Flickr images (PUH) in the Annapurna Conservation Area were taken every month for major periods (A) and ranking of months in terms of mean monthly visitor numbers and Flickr images (PUD) for 2016–2019 (B).

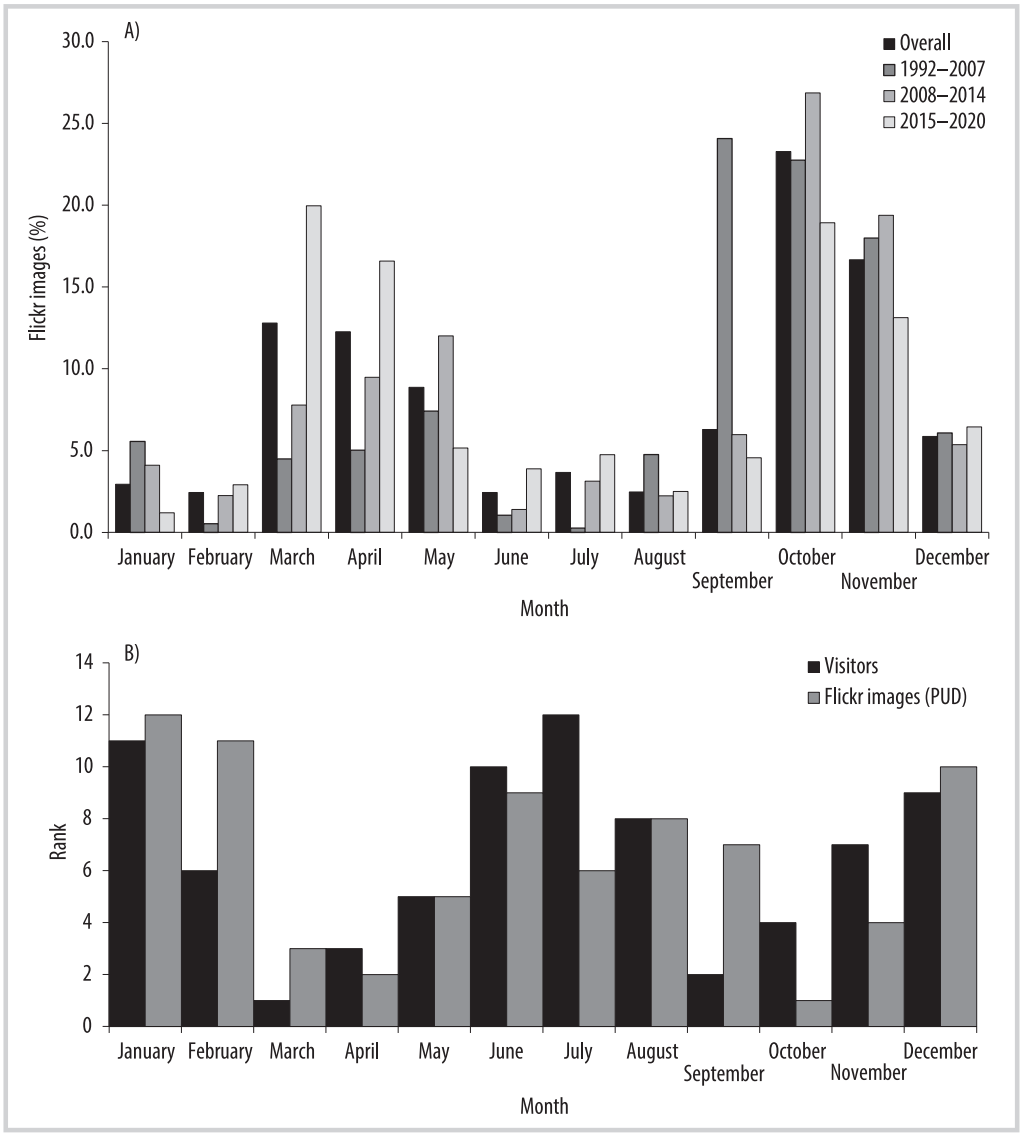


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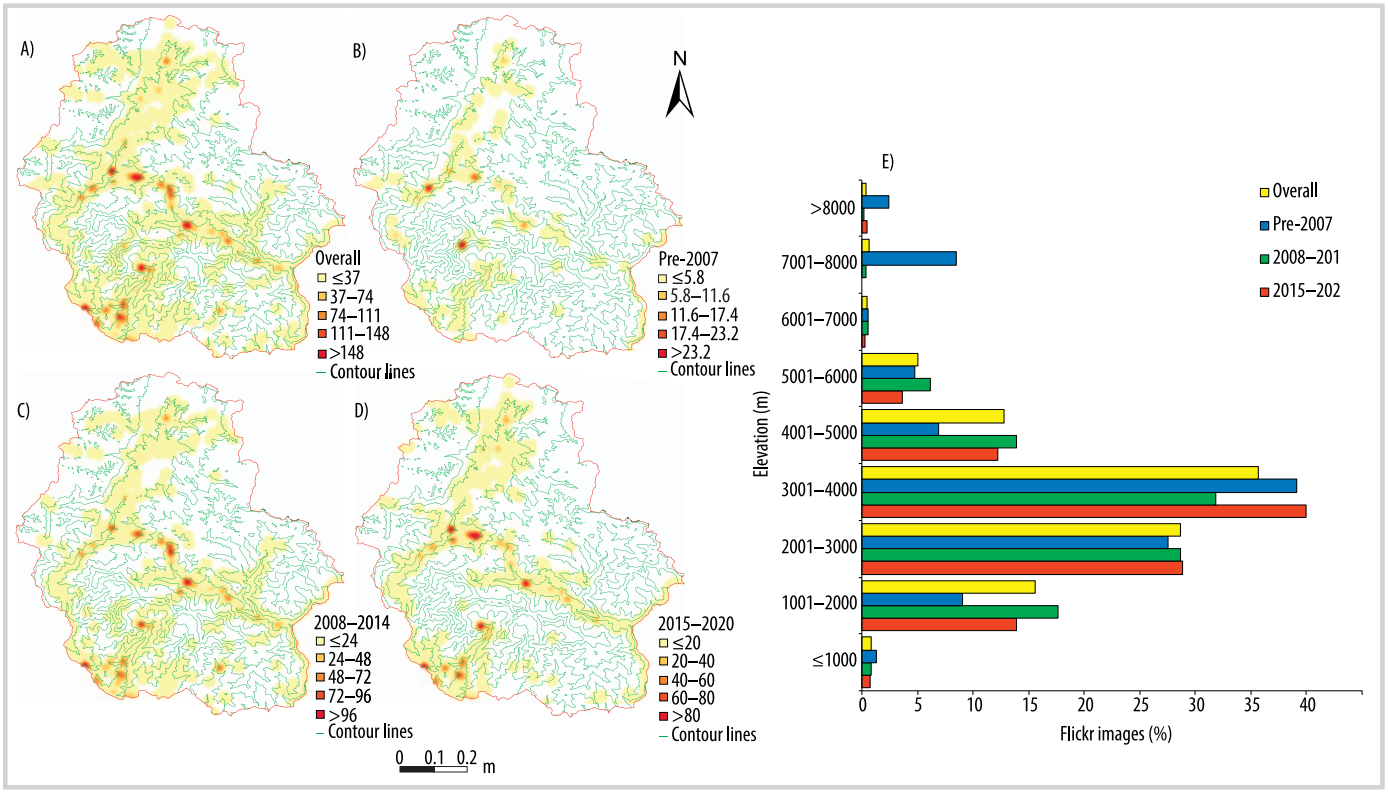
FIGURE 3 Kernel density heatmaps of Flickr images in the Annapurna Conservation Area, (A) overall and for 3 major periods: (B) 1992–2007, (C) 2008–2014, and (D) 2015–2020 and (E) the percentage of images per elevation band.



the numbers have been relatively constant (Figure 2A; Table 1).

Where do people go?

There was highly concentrated use of ACA with most images along major trekking trails and roads, such as the main Annapurna Circuit, with clusters at destinations, as well as in the popular Annapurna Base Camp in the south (Figure 3A). In contrast, there were no images in much of the northeast and west of ACA, in part reflecting the challenges in accessing more remote and higher elevation areas away from roads and trails. Over time, reflecting increased visitation, the popularity of Flickr and the construction and use of roads and trails hotspots increased (Figure 3B–D). Most images were taken in mid-elevations (2000–4000 m), reflecting the geography of ACA and the location of most roads, trails, and villages (Figure 3E). Those images taken at high elevation (>8000 m), were mainly earlier, potentially reflecting how some mountaineers posted images pre-2007 to Flickr, but also how more recently ACA and Flickr itself have become popular with a wide range of tourists.

There were clear seasonal differences in where people went in ACA (Figure 4). In winter, tourists were restricted to the south (Figure 4A), while in summer, additional hotspots were found in the north (Figure 4C). In spring, tourist hotspots were more dispersed (Figure 4B), and in autumn, clusters were similar to spring but less dense (Figure 4D). Seasonality also affected the elevation where images were taken ($\chi^2 = 323.7$, $P < 0.001$, Cramer's $V = 0.120$), with most images taken in mid-elevations (2000–4000 m). Those at high elevations were in the warmer months, while the winter images were restricted to lower elevations (Figure 4E).

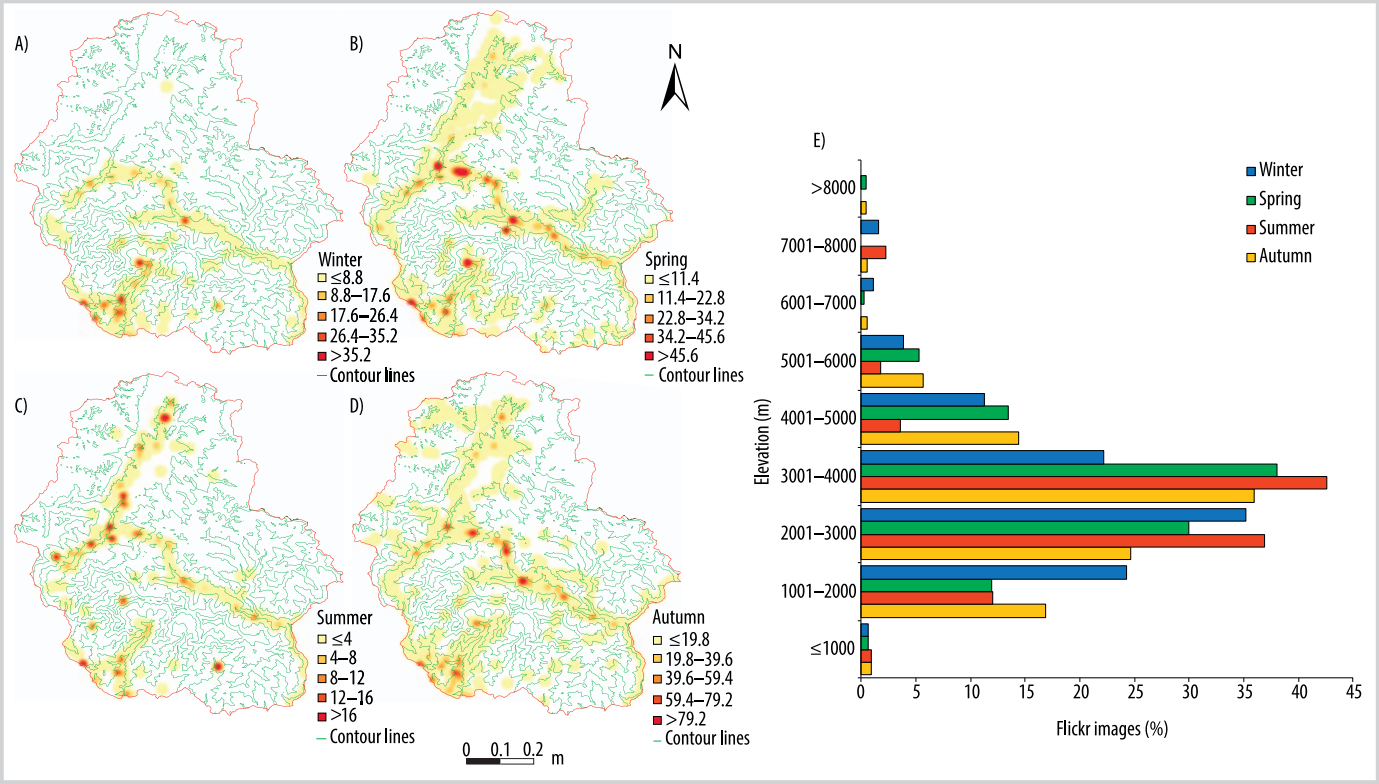
Distribution in relation to roads and trails

Reflecting the importance of roads and trails in shaping where tourists go, 92.8% of images were taken on roads or trails (0–10 m). However, slight seasonal differences were apparent ($\chi^2 = 308.8$, $P < 0.001$, Cramer's $V = 0.117$; Figure 5). In winter when there is deep snow, and spring and autumn, with moderate weather, tourist images were more likely to be taken on trails or roads (92.1%, 92.8%, and 93.9%, respectively), but with warmer weather in summer there were slightly more images off trails or roads (12.1%).

Discussion

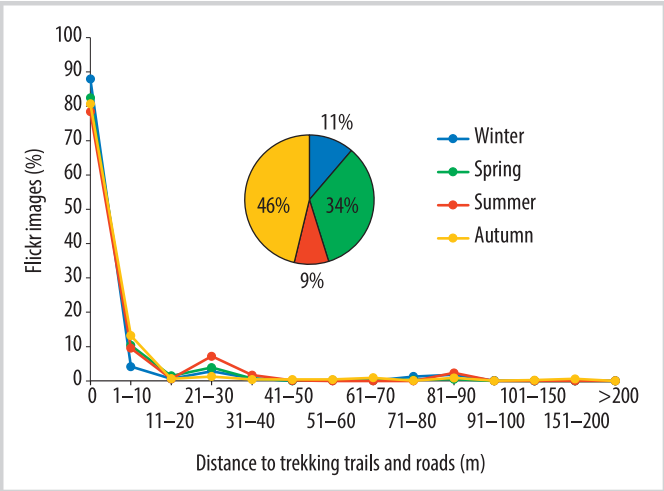
User-created content on social media, particularly geolocated images, can provide insights into how, when, and where people visit remote mountain protected areas (Walden-Schreiner, Rossi, et al 2018). For ACA, there were few images before 2007, in part because this predated the popularity of Flickr and social media in general, but also because access to many areas within ACA was difficult before the construction of major roads and trail networks (Bardecki 2009) and because of broader political instability in Nepal during the Maoist insurgency (Bajracharya 2011; Baral 2014). The accuracy and availability of geolocated data on social media have also increased with more automatic coding and higher accuracy from smartphones (Walden-Schreiner, Leung, and Tateosian 2018). Despite

FIGURE 4 Kernel density heatmaps of Flickr images in the Annapurna Conservation Area per season (A) winter, (B) spring, (C) summer, and (D) autumn and (E) the percentage of Flickr images per elevation band.



these important considerations, Flickr data provided useful insights into visitation patterns in ACA, including over time. The monthly patterns of visitation based on PUD were similar to official statistics for the last 5 years, adding to the few studies that have already found correlations in visitation between social media and official data for protected areas, and one of the few studies comparing monthly patterns of use (Wilkins et al 2021). The Flickr PUH heatmaps highlighted the popularity of certain destinations and routes with international visitors, as well as how the expanded road and trail networks channel visitors' movements within ACA (NTNC 2020), particularly at certain times of the year.

FIGURE 5 Percentage of Flickr images taken at different distances from trails and roads in the Annapurna Conservation Area in each season.



The kernel density heatmaps highlight the potential of Flickr data to identify hotspots of visitor use and the effects of factors such as seasons, elevation, and infrastructure (trails, roads, temples) on the distribution of visitors in ACA. The clusters of visitor images around major attractions and on trails and roads represent typical visitation patterns concentrated at specific sites (Wolf et al 2012). This can assist in future planning, including facilities for tourists, such as trails and accommodation and security arrangements, but also safe drinking water stations, waste disposal bins, information centers, signposts, and first aid centers that can enhance visitor experiences (Bajracharya 2011). Such detailed information on visitor use can also assist in monitoring the environmental and social impacts at popular times and places along with the provision of facilities and strategies to minimize impacts (Leung et al 2018). Assessing visitor carrying capacity for specific places could also be undertaken with management options, including restricting visitor use of some areas and promoting attractions in underused locations to disperse visitation (Leung et al 2018), while providing new economic opportunities in ACA. Flickr and other sources of social media data are also likely to be used by tourists when planning their trips (García-Palomares et al 2015), because people increasingly harness social media as more authentic and reliable sources of tourism information (Tas 2021).

Seasonality in tourism of mountain areas is common and reflects factors such as visitors' comfort and safety (Newsome et al 2012). Such seasonality has important implications for tourism and can result in unequal resource utilization and

revenue (Connel et al 2015; Choe et al 2019). In some protected areas, the length of tourist seasons has been expanded by developing new events and attractions suitable for "off-peak" times, such as cultural and food festivals, or alternative activities such as natural product harvesting, mountain biking in summer, and snow activities including skiing and ice skating in winter (Marković and Petrović 2013; Connel et al 2015). Some aspects of local culture and traditions in ACA are not well known to visitors (Apollo et al 2020), so cultural events similar to the Yartung (horse riding), Archery, Tiji, and Torkya festivals that are currently held in spring and autumn (Bajracharya 2011) could be further promoted including in off-peak times and in areas where tourism is currently limited. Different types of skiing are beginning to be promoted in Nepal including at Annapurna Base Camp in ACA (Ski Guides Nepal 2021) and may result in increased visitation in winter (Wengel 2020). Another recent tourism activity in Nepal is mountain biking, and this is also increasingly popular in ACA (Nepal Government 2021). Although mountain biking is currently offered commercially in spring and autumn in ACA, there is the potential to expand to summer (Wengel 2020).

Reflecting the steep and often inaccessible nature of much of ACA, nearly all the images on Flickr in ACA were taken on roads and trails. This differs from some other high-elevation mountain parks, such as in Argentina and Australia, where there is more use of areas off trails (Rossi et al 2019; Pickering et al 2020). Off-trail use of mountain areas by tourists can have environmental impacts, contributing to trail erosion and degradation due to trampling, which damages vegetation and compacts soils (Nepal 2003; Bajracharya 2011; Newsome et al 2012), with implications for visitor safety (Saunders et al 2019; Goh 2020). Motivation for off-trail movement includes pull factors, such as seeing and photographing animals, specific places, or views (Kolasinka et al 2015), or hunting (Castilho 2018), or to take shortcuts (Goh 2020). There are also push factors, such as avoiding dust and noise from traffic (Skach 2016) or overcrowding (Sim et al 2018), while some off-trail movement occurs by accident, when visitors miss trails and roads because of lack of signage (Bradford and McIntyre 2007) or because they misinterpret signs (Sever and Verbic 2018). Further research including surveying visitors and involving locals to observe the visitor behavior in ACA could identify what motivated people to leave trails, and hence what may be the most appropriate management responses (Leung et al 2018).

Social media can provide useful data for visitor monitoring (Wilkins et al 2021) with insights for ACA, as seen here. Some data are free and easily available, including highly accurate data about where and when people visited specific locations within parks (Wilkins et al 2021). It therefore offers additional ways to monitor visitation and manage protected areas, especially in remote and topographically complex locations such as mountains (Walden-Schreiner, Rossi, et al 2018). However, there are important limitations. Only a few visitors share their experience on social media or on a particular platform, and access to data from some platforms is increasingly limited (Walden-Schreiner, Rossi, et al 2018; Wilkins et al 2021). The popularity of different social media platforms also varies among regions and countries and over time (Barros, Moya-Gómez, and García-Palomares 2019; Wilkins et al 2021). For instance, Flickr is more popular with people from Europe and the United States than from Asia (Zaccomer and Grassetti 2017), while people in China tend to use Sina Weibo (Li et al 2020). For example, very few images about ACA on Flickr were posted by Nepalese, and few appeared to be from Chinese tourists, although they were increasingly visiting Nepal pre-COVID (Nepal Government 2020a). Also, younger, wealthier, and more educated people are more likely to use social media than others (Smith and Anderson 2018; Wilkins et al 2021). Although data for many popular protected areas are found on social media, this does not apply to all areas and all parks (Barros, Moya-Gómez, and García-Palomares 2019; Wilkins et al 2021). Finally, there are increasing ethical and privacy issues with the use of social media that need to be considered, particularly when collecting and using the data could be seen as profiling visitors (Pickering and Norman 2020; Di Minin et al 2021).

Conclusion

This study showed how geolocated social media images can be used for visitor monitoring in remote mountains and adds to the still limited literature on the use of social media data in monitoring visitors to protected areas (Wilkins et al 2021) and more generally in Nepal (Batala et al 2019; Sigdel 2020). It further highlighted how social media data can complement and, in some ways, expand on other methods, particularly when examining spatial and temporal patterns of visitation. This includes identifying visitor hotspots, seasonal variation, and the way infrastructure such as trails and roads shapes visitors' movements. Although there are important limitations, this can provide insights for visitor management in remote protected areas with fluctuating topography and high conservation value but where resources remain constrained, such as in Nepal.

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