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Using crowdsourced imagery to assess cultural ecosystem services in data-scarce urban contexts: The case of the metropolitan area of Cali, Colombia

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A R T I C L E I N F O

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A B S T R A C T

Sustainable urban and metropolitan planning is increasingly benefiting from differentiated assessments of ecosystem services. Cultural ecosystem services (CES) are particularly relevant for urban residents' mental and physical health, yet, quantification and mapping of CES are often challenging, especially so in the Global South. The use of social media data (SMD), which has recently gained importance for assessing CES at larger spatial and temporal scales, provides a promising entry point for mitigating this informational gap in land-use planning. However, its application is mainly limited to European and North American cases and rarely applied to data-scarce urban regions in the Global South, with South America as no exception. Addressing this geographical gap, this study assesses CES of urban green spaces in the city of Cali, Colombia, based on 1,686 crowdsourced and geolocated photographs, and compares those results with a metropolitan scale CES potential assessment based on expert opinions performed in a previous study. Despite some important limitations primarily related to Flickr as a data source, we demonstrate the utility of this approach, especially for understanding the fine-scale generation of CES by small green spaces located within the urban fabric that are overlooked in the metropolitan scale expert-based assessment. These green spaces are highly relevant as inner-city pockets for CES production, especially in the form of "existence value" and "aesthetic experiences", in contrast to green areas highlighted by experts at the metropolitan scale that serve primarily recreational purposes. Our results indicate the large potential of SMD-based CES assessment approaches for informing urban planning processes in the Global South.

1. Introduction

Ecosystem service (ES) assessments are quickly gaining importance for urban planning, including in the Global South (Lapointe et al., 2019; Leh et al., 2013; Nahuelhual et al., 2013). However, spatial data availability, especially on cultural ecosystem services (CES), is often limited. CES are understood here as the non-material benefits derived from and subject to relational values resulting from people's perceptions, valuation, and interactions with and within the green infrastructure (Chan et al., 2016). Important examples of CES are opportunities for outdoor recreation and aesthetic appreciation (Langemeyer et al., 2015; Martin et al., 2016; Pleasant et al., 2014; Willcock et al., 2016). Lack of consideration of CES in landscape and urban planning can lead to planning failures, as seen in Chan et al., (2012) and Tenerelli et al., (2016).

In the absence of empirical data of CES, expert-based methods such as the ES matrix model are frequently used to determine ES "supply" or "capacity," i.e., the potential to generate CES based on land-cover types (Jacobs et al., 2015). In addition to limitations stemming from expert biases (Amorim Maia et al. 2020; Langemeyer et al. 2018), most of such

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assessments rely on medium resolution regional spatial land-cover data, which tends to overlook smaller green areas embedded within the urban fabric, such as parks (Buitrago-Bermúdez et al., 2019), despite their critical importance for the local production of ES, especially CES (e.g., Burkhard & Maes, 2017; Locke & McPhearson, 2018; Ramírez-Gómez et al., 2015). High resolution data and approaches are required in this context. However, more accurate approaches to assess CES based on expert interviews or user surveys are expensive and difficult to implement, especially for larger geographic areas such as metropolitan regions (Bagstad et al., 2016; Dou et al., 2017).

Another critical issue stems from a discrepancy between the expert-based mapping of CES potential and the actual realisation—i.e., the "flow"—of such benefits (Andersson et al., 2019). Unlike regulating ES, which can be well determined based on biophysical characteristics, such as land-cover, the realisation of CES depends on a complex interaction between institutional settings, social preferences, and abilities as well as the availability of green spaces (Andersson et al., 2021). For instance, Langemeyer et al. (2018) observed a considerable mismatch between the landscape aesthetics potential suggested by local experts based on landscape characteristics and realisation estimates, particularly in urban and peri-urban areas based on a fine-grained assessment of social media data (SMD).

Considering methodologies, Ilieva & Mcphearson (2018) argue for a strong potential of sustainable urban planning approaches to benefit from the increasing availability of high resolution spatial and temporal SMD. SMD, including georeferenced photographs and tracks, allow for novel and cost-efficient approaches to identify and map the realisation of CES based on the observation of people's actual behaviour (Ghermandi & Sinclair, 2019). For example, Oteros-Rozas et al. (2017), using photographs posted to the photo sharing platforms Flickr and Panoramio, showed context-dependent preferences by looking at how landscape heterogeneity is related to CES diversity in five different landscapes in Europe. Donahue et al. (2018) used SMD to characterise park use in order to inform green space management in the Twin Cities (Minneapolis and Saint Paul), Minnesota, United States. While SMD-based CES assessments are increasingly used in urban or metropolitan areas in Europe, North America (e.g., Calcagni et al., in this issue; Donahue et al., 2018; Oteros-Rozas et al., 2017, 2018; Tammi et al., 2017), and parts of Asia, including Singapore and Japan (e.g., Richards & Friess, 2015; Thiagarajah et al., 2015; Yoshimura & Hiura, 2017), these approaches have not yet been well tested for cities in the Global South.

In most developing regions, the use of SMD to map CES is still at its infancy and often not well aligned with local planning needs. In Africa, SMD has so far been mainly used for assessing the influence of wildlife hotspots on the attractiveness of protected areas (Hausmann et al., 2018; Willemen et al., 2015). In South America, SMD has been used to map CES mostly in the southern and eastern parts of the continent, including Argentina, Ecuador, Chile, and Brazil, addressing primarily rural areas (see Catana, 2016; Kong and Sarmiento, 2022, in this issue, Martínez-Harms et al., 2018; Martínez-Pastur et al., 2015 respectively). Ghermandi et al. (2020) studied visitation and benefits of natural and cultural heritage sites in Mexico using SMD. Yet, the potential for using SMD to assess CES as a response to the stated need for spatially explicit CES assessments (La Rosa et al., 2016; Nahuelhual et al., 2014) and in order to support urban planning, has not been widely explored anywhere in South America.

In this study, we examined the potential of applying SMD-based CES assessments in urban planning and decision-making processes in Colombia, South America. Reports on CES in Colombia include Escobedo et al. (2020), who examined perceptions and spatial literacy in identifying urban and peri-urban types of ES—including aesthetics value CES—based on interviews, quantitative machine-learning statistics, and qualitative methods. In another article, Angarita-Baéz et al. (2017) studied the perceptions of CES among indigenous populations in the Colombian Amazon by conducting semi-structured surveys. Other researchers have addressed impacts of human activities on CES of wetlands related to ecotourism and education by using a participatory rural assessment, participatory mapping methods, and interviews (Ricaurte et al., 2014, 2017; Toledo et al., 2018). De Juan et al (2020), who analysed photographs from Instagram to assess the CES most valued by visitors of the Tairona National Park, conducted so far the only SMD-based study of which we are aware.

Our study in the metropolitan area of Cali—as a case study area—based on SMD derived from the photo-sharing platform Flickr (https://www.flickr.com/) and related to CES, is the first SMD-based study in an urban context in South America. The study objectives were twofold: (1) We aimed to map the realisation of CES in a high resolution, spatially explicit manner, and (2) to facilitate the uptake of SMD assessments by urban planning, comparing them with results of an expert-based estimation of CES potentials based on land-cover maps—still the most common approach for incorporating CES in to urban planning at a metropolitan scale (Buitrago-Bermúdez et al., 2019)—and with fine-grain land-cover data to indicate the green spaces most important in fostering the realisation of CES.

2. Material and methods

2.1. Case study area

The case study area is the metropolitan area of Cali (MAC), located in the southwest of Colombia in the valley of the Cauca River, with an area of about 8,500 km^2 (see Fig. 1-B). The MAC is an example of a large Andean metropolis, including 30 municipalities and 30 watersheds, that ranges in altitude from 702 to 4,723 masl. According to the National Administrative Department of Statistics (DANE, 2020) its population in 2018 was about 4.2 million people (516 inhabitants/km^2), mostly concentrated in the city of Cali (57 %) (see Fig. 1-C). In the absence of a political-administrative metropolitan area, the MAC has been defined by Tabares-Mosquera et al. (2020) as a social-ecological system (*sensus* Berkes & Folke, 1998) based on urban-functional and biophysical (watersheds) criteria, and high social and ecological connections and interdependencies.

According to the land cover map developed by Buitrago-Bermúdez et al. (2019), which applied the Corine Land Cover legend adapted to Colombia (IDEAM, 2010), the MAC is characterised by 28 different land cover types, 21 of which were identified as natural or semi-natural. The map was created at a 1:25,000 scale using a minimum mapping unit of one hectare (Salitchev, 1979).

2.2. Assessing the realisation of CES

In this study we use geolocated photographs from within the MAC posted on Flickr between 2004 and 2018. Flickr is a well-known photo-sharing platform with about 90 million monthly users (cf. 101 Toivonen et al., 2019); its content has been widely used around the world for assessing the realisation of CES in a spatially explicit manner (e.g., Angradi et al., 2018; Donahue et al., 2018; Dunkel, 2015; Martínez-Harms et al., 2018; Tenerelli et al., 2016; Yoshimura & Hiura, 2017). Similarly to other studies (e. g. Gliozzo et al., 2016; Langemeyer et al., 2018; Amorim Maia et al., 2020), we assume that photographs shared online represent what people enjoy doing or seeing and what is believed to align with shared social values (Calcagni et al., 2019). Filtering photographs for natural elements and human-nature experiences can thus be assumed to be a relevant proxy for representing the realisation of CES—i.e., "the actual production of a service experienced by people" (Villamagna et al., 2013) based on the appreciation of and beneficial relationships with or within nature (Chan et al., 2016), including a full range of human-designed to pristine ecosystems.

Access to public geotagged photographs is relatively easy via the Flickr Application Programming Interface (API). Unlike other SMD platforms, such as Facebook and Instagram, which have more restrictive

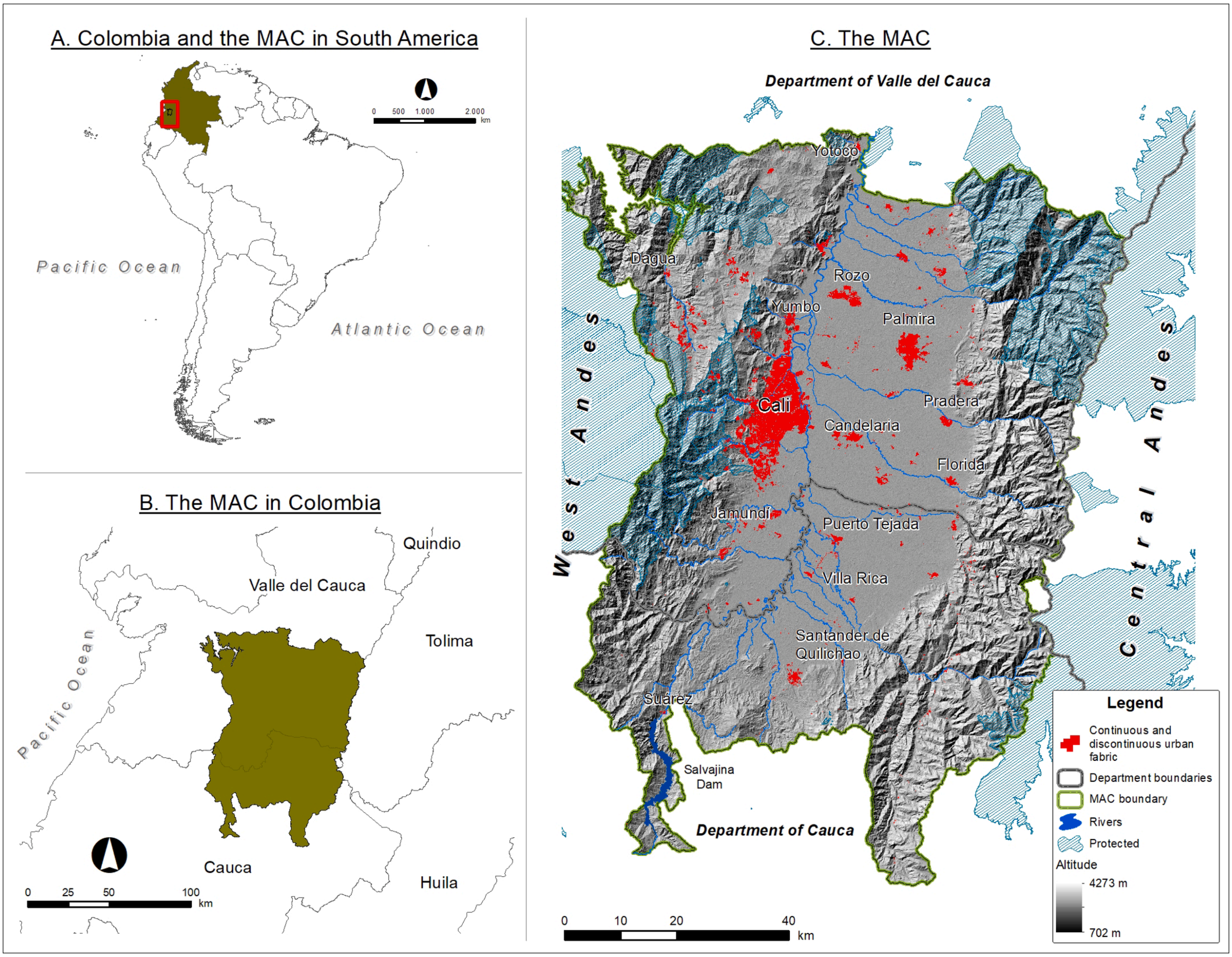

Fig. 1. Location of the MAC and the city of Cali in Colombia, South America.

regulations for access and terms of use, Flickr widely permits the use of its data for scientific research (e.g., Ghermandi & Sinclair, 2019). On the other hand, there are some known biases about Flickr data, including a disproportional use of the social network by males (O'Hare and Murdock, 2012). Particular biases for South America are not known to us, beyond the limitation of Flickr being less popular in that part of the world compared to Europe and North America.

The visual content of the retrieved photographs was manually coded (adapting methodological approaches applied by Amorim Maia et al., 2020; Hollenstein & Purves, 2010; Langemeyer et al., 2018; Tenerelli et al., 2016, Tenerelli et al., 2017) and classified according to the Common International Classification of Ecosystem Services (CICES) 5.1 (Haines-Young & Potschin-Young, 2018). Three categories of CES were considereed: 1) activities promoting health, recuperation, or enjoyment through active or immersive interactions—henceforth, recreational activities—; 2) aesthetic experiences; and 3) existence value (see also Table 1). The selection of these three CES resulted from an initial screening of the content of photographs.

All duplicate photographs and photographs with irrelevant content (e.g., taken indoors, selfies, etc.) were excluded from the analysis. Given the relatively low number of relevant photographs, similarly to Calcagni et al. (in this issue), we did not apply the photo-user-day (PUD) approach, which is commonly used with bigger datasets, to avoid a high influence on the results by very active individual users (Martínez-Harms et al., 2018; Wood et al., 2013).

Table 1
CICES classes: Simple descriptors and sample services. Based on Haines-Young & Potschin-Young (2018).

CICES 5.1. classes	Simple descriptor	Example CES	Coding
Recreational activities (activities promoting health, recuperation, or enjoyment through active or immersive interactions)	Using the environment for sport and recreation; using nature to help stay fit	Ecological qualities of woodland that make it attractive to hike; private gardens or opportunities for diving, swimming	Pictures representing activities such as biking, running, swimming, hiking
Aesthetic experiences	The beauty of nature	Areas of outstanding natural beauty; panoramic views	Panoramic or landscape pictures
Existence value	The things in nature that we think should be conserved	Wilderness; charismatic wildlife	"Close-up" pictures of plants or animals

Photographs were assigned to the CES "recreational activities" if the features represented therein were related to enjoyment and engagement with nature when triggered by sports or other physical activities. These activities are associated with benefits such as good health as well as physical and mental well-being. Examples of this CES in photographs from the MAC were people climbing mountains and walking, cycling, or running through natural environments. Photographs were coded as “aesthetic experiences” if they depicted intellectual interactions with nature—most commonly images conveying the beauty of the biophysical characteristics or qualities of certain ecosystems. Many photographs in this CES category consisted of sightseeing places (i.e., panoramic images, sunrises, and sunsets), which reflected benefits such as pleasure and inspiration. Finally, the CES “existence value” was coded in photographs representing living systems that generated sentiments of appreciation for their existence. Most of these photographs included “close-ups” of flowers and/or animals (some of them in the context of the city zoo). Even though the zoo can be seen as a place for utilitarian engagement with nature, this does not exclude non-use values, such as existence values, to arise together with experiential and outdoor tourism values. To differentiate between the two, we assume that the pictures indicate a specific importance given to the “existence” of the depicted element of the natural system—based on the eco-centric perspective, which emphasizes the intrinsic value of nature (Rea & Munns, 2017; Scholte et al., 2016)—while experiential values potentially are represented by the number of visitors to the zoo facility (Chan, 2012).

ArcGIS 10.6 software was used to create photo count vector grid maps for each CES. To do so, we used the *Joint Count* output of the Optimised Hot Spot Analysis tool from ArcGIS (ESRI, 2018) to aggregate photographs located within a vector grid of 1 × 1 km square size. Sum of photos was based on Eq. (1) after Langemeyer et al. (2018):

$$f_{i,tot} = \sum_{i} Pi$$

where $f_{i,t}$ is the CES realisation in the grid cell i given by the sum of photos geolocated in the same grid cell, Pi.

2.3. 2.3. Comparing CES potentials and realisation

This second part of our analysis builds on a land cover-based CES potential assessment performed by Buitrago-Bermúdez et al. (2019), consistent with CICES 4.3 (Haines-Young & Potschin-Young, 2013) and thus comparable to the social-media based assessment of CES realisation for which our study uses the updated but back-compatible classification by Haines-Young & Potschin-Young (2018).

To facilitate the comparison of the land cover-based potential assessment and the CES realisation at the metropolitan scale, we created tables with three columns: *CES realisation* (i.e., number of photographs that fell into each land cover category); *normalised CES realisation* (i.e., realisation divided by land cover area—number of photographs/land cover area [km^2]—to determine whether the realisation of CES was high ($\geq 3^{rd}$ quartile of the normalised CES realisation range; Fig. 4), medium (between 1st and 3rd quartile), or low ($\leq 1^{st}$ quartile); and expert-estimations of *potentials to provide CES* (i.e., land cover-based assessment of CES potential).

Lastly, we evaluated the city level CES realisation by overlapping the resulting map with high-resolution spatial land cover data from the Alcaldía de Santiago de Cali (2014). To assess the types of urban green areas associated with the realisation of CES within the city of Cali, it was necessary to use land cover data on a finer scale than the 1:25,000 spatial scale of the MAC land cover map. Instead, we used spatial data from the *Plan de Ordenamiento Territorial* of Cali (Alcaldía de Santiago de Cali, 2014) to identify parks, ecological corridors, wetlands, and recreational areas.

3. Results

The spatial distribution of the photographs within the MAC is shown in Fig. 2. The total amount of photographs uploaded to Flickr from

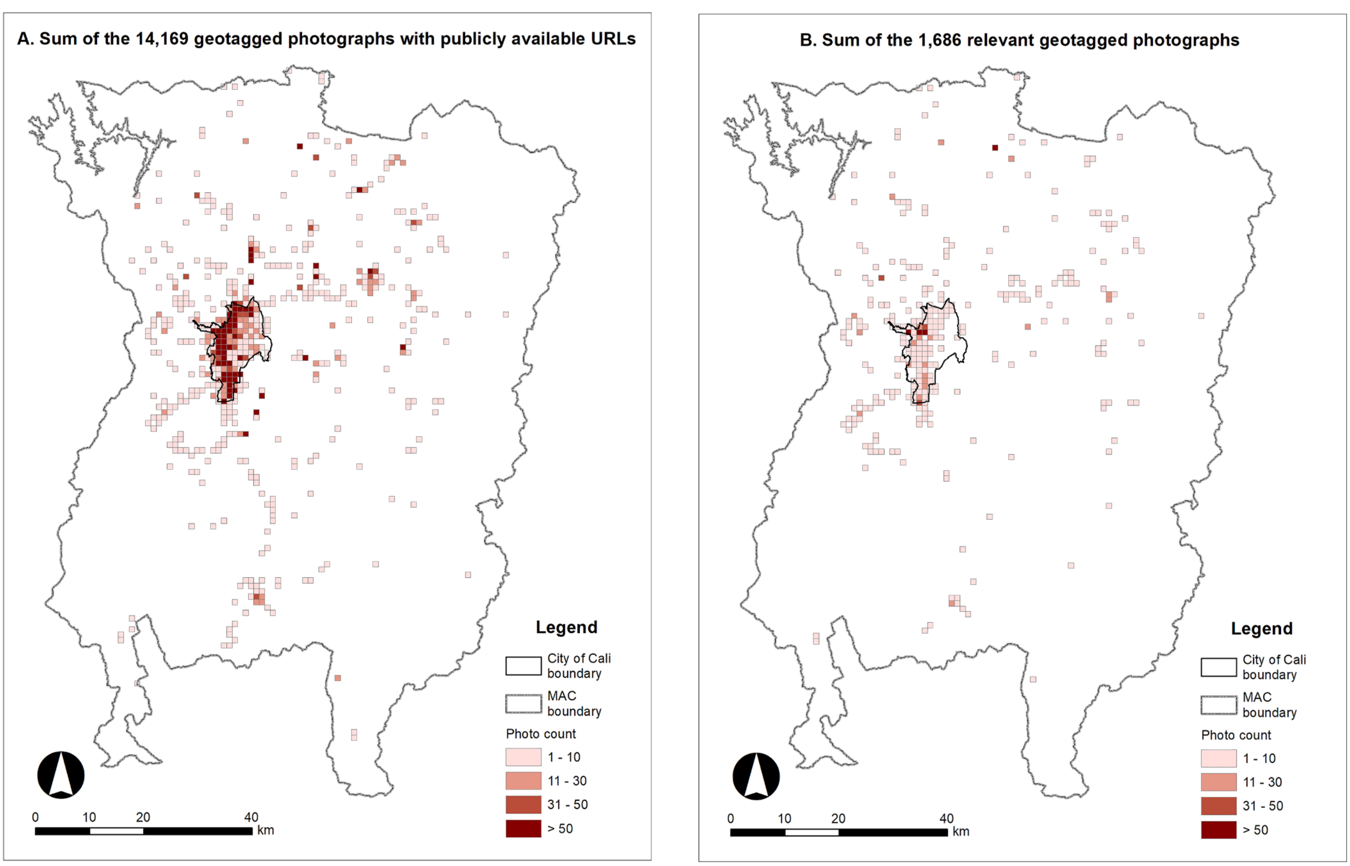

Fig. 2. Photo count of the geotagged photographs from Flickr in a vector grid of 1 × 1 km per square.

December 2004 to June 2018 and located within the study area was 20,537 (Fig. 2A). Of these, 14,169 photographs had publicly-available URLs at the time of the assessment in August 2018 (Fig. 2B) and were therefore accessible for the study. Out of these 14,169 photographs, we classified 1,686 (12 %) as relevant—i.e., representing the realisation of CES—and further classified them with regard to their content into one of the three CES categories considered in this study (Table 1). The density of relevant photographs reached more than 1,000 photographs/km^2 in some areas of the city of Cali. About half of them (52 %) were classified as "existence value", followed by "aesthetic experiences" (39 %), and "recreational activities" (9 %) Fig. 3.

3.1. Comparison at the metropolitan area of Cali scale

Photographs representing "existence value" were widespread in the northern part of the MAC, but mostly present within the city of Cali. More precisely, 12 % (104) of the photographs fell into urban green areas (with a high normalised realisation; Fig. 4);, 26 % (231) were located in the continuous urban fabric, which in the expert estimation based on land-covers was not considered to have any potential to provide CES, and 32.3 % (281) in pastures (Fig. 4). Another land cover that stands out is "industrial or commercial units" which, despite having a low number of photographs and reporting zero potential to provide CES, its normalised realisation is high compared to other land covers (Fig. 4).

With regard to "aesthetic experiences", the distribution pattern of the photographs is quite similar to that of "existence value". The city of Cali and its surroundings account for most of the photos and the highest numbers are found in the north-western part of the city (Appendix A). A total of 662 photographs were assigned to this CES. Urban green areas have a high normalised realisation (82 photos, or 12.3 %), followed by industrial or commercial units (27 photos, also with a high normalised realisation) and, finally, continuous urban fabric contains most of the

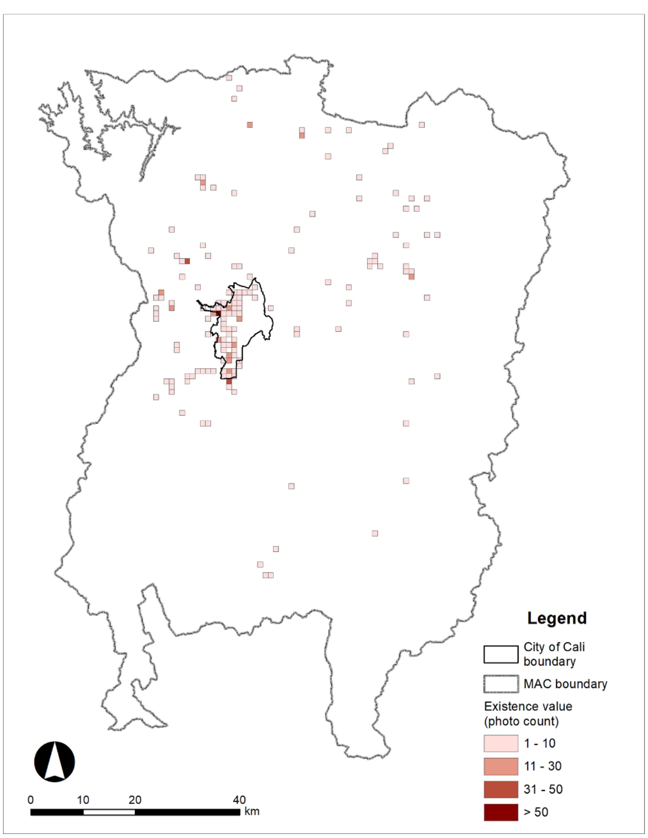

Fig. 3. Photo count of the "existence value" CES. Sum of photographs at the vector grid level (1 × 1 km per square).

photographs (287, 43.3 % of the total and medium normalised realisation) (Appendix B).

Furthermore, 154 photos were classified under "recreational activities". Once again, most photos are found within Cali and its surroundings (Appendix C), mainly within three land covers: recreation facilities (3.9 % of the photographs, with a high normalised realisation), followed by urban green areas (6.5 %), and continuous urban fabric (27 %), both with a high normalised realisation but with differences in the potential to provide CES—4.8 and zero, respectively. Most photos are located within the sugar cane land cover (47.4 % of the total), however this land cover has a medium normalised realisation and its potential to provide CES is 1 over 5 (Appendix D).

3.2. Spatial patterns of CES realisation at the city scale

When analysing the realisation of CES in relation to the high-resolution land cover map from Cali's *Plan de Ordenamiento Territorial*, we observed that only 425 photographs—approximately a third of the relevant pictures (i.e., 1,686 photographs)—intersected with one of the four types of land covers associated with urban green areas at the city scale (see Fig. 5). The CES "existence value" reported 366 associated photographs at the city scale (86 % of the total number), while the CES "aesthetic experiences" reported 59 photographs (14 %).

Fig. 5 shows that photographs are distributed within the north-western and southern extremes of the city (322 and 103 photos respectively). In the north-west, 289 photographs were taken in the *Zoológico de Cali,* 6.6 % of them associated to "existence value" and 3.4 % to "aesthetic experiences" (Fig. 5). The remaining land covers had low numbers of photos (under 11) and three of them only reported photographs for "aesthetic experiences" (i.e., *El Aguacatal* and *Cristo Rey* parks, and the *Río Cali* ecological corridor). On the other hand, in the southern part of the city, the *Las Garzas* wetland registered most of the photographs (64 in total) of which 92.2 % were associated to "existence value" and 7.8 % to "aesthetic experiences". The remaining land covers reported less than eight photographs (Fig. 5).

4. Discussion

4.1. Mismatches of CES potential and realisation in the metropolitan area of Cali

One important finding of our SMD-based assessment is the mismatch between the (high) potential to provide CES estimated by Buitrago-Bermúdez et al. (2019) for most of the land covers and the low normalised CES realisation based on the analysis of photographs posted to Flickr. This is the case for dense forests, grasslands located in paramos, rivers, and the two different types of mosaic landscapes (i.e., mosaic of crops, pastures and natural spaces, and mosaic of pastures with natural spaces). The only exception is related to urban green areas, which reported both high CES potential and high normalised realisation. The distribution of population density is likely a key driver explaining this observed pattern, which corroborates comparable studies from Europe that found peri-urban areas to be most relevant for sustaining CES (e.g., Baró et al., 2016; Langemeyer et al., 2018).

This pattern could likely be attributed to barriers in terms of accessing and obtaining CES related to institutional settings, people's perceptions, and biophysical infrastructure (Andersson et al., 2021; Wolff, 2021). Through this understanding, institutional factors, in the form of access restrictions and non-public ownership, might constitute a major obstacle for the use of peri-urban green spaces in the MAC. For instance, environmental protection (e.g., regional, and national natural parks) seems to constrain CES realisation. There is evidence that protected areas can create a barrier for people to access ecosystem services when safeguarding biodiversity from human threats results in the exclusion of people from these areas with high CES potential (Mcdonald et al., 2008; Palomo et al., 2011).

Land cover	CES realisation (# of photographs)	Normalised realisation (# of photographs / Area [km^2])	Potential to provide CES in the metropolitan scale assessment (0 to 5)
Mosaic of pastures with natural spaces	8	0.020	3.9
Sugar cane	43	0.022	0.9
Dense forest	23	0.024	5
Wood pastures	3	0.025	2.9
Secondary or transition vegetation	17	0.036	2.6
Fragmented forest	37	0.045	3.4
Riparian forest	3	0.050	4
Transitory crops	7	0.082	2.7
Mosaic of crops, pastures and natural spaces	68	0.089	4.3
Artificial water bodies	2	0.089	2.8
Other permanent crops	9	0.090	3
Pastures	281	0.207	1.1
Discontinuous urban fabric	18	0.225	0
Industrial or commercial units	16	1.273	0
Continuous urban fabric	231	1.387	0
Urban green areas	104	4.414	4.8

Fig. 4. Comparison of land cover-based potential for "existence value" CES and CES realisation at the MAC scale. Normalised realisation was calculated dividing CES realisation by land cover area (i.e., number of photographs/land cover area [km^2]) to determine whether the realisation was high (≥3rd quartile [blue]), medium (between 1st and 3rd quartile [yellow]), or low (≤1st quartile [orange]). Elaborated by the authors based on data of land cover-based CES potential assessed by Buitrago-Bermúdez et al. (2019).

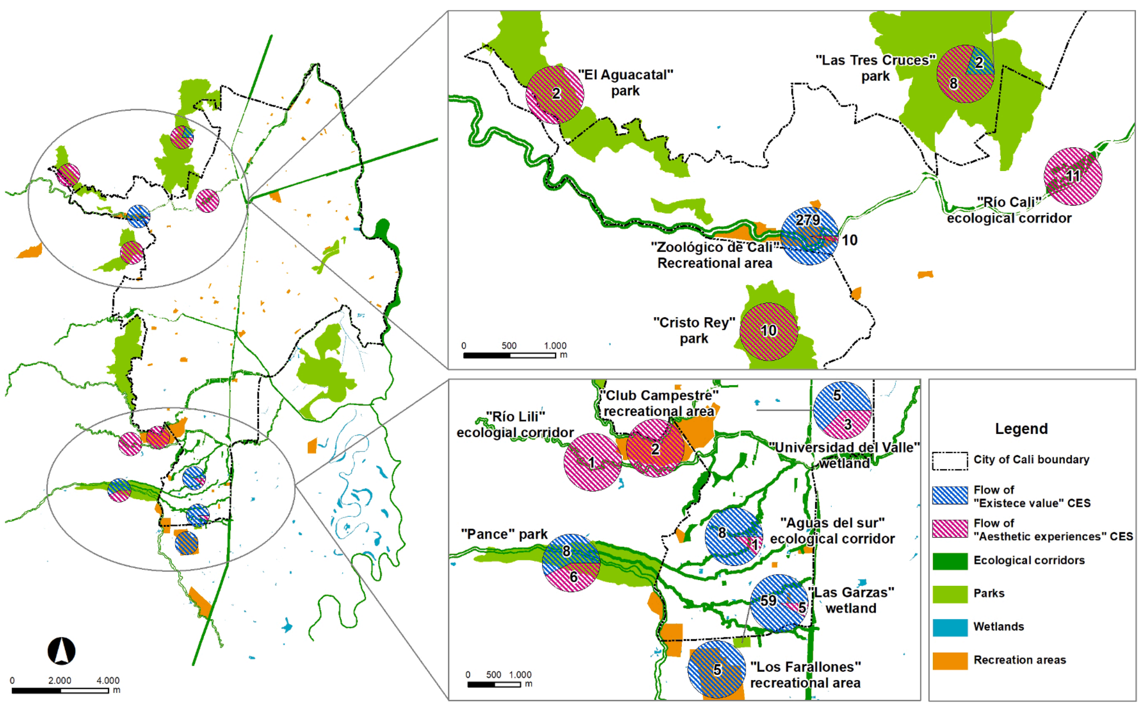

Fig. 5. Number of photographs per land cover in the city of Cali. Elaborated by the authors based on data from Cali's *Plan de Ordenamiento Territorial* (Alcaldía de Santiago de Cali, 2014).

That a considerable realisation of CES was concentrated in the north-western part of the city of Cali cannot be related directly to a particular land-cover (or green space) type but might be better explained by aspects associated to perception—more specifically, perception of security or the lack thereof. While crime events, such as robbery and homicides, are more frequently associated with the city centre and the eastern part of the city, the north-western area is generally perceived as safer (Alcaldía de Santiago de Cali, 2011; Loaiza-Cerón, 2012). Safety perceptions might be a significant barrier or enabling factor for the realisation of CES in many South American cities, which historically have been characterised by having some of the highest crime rates in the world (Soares & Naritomi, 2013).

In our study, and in line with other studies on urban CES (e.g., Amorim Maia et al., 2020; Langemeyer et al., 2018), high profile infrastructure seemed to influence the realisation of CES. For instance, the *Zoológico de Cali*, located in the north-western part of the city, was the source of 68 % of the photographs related to the "existence value" and "aesthetic experiences", while the *Las Garzas* wetland in the south Cali suburbs was the source of 15 % of the photographs. This concentration of pictures in these photogenic destinations could be attributed to the fact that people are less likely to take photographs in neighbourhood or pocket parks, used for daily recreation. Follow-up research, for instance through grounding surveys (e.g., Winder et al., 2021), will have to confirm this assumption.

4.2. CES assessments in South American cities

Our assessment underscores the need for finer-scale land cover data in South American cities to better understand the generation of CES. The analysis of the realisation of CES in urban green areas of the MAC allows for differentiating the land covers related to such realisation, in line with the relationship between land cover diversity and CES diversity (Oteros-Rozas et al., 2018).

Nevertheless, our results remain partly inconclusive at the scale of the MAC due to the relatively low number of photographs available from Flickr. But the SMD-based analysis allowed us to identify spatial patterns of the realisation of CES in the city of Cali, showing higher realisation levels in the northern and southern parts of the city associated with the zoo and a wetland (see Fig. 5). This was interpreted thanks to the use of land cover data from Cali's *Plan de Ordenamiento Territorial*, which allowed us to identify more specific urban green areas supporting CES (i.e., parks, ecological corridors, wetlands, and recreational areas). Therefore, the city-scale analysis clearly underlined the need for the use of finer-resolution land cover data (Locke & McPhearson, 2018), which considers small urban green areas in Cali, such as pocket parks, as these are expected to be critical providers of CES. Projects similar to the European Urban Atlas (Copernicus Land Monitoring Service, 2021) could be developed for Colombia and other South America cities to stimulate spatial data required for urban planning.

Compared to similar exercises developed in European studies (Langemeyer et al., 2018; Tenerelli et al., 2016, Tenerelli et al., 2017), the final number of relevant photographs was low compared to the total amount of SMD for the area. Clearly there are many photographs that do not explicitly or implicitly include CES content. However, compared to the amount of data collected through traditional subject methods, such as surveys or interviews, studies based on SMD are cost- and time-effective in terms of data collection (Ghermandi & Sinclair, 2019). In this specific case, SMD provides a starting point to understand CES realised by residents and visitors to the MAC, which, according to our findings, is mostly provided by urban ecosystems located close to urban areas (i.e., urban parks, green corridors, and other urban green spaces), in contrast with a wider range of opportunities observed in different cities of North America (Donahue et al., 2018).

4.3. Future research needs

In contexts in which SMD analyses are not yet highly developed, exploratory studies can serve as a first indicator of the usefulness of SMD-based methodologies (Martínez-Harms et al., 2018; Martínez-Pastur et al., 2015). In this sense, our research serves as a pilot study for the use of SMD in South American urban and metropolitan areas. While indicating the general usefulness of SMD to assess the realisation of CES in data-scarce urban contexts like South America, it also highlights several needs for future research.

Although we applied a methodology widely used and validated elsewhere (Dunkel, 2015; Langemeyer et al., 2018; Richards & Friess, 2015), in South America Flickr is used less than other SMD platforms. Thus, including other such platforms in the study (e.g., Instagram, Facebook, or Twitter) would probably provide more relevant data (Mejia-Llano, 2020). As can be observed in Fig. 6, in the context of the MAC, 2013 was the only year within the period assessed—i.e., 2004 to 2018—that exceeded 200 Flickr photos for the "existence value" CES. Overall, that CES was the most represented in the study area, followed by the "aesthetics experiences" and "recreational activities" CES. This situation underscores the need for other SMD sources in the given context.

It is also likely that the low use of Flickr as a social photo-sharing network in Colombia (Flickr, 2020), in comparison with European and North American countries, has played a role in the non-identification of CES in some land covers with high potential to provide CES (e.g., continuous urban fabric and industrial or commercial units). Therefore, the legal restrictions on the use of data for research as established by Facebook or Instagram—which have proven to be more widely used in the Colombian context (Bailey et al., 2018; Mejia-Llano, 2020—unequally hamper CES research in developing countries such as Colombia, compared to Europe and North America (Calcagni et al., 2019; Wood et al., 2013). In recent years, the steady increase in the number of studies showing the usefulness of public good research has contributed to the revision of Twitter's data accessibility policy. The case of Cali presented in this study further corroborates this stand and might contribute to inspire other platforms to support open science and grant wider access to their data streams.

Furthermore, this study reinforces the need for (mis)match assessments between CES potential and the actual realisation of CES as already highlighted in previous studies (e.g., Baró et al., 2016; Schröter et al., 2014; Langemeyer et al., 2018) while also complementing them by analysing these mismatches at two different urban scales. This research has proven that SMD data can fill in data gaps of coarser land cover-based approaches for mapping CES. Identifying mismatches between the realisation of CES and the potential to provide CES thus requires the use of even finer land cover data. Future research should consider alternative land-cover data, such as Open Street Maps (OSM, 2020), to complement the official data provided by the city's administration (Levin et al., 2017; Upton et al., 2015).

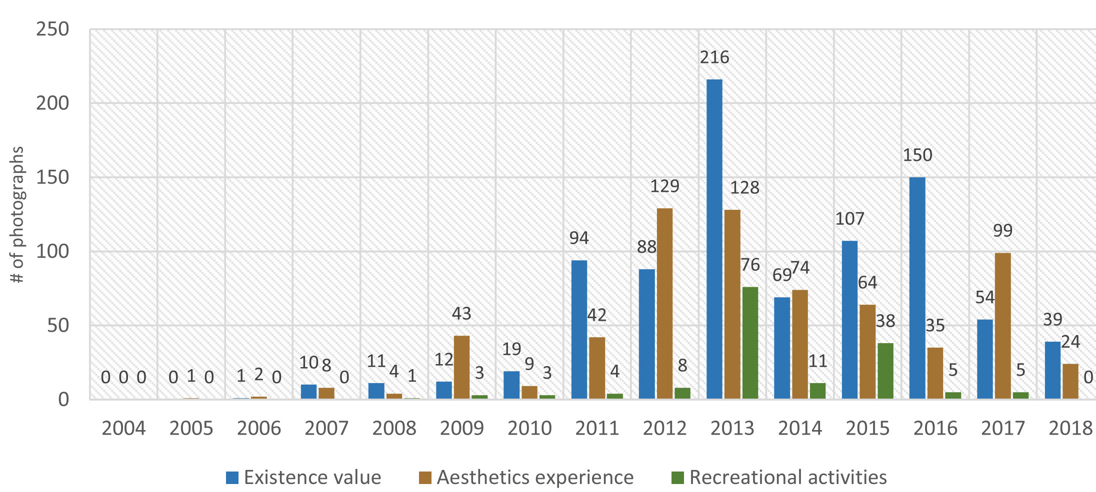

Fig. 6. Number of photographs per year from 2004 to 2018 in the MAC.

5. Conclusions

This study is a novel application of SMD approaches related to CES in the urban context of Colombia and other developing countries in the Global South with a focus on South America, where studies have been carried out mainly in rural and protected areas. A finding related to CES in Cali is the potential for assessing CES through SMD to better inform the urban planning process. This approach provides data insights that would be difficult and expensive to collect through other commonly used means, such as expert interviews or user surveys.

This paper sheds light on an alternative way for data collection to inform decision-making processes related to urban green infrastructure planning at the metropolitan and city scales in the Global South. We believe that this field of research can be further developed and boosted with additional studies in the coming years, both in Colombia and in South America. To achieve that, the contribution of SMD to urban planning processes must be better acknowledged.

In the field of urban ecosystem service research, it is fundamental to implement approaches that compare potential and realisation assessments of CES at different spatial scales to quantify the actual use of urban green areas by urban residents. In our study, high-resolution spatial data was necessary for understanding the spatial patterns of urban CES realisation.

Ethics statement

Flickr data were collected through the Flickr API complying with Flickr's terms of service. To reinforce the anonymity, and guarantee to Flickr users, we applied safety precautions to the only computer containing all data. Individual data and spatial data had always been stored separately, guaranteeing fully anonymized data sets. The most sensitive of this data, such as names and places of residence, was removed once the assessment had finished. Concerns on whether data should be considered public or private underlie an ongoing ethical debate that, to date restricts data access to social media researchers. Even in the absence of a common and clear ethical framework, given the relevant information that it facilitates, the debate about the scientific use of social media data must continue in motion.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix. A

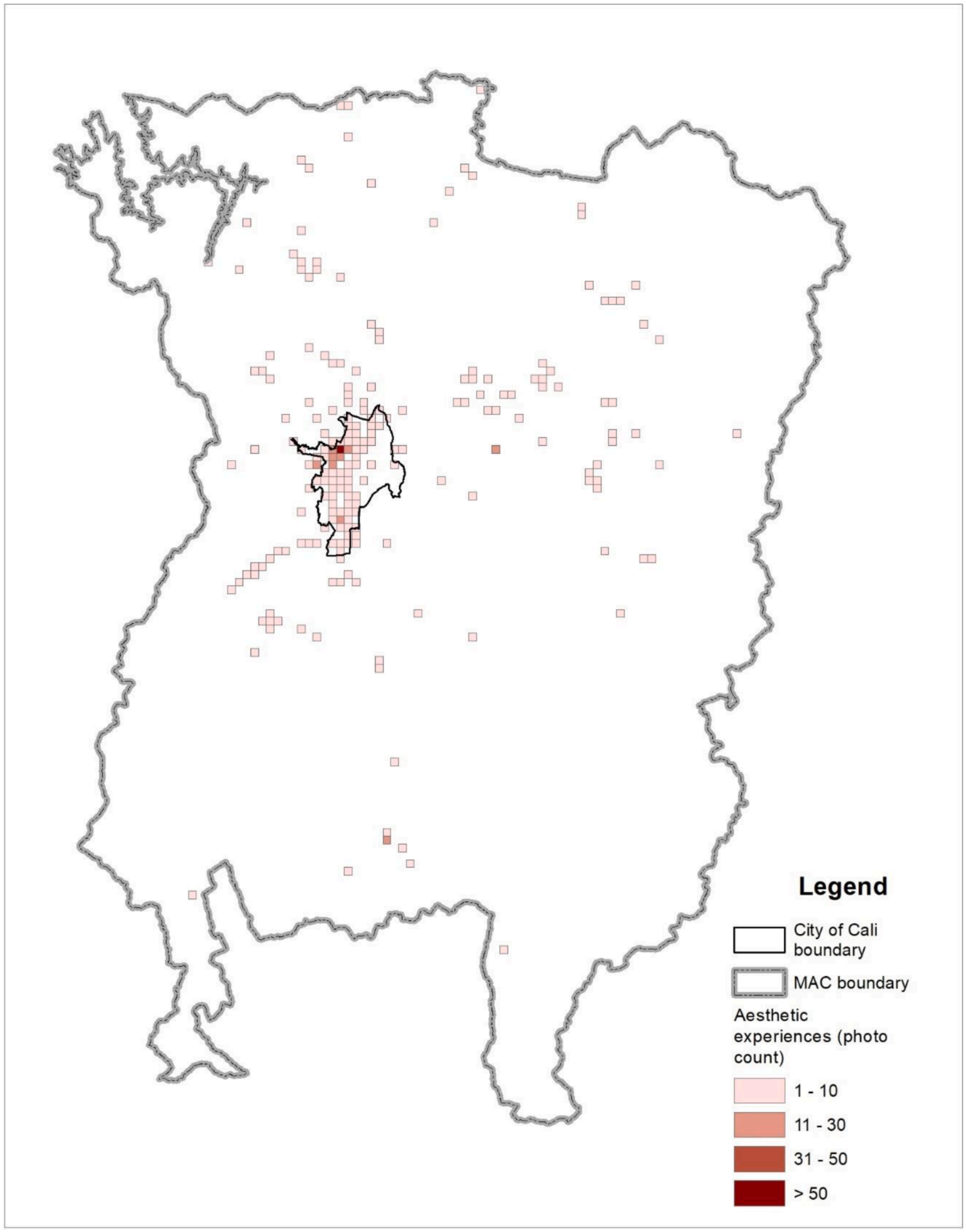

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Photo count of the "aesthetic experiences" CES. Sum of photographs at the vector grid level (1 × 1 km per square).

Appendix B

Land cover	CES realisation (# of photographs)	Normalised realisation (# of photographs / Area [km^2])	Potential to provide CES in the metropolitan scale assessment (0 to 5)
Grassland (paramo ecosystem)	1	0.002	4.6
Dense forest	10	0.011	5
Secondary or transition vegetation	9	0.019	2.9
Mosaic of crops, pastures and natural spaces	16	0.021	4.3
Bare and degraded lands	1	0.027	0.4
Pastures	47	0.035	1.7
Transitory crops	3	0.035	2.7
Fragmented forest	29	0.035	3.6
Sugar cane	73	0.038	1.9
Wood pastures	5	0.041	3
Mosaic of pastures with natural spaces	17	0.042	4.3
Other permanent crops	5	0.050	3.6
Rivers	2	0.065	4.3
Mining extraction areas	1	0.077	0
Forest plantation	11	0.090	2.7
Riparian forest	11	0.185	3.9
Discontinuous urban fabric	22	0.275	0
Recreation facilities	3	0.343	3.2
Continuous urban fabric	287	1.724	0
Industrial or commercial units	27	2.149	0
Urban green areas	82	3.480	4.6

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Land cover-based potential for “aesthetic experiences” CES and CES realisation comparison at the MAC scale. Normalised realisation was calculated dividing CES realisation by land cover area (i.e., number of photographs/land cover area [km^2]) to determine whether the realisation was high (≥3rd quartile [blue]), medium (between 1st and 3rd quartile [yellow]), or low (≤1st quartile [orange]). Elaborated by the authors based on data of land cover-based CES potential assessed by Buitrago-Bermúdez et al. (2019).

Appendix C

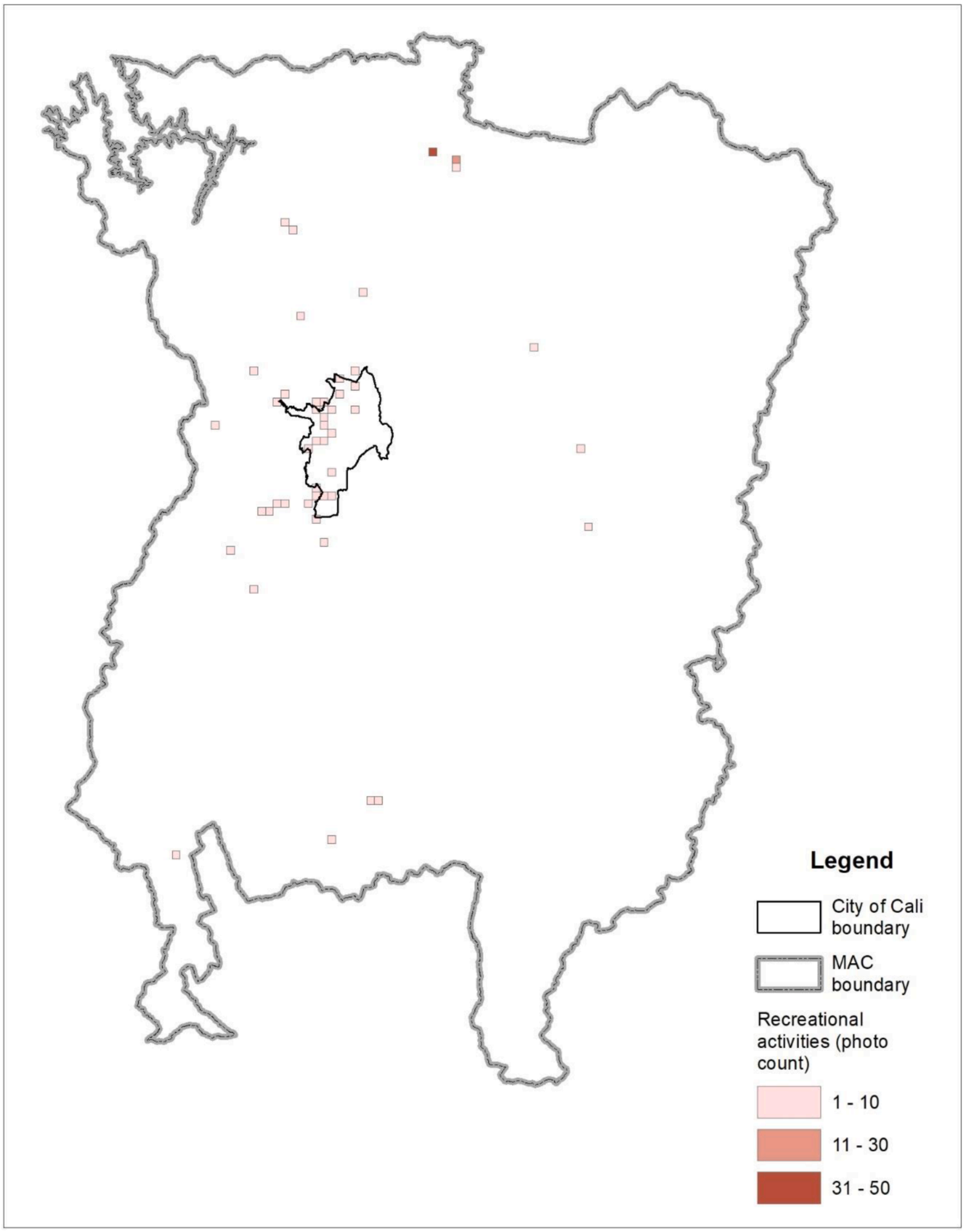

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Photo count of the “Recreational activities” CES. Sum of photographs at the vector grid level (1 × 1 km per square).

Appendix D

Land cover	CES realisation (# of photographs)	Normalised realisation (# of photographs / Area [km^2])	Potential to provide CES in the metropolitan scale assessment (0 to 5)
Fragmented forest	822	0.004	3.4
Pastures	1355	0.004	1.9
Secondary or transition vegetation	472	0.008	2.9
Discontinuous urban fabric	80	0.012	0
Dense forest	947	0.014	4.7
Riparian forest	60	0.017	3.7
Sugar cane	1935	0.038	1
Continuous urban fabric	166	0.222	0
Urban green areas	24	0.424	4.8
Recreation facilities	9	0.685	4

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Land cover-based potential for "recreational activities" CES and CES realisation comparison at the MAC scale. Normalised realisation was calculated dividing CES realisation by land cover area (i.e., number of photographs/land cover area [km^2]) to determine whether the realisation was high (≥3rd quartile [blue]), medium (between 1st and 3rd quartile [yellow]), or low (≤1st quartile [orange]). Elaborated by the authors based on data of land cover-based CES potential assessed by Buitrago-Bermúdez et al. (2019).

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