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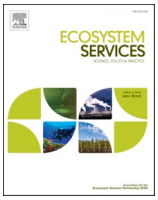

Public participation GIS versus geolocated social media data to assess urban cultural ecosystem services: Instances of complementarity

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ABSTRACT

Cultural ecosystem services (CES) are important components of urban quality of life. Public participation GIS (PPGIS) is widely used to assess and map these services. However, it is often a time-consuming exercise with which only small spatial and temporal scales can be addressed. Assessments based on geolocated, passively crowdsourced data from social media present new opportunities to assess CES through a large amount of available data and for broad spatial and temporal scales. We assess the potential of these two methods to substitute, supplement or complement each other in terms of the qualitative information they provide (i.e., landscape features of interest and CES). We take as a case study seven green and blue open spaces of the city of Haifa (Israel), each presenting different elements of interest in the landscape and degrees of accessibility. Results indicate that the two methods provide unique results and are complementary in many instances. We discuss the representativeness of the social media data, the strength of the two methods with respect to the qualitative information obtained, the specificities related to the urban context and the instances of complementarity. We suggest that crowdsourced social media data should be included in broad, multi-methodological approaches to CES.

1. Introduction

Cultural ecosystem services (CES), defined as "all the non-material, and normally non-rival and non-consumptive, outputs of ecosystems (biotic and abiotic) that affect physical and mental states of people" (Haines-Young and Potschin, 2018), are important components of human well-being. They include spiritual, educational, inspirational, aesthetic, heritage, sense of place, recreational (Cheng et al., 2019; Haines-Young and Potschin, 2018; MA, 2005; Plieninger et al., 2013), and discovery services (Bieling, 2014; Fish et al., 2016). CES are unique in that they are rarely substitutable by technological means, making them nearly irreplaceable (Plieninger et al., 2013). The appreciation and awareness of the CES provided by urban green and blue areas (such as urban forests and parks, lawns, gardens, street trees, wetlands, ponds, lakes, rivers) have also been documented to increase the public support for environmental protection, thus potentially playing a significant role in defining and strengthening nature conservation policies (Andersson et al., 2015; Daniel et al., 2012; Gobster et al., 2007).

To support open space planning and management, it is important to understand which sites and what landscape features provide opportunities for CES and how these are distributed spatially within sites. The assessment of CES generally entails socio-cultural, economic or ecological (i.e., those considering landscape potential to provide cultural services) approaches which allow for gathering information on users' perceptions, preferences, values, attitudes, and beliefs (Katz-Gerro and Orenstein, 2015; Plieninger et al., 2013). Despite a growing body of research, assessing CES remains a challenge due to the subjective and immaterial character of these services (Small et al., 2017). Socio-cultural methods to assess this category of services include: Delphi Survey (Edwards et al., 2012); Q Methodology (Pike et al., 2015); photo-based methods (Williams and Cary, 2001); spatial assessments based on geolocated data derived from social media (Donahue et al., 2018; Hamstead et al., 2018; Keeler et al., 2015; Langemeyer et al., 2018; Sinclair et al., 2019); GPS-based activity data gathered through ad-hoc apps (Heikinheimo et al., 2020); questionnaire-based surveys, interviews and focusing (Bieling and Plieninger, 2013; Brown et al., 2014; Brown and

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Weber, 2013; Fish et al., 2016; Norton et al., 2012; Teff-Seker and Orenstein, 2019); focus group discussions (Orenstein et al., 2015; Stålhammar and Pedersen, 2017); and public participation or participatory GIS (PPGIS or PGIS) (Brown and Fagerholm, 2015; Brown and Kyttä, 2014; Brown and Weber, 2013; Bryan et al., 2010; Plieninger et al., 2013; Raymond et al., 2009; Tyrväinen et al., 2007). A general review and comparison of these methods is presented by Cheng et al. (2019).

In this paper, we focus on two of these methods: PPGIS, a specific type of active participation method involving a spatial component and used to enhance public involvement to inform land use planning and management (Brown and Kyttä, 2014); and a spatial assessment based on geotagged photographs from social media. Our aim is to compare their potential to assess CES and derive considerations regarding their substitutability, supplementarity or complementarity. The rationale behind this comparison is that social media-based assessments facilitate work with large amounts of data available for broader spatial and temporal scales and at relatively low cost compared to methods that entail active participation of respondents. Active participatory methods are generally more resource and labor intensive, however social media-based assessments are recent and little is know about their potential biases.

The extent to which social media-based assessments can substitute, supplement or complement PPGIS in the assessment of CES, and vice versa, is an expanding research subject (Crampton et al., 2013; Figueroa-Alfaro and Tang, 2017; Heikinheimo et al., 2017; Ilieva and McPhearson, 2018; Richards and Tunçer, 2018). A handful of recent case study-based comparative assessments are available (Heikinheimo et al., 2020; Komossa et al., 2020; Levin et al., 2017; Moreno-Llorca et al., 2020; Muñoz et al., 2020). The outcomes of this initial research on the topic indeed suggest that the social media method could contain numerous potential biases (such as poor representativeness of the different communities of users of green and blue areas – see Section 1.2) that have not yet been extensively assessed.

The specific objectives of this study are to: (1) identify strengths and weaknesses of the two methods to capture qualitative information related to landscape features of interest and CES; (2) identify and characterize potential biases of social media and PPGIS methodologies; (3) assess the substitutability, supplementarity or complementarity of the two methods, particularly with respect to the characteristics of the qualitative information conveying user preferences. To these ends we analyze: (1) the relative importance of seven categories of landscape features in co-creating the cultural value of seven green and blue spaces of the city of Haifa, Israel, as assessed with the two methods; and (2) the intensity of different types of CES enjoyed by users in each area, as captured by the two methods. The seven green and blue spaces of Haifa were selected for their diversity of landscape features potentially of interest, as detailed in Section 3.1.

2. State of the art

2.1. CES assessments based on PPGIS

PPGIS refers to "spatially explicit methods and technologies for capturing and using spatial information in participatory planning processes" (Brown and Fagerholm, 2015, p. 119). More specifically, PPGIS is a mapping exercise which, based on (collective or individual) people's knowledge, experiences, and perceptions, enables the researcher to define geographically and characterize user's cultural values or landscape features of interest. It is a place-based approach which allows to capture local knowledge and public preferences to integrate them into planning, management and decision making (Brown and Fagerholm, 2015; Raymond et al., 2009). The approach has demonstrated to be a pathway to robust insights and to be valuable to assess CES (Gosal et al., 2018; Tyrväinen et al., 2007). PPGIS indeed allows for assessing multiple social and cultural benefits from a wide range of stakeholders (Garcia-Martin et al., 2017; Potschin and Haines-Young, 2013), and for collecting detailed information about perceptions and preferences of the informants regarding (more or less specific) sites. Socio-demographic information on respondents can be gathered with this method.

PPGIS can be based on voluntary participation, as well as on targeted recruitment of specific samples of the population (Muñoz et al., 2020). It can be web-based or facilitated through face-to-face interviews (Brown et al., 2012). Web-based PPGIS allows for the collection of data from broad audiences (Brown et al., 2012), however the detail of the information on the motivations of the respondents and the quality of the data collected might decrease in comparison to facilitated (i.e., face-to-face) PPGIS (Fagerholm et al., 2016; Heikinheimo et al., 2020). When facilitated, the method provides an opportunity to engage participants in in-depth discussions (Fagerholm et al., 2012), and to monitor consistency in data during collection (Brown et al., 2012). Actively involving the public through PPGIS can lead to an increase in the legitimacy of, and support and trust in, the decision-making and planning process (Brown and Weber, 2013; Brown and Reed, 2009; Dunn, 2007).

The PPGIS approach also presents some challenges. It is generally time-consuming (Brown and Fagerholm, 2015; Heikinheimo et al., 2020; Muñoz et al., 2019b), and, often, a costly exercise, in which only specific and limited areas can be investigated (Brown and Reed, 2009; Wood et al., 2013) for a limited period. The precision in the location of the sites of interest varies depending on the design of the method (from paper-based to sophisticated online mapping) (Brown et al., 2014, 2012; Stopher and Greaves, 2007). The subjective nature of the PPGIS-based assessment can lead to an ambiguous spatial delineation of CES supply areas (Brown and Fagerholm, 2015). If the method is not web-based, achieving high participation rates can be difficult and costly (Brown and Fagerholm, 2015). Asking many detailed questions (e.g., regarding the specific position of elements of interest, duration and frequency of the visits at each site) might generate response fatigue (Brown et al., 2014). Finally, some respondents might refuse to selectively map specific zones of a natural area for fear of excluding others and, in this way, devaluing them (Klain and Chan, 2012).

2.2. CES assessment based on geolocated, crowdsourced photographs from social media

Assessments based on geolocated, crowdsourced data from social media represent a new opportunity to spatially assess CES. Sinclair et al. (2019) suggest that models developed using these data have the potential to complement, or even replace, field-based research techniques. Social media-based techniques offer numerous advantages compared to survey-based methods, mainly due to the large amount of relatively easily accessible, publicly shared, online data (Ghermandi, 2018; Ghermandi and Sinclair, 2019; Ilieva and McPhearson, 2018). Broad spatial scales, such as entire countries or regions (including traditionally data-scarce regions), can also be covered with this approach (Muñoz et al., 2019b; Sinclair et al., 2019). The detailed spatial resolution, and the availability of in-situ and site-specific data are additional strengths of social media-based approaches (Bubalo et al., 2019; D'Antonio et al., 2010; Figueroa-Alfaro and Tang, 2017; Muñoz et al., 2019b; Zielstra and Hochmair, 2013). Furthermore, this approach allows for the direct survey of movement patterns of people in the studied area (Gosal et al., 2018), and this can be performed and repeated over time at low costs (Tenerelli et al., 2016; Wood et al., 2013), without the need to resort to facilitation. Quasi real-time information, temporal patterns of activities and, in some cases, data covering relatively long time spans can be gathered (Bubalo et al., 2019; Heikinheimo et al., 2020; Zhou and Zhang, 2016). Access to, and visitation in, natural parks and other green areas are easy to estimate with a high degree of precision through geolocated data and this is done in a more efficient and less resource-intensive way than with survey-based methods (Chan et al., 2012; Donahue et al., 2018; Hamstead et al., 2018; Levin et al., 2017, 2015; Sinclair et al., 2019; Sonter et al., 2016). Off-trail use (i.e., of areas that are outside marked routes) can, in certain cases, be captured by this

method, without the need to engage in time-consuming fieldwork (Levin et al., 2015).

Because of these advantages, passive crowdsourced data, and, among them, geotagged photographs in particular, have been widely used in the context of nature conservation to: estimate the socio-economic value of a landscape (Sonter et al., 2016); investigate the potential of a site to support tourism and recreation (Ghermandi et al., 2020a; Teles da Mota and Pickering, 2020; van Zanten et al., 2016); identify popular locations and visitor flows (Orsi and Geneletti, 2013); and easily link visitation intensity to salient features of the landscape (e.g., types of forest, water bodies, particular species of trees and animals), allowing for assessing the relationships between these elements of the landscape and the supply of CES (Bernetti et al., 2019; Hausmann et al., 2018; Martínez Pastur et al., 2016; Oteros-Rozas et al., 2018; Sonter et al., 2016; Tenerelli et al., 2016; Van Berkel et al., 2018; Vaz et al., 2019; Willemen et al., 2015; Wood et al., 2013; Wu, 2013). Another strength of the social media method is that it provides a source of passive and non-authoritative crowdsourced geographic information which is independent of explicit and specific planning and policy goals, in contrast to PPGIS (Heikinheimo et al., 2017; See et al., 2016).

Nonetheless, some limitations of social media-based CES assessments have also been identified. Some of these are technical, including: exiguous locative data (Ilieva and McPhearson, 2018); noise in the data (Huang et al., 2013); variable spatial accuracy due to changing intensity of cellular signal or variable precision of GPS receivers (Figueroa-Alfaro and Tang, 2017); low quality of the photographs (Ilieva and McPhearson, 2018); and *a posteriori* mapping with consequent uncertainty regarding the precision of the geolocation (Guerrero et al., 2016; Muñoz et al., 2019b). The spatial distribution of the data might not be even because of a lack of information for remote locations (Richards and Friess, 2015) or due to the spatial clustering of the data (Levin et al., 2017). Other technical limitations may be due to the elaboration phase of the data, which can be time consuming, particularly when manual content analysis and classification of large numbers of photographs is needed to identify mistakes in the geolocation (Ilieva and McPhearson, 2018). The lack of detailed socio-demographic information on the users is also a well-known limitation of the method (Ghermandi and Sinclair, 2019). This generally prevents testing for sample selection bias, leading to uncertainty regarding the sample's representativeness of any target population (Bubalo et al., 2019; Ilieva and McPhearson, 2018; Muñoz et al., 2019b; Sinclair et al., 2019). The representativeness of the data obtained might be limited by different factors, including digital divides related to economic disparities, income, age, gender and social power relations that affect internet and social media penetration and are difficult to trace (Huang et al., 2013; Muñoz et al., 2019b). Such biases can cause uncertainty regarding the reliability and validity of the information obtained (Figueroa-Alfaro and Tang, 2017; Guerrero et al., 2016; Levin et al., 2017). As not all people who take pictures upload them onto social media platforms or as some people may take or upload pictures more than others, the results of the analysis might be over influenced by certain groups (Figueroa-Alfaro and Tang, 2017; Ghermandi and Sinclair, 2019). Further, the method often requires assumptions regarding the actual degree of satisfaction of the visitors and their travel motives (van Zanten et al., 2016). Often, only partial information can be gathered on the physical, perceptual, evaluative aspects of landscapes, or on sentiments, through the sole analysis of photographs (i.e. excluding from the analysis associated text and tags) (Figueroa-Alfaro and Tang, 2017; Ghermandi et al., 2020b; Ilieva and McPhearson, 2018). Little or no information is also available regarding the reasons why the users generate and share the content online (Bubalo et al., 2019; Moreno-Llorca et al., 2020; Richards and Tunçer, 2018). Finally, some recreational activities are more or less suited for taking photographs (Tenerelli et al., 2016; Wood et al., 2013), leading to only a limited representation of all possible benefits that can be derived from a specific landscape.

3. Methods

3.1. Study area

This study focuses on the green and blue areas of Haifa, Israel's third largest city. Haifa is in the northwest of the country, on the coast of the Mediterranean Sea (32°49′0″N 34°59′0″E) (see Fig. 1), and hosts about 280,000 inhabitants (CBS, 2018). The city's climate is typically Mediterranean, with warm summers and mild, rainy winters. Average temperatures range between 8.7 ℃ (in February) and 31.4 ℃ (in August), with high summer humidity levels. Precipitation averages 630 mm/year, almost all concentrated in the winter and spring. The city is built on the top and slopes of Mount Carmel (max elevation = 525 m a.s.l.). The built-up area is interspersed with ephemeral riverbeds ("wadis"), which are undeveloped, vegetated (often forested), corridors that run through the city, from the coast to the higher elevations. These open spaces host a rich vegetative community, including the common oak, terebinth, carob tree and mastic tree. Aleppo pines (*Pinus halepensis*) are also widespread in the area, primarily because of past tree planting campaigns (Ne'eman et al., 1997). The wadis and green areas provide habitat for wildlife, such as wild boars, salamanders, golden jackals, porcupines, hyraxes, Egyptian mongooses, owls, and chameleons. Many of Haifa's wadis are marked by hiking trails, providing extensive recreational opportunities. Other city green open spaces host infrastructure of broader touristic interest, including equipped beaches, historical sites, monasteries and churches, and a zoo. Overall, the mosaic of wadis and other vegetated areas give the city a green and forested appearance, especially in comparison to other urban agglomerations in Israel. This green configuration of the city is particularly valued by its inhabitants (Depietri and Orenstein, 2020).

For the present study, we selected seven green and blue areas within the municipal boundaries of the city (Fig. 1). This subset was chosen from the broader range of areas mentioned by the respondents, as detailed in a companion study (see Depietri and Orenstein, 2020). Each of the seven areas was selected for this study as it presents different features of potential interest in the landscape (i.e., freshwater sources, archeological or religious sites, viewpoints on the landscape, geological features, fauna and flora, and degrees of wilderness). Principally aimed at the assessment of a variety of user preferences, the selection reflects a range of recreational and touristic options, from more wild areas to more accessible and developed sites, often including religious and cultural points of interest (see Table 1 for a detailed description of each of these seven areas).

3.2. Public participation GIS

The PPGIS component of the research applies spatial analysis and social research methods through semi-structured interviews for the identification and characterization of places that are highly valued for aesthetic, recreational or ecological reasons. Respondents were frequent users of Haifa's green and blue areas, and were selected from among coworkers (researchers, ecologists, environmental scientists), students, as well as local environmental activists, local authorities, and other residents of Haifa, specifically due to their knowledge of the city's open, green, and blue spaces. The respondents thus collectively represented people who often use open spaces across Haifa and whose interests in the city's green and blue infrastructure is not limited to a single neighborhood, but rather to the entirety of the city. The sample of interviewees was aimed at yielding results that can be considered closer to local expert judgment than to public judgment (Brown et al., 2012). The initial group of interviewees was expanded through a snowball sampling technique (see Johnson, 2014) and by posting announcements on relevant pages on Facebook. The pool of respondents was expanded until significant redundancy in information emerged. The final sample consisted of 27 users of the green and blue areas of Haifa. The sample size is comparable to that of similar PPGIS studies that also used in-depth

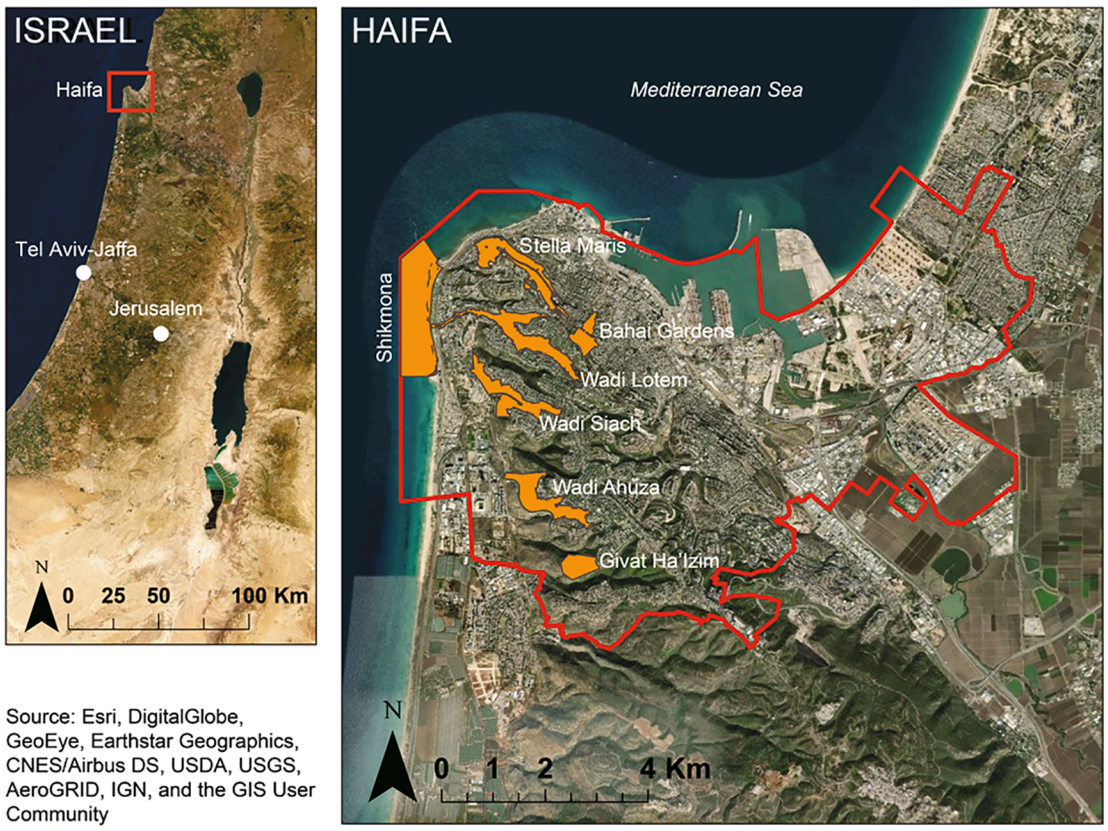

Fig. 1. Location of Haifa and the seven selected green and blue open spaces within the city, marked in the orange polygons (Source of the shapefile: *Israel National Ecosystem Assessment, Interim Report*, 2017).

interviews to assess CES (see for instance Blake et al., 2017 with 47 respondents; Klain and Chan, 2012 with 30 respondents; Raymond et al., 2009 with 56 respondents). Information about the occupation and the place of residence of the respondents was collected.

The method entailed face-to-face, in-depth interviews, conducted between August 2018 and January 2019. The respondents were asked to identify and show the location and boundaries of up to five open green or blue spaces of cultural or recreational interest within the municipality of Haifa, using a satellite map of the region. Polygons were drawn on the satellite map which was embedded in the online tool "Scribble Maps" (www.scribblemaps.com). For each selected area, the respondents were asked to explain why they chose it, what makes it special to them, and in what type of activities they partake in each location. Each interview lasted approximately 90 minutes.

Amongst all the areas selected by the respondents, seven were chosen, as detailed in the above case study description. Using text gathered in the semi-structured interviews, we indentified both the features of interest in the landscape and the types of CES enjoyed by the respondents at by each site. The method was similar to Langemeyer et al. (2018), although we focused on a broader range of services and did not restrict our study exclusively to the aesthetic value of the landscape. We analyzed the content of each response, translating the text into keywords that were subsequently grouped into seven categories of features of interest in the landscape: (1) wilderness/nature; (2) flora; (3) fauna; (4) water; (5) geology; (6) landscape (view); (7) archeological/historical/religious/art. We also identified, from the responses, the types of CES from which the respondents benefitted in each site. The full range of CES was restricted to four direct, in-situ and outdoor interaction types, namely: recreational, discovery, aesthetic and educational. These could reliably be assessed with both the PPGIS and the social media methods. In Table 2, we provide the list of these types of CES with the criteria for identification we used in both methods.

3.3. Social media-based assessment

We retrieved data of photographs, geotagged within the boundaries of Haifa's municipality, as uploaded to three distinct social networking services: Flickr, VKontakte and Panoramio. Flickr and VKontakte photographs were retrieved using their respective Application Programming Interfaces (APIs). For Flickr, the photographs cover the years 2005–2018; for VKontakte, they cover the period since the launch of the service in 2006 to 26 November 2018. Data for Panoramio, which is no longer operational, were retrieved from Lotan et al. (2018), who used counts of Panoramio photographs as a proxy for recreational activities in open spaces in Israel. These data cover the period 2005–2014.

Using the QGIS software, we extracted the sets of pictures geotagged within each of the seven sites using the landcover map provided by the Israel National Ecosystem Assessment, Interim Report (2017) (6021 pictures in total). For the Bahai Garden site, due to the large number of photographs geotagged (10 to 400 times higher than for any other site), we randomly considered 20% of the photographs uploaded to each of the three social media platforms for in-depth analysis. We then manually investigated the content of the photographs. For all the sites, duplicates, pictures that were not relevant to the scope of the study or that did not belong to the area in which they were uploaded were removed from the sample.

The content of each photograph was analyzed using the cloud computing platform Clarifai (https://www.clarifai.com), which uses machine learning to automatically assign tags through deep convolutional neural networks (Karasov et al., 2020; Lee et al., 2019). Using a pre-trained model, 20 tags characterizing elements present in the picture were assigned to each photograph by Clarifai, each tag being associated with a probability. We manually associated the list of all retrieved machine tags to one of the seven categories of features of the landscape listed in the previous section. We then summed up the number of tags

Table 1
Description of the seven green and blue areas of Haifa selected for this study.

Site	Description highlights
Bahai Gardens	Garden terraces around the Shrine of the Báb (founder of the Bábí Faith) - Considered the second holiest place for Baháís - Attracts many domestic and international tourists throughout the year - Is a prominent attraction for promoting Haifa tourism
Shikmona	Rocky seashore with tidal pools - Previously degraded and now declared a marine reserve - Developed for recreational use with walking and bicycle paths, grassy areas, playgrounds, and workout equipment
Stella Maris	Panoramic lookout points over the sea and surrounding areas - Carmelite Monastery (the Stella Maris Monastery) - Vegetated hillside crossed by a short trail connecting the lookout point with the small "Holy Family Chapel" - Cave of Elijah the Prophet - The main lookout point is connected to the seashore (Bat Galim Promenade) via cable car
Wadi Lotem	Ephemeral riverbed (wadi) featuring a dense Mediterranean *maquis* with tall trees - Crossed by a marked trail connecting the top of the wadi to the sea - Haifa's Educational Zoo located at the top of the wadi
Wadi Siach	Ephemeral riverbed (wadi) characterized by Mediterranean *maquis* - Marked trails suitable for nature walks and hiking - Towards the bottom of the wadi is "Bustan Khayat", featuring agricultural terraces planted with fruit trees - Adjacent to the terraces are pools that collect water coming from natural springs, where it is possible to bathe - Remains of a 13th century Carmelite monastery and church
Givat Haizim	One of the last flat, non-urbanized areas on the top of Mount Carmel within the administrative boundaries of the city - Currently designated for residential development - Used for picnics and bonfires - Featuring numerous lookout points to the sea through short nature trails
Wadi Ahuza	Ephemeral riverbed (wadi) covered by the typical Mediterranean *maquis* - Features marked trails, a small pool, and a spring

Table 2
List and descriptions of the types of CES, partially based on the Common International Classification of Ecosystem Services (CICES) version 5.1 (Haines-Young and Potschin, 2018), with details regarding how they were identified and classified with the two methods.

Type of CES	Simple description	Criteria for identification
Recreational	Using the environment for sport and recreation; using nature to help stay fit.	Mentions by respondents or photos of people engaged in recreational activities (e.g., hiking, swimming, surfing, biking), including photos without people but showing recreational equipment and infrastructure (e.g., trails).
Discovery	Watching plants and animals where they live as well as the physical, geological environment.	Mentions by respondents or photos of single plants and animals and of single elements of the physical, geological environment.
Aesthetic	The beauty of nature.	Mentions by respondents or photos related to the landscape beauty, including panoramic views.
Educational	Studying nature.	Mentions by respondents or photos of educational activities; children or students engaged in educational activities.

that appeared in association to each of the seven categories, separately at each site. During the mentioned manual screening of the photographs, we assigned each photograph up to three types of CES, as could be identified from the subject and/or from the background of the photograph, as detailed in Table 2.

3.4. Data analyses

First, we compared the information collected regarding the elements of interest of the landscape and the CES provided by each site by means of graphical representations (Figs. 2, 3, 5, and 6). We then used a Principal Component Analysis (PCA) to further derive elements of comparison between the two methods. The PCA allowed us to: (1) plot the variables into two-dimensional Cartesian planes and obtain a simplified representation of the data frame; (2) minimize noise that is naturally occurring in the data structure; (3) improve the identification of patterns across the sites. According to conventions, the arrows (in Figs. 4 and 7) represent the "loading" of the attributes onto the principal components. The points correspond to the new coordinates of the sites of interest in relation to the principal components. Statistical analysis was performed using R statistical software with associated packages "Tidyverse" and "Tableone".

4. Results

4.1. Interest in each site as estimated with the two methods

Table 3 presents the number of users that uploaded photographs for each site and the number of times each site was mentioned during the interviews. Based on these data, Fig. 2 shows public interest in each site, as it emerged from the two methods. The Bahai Gardens stood out in this analysis, being associated with a substantially larger number of social media users than any other site but being mentioned only once in the interviews. The popularity of the Bahai Gardens in the social media data is consistent with its status as the primary tourist attraction in Haifa (Gatrell and Collins-Kreiner, 2006). For ease of visualization, we separated this site from the others in Fig. 2.

From Table 3 and Fig. 2, it appears that the seven sites considered can be categorized into three groups: group 1 includes only the Bahai Gardens, which is an intensely visited site according to the number of pictures uploaded, but which was mentioned only once by PPGIS respondents; group 2 includes Shikmona, Wadi Lotem and Stella Maris, for which the comparative interest expressed by the social media data is higher than that expressed by the PPGIS respondents; and group 3 includes Wadi Siach, Givat Haizim and Wadi Ahuza, for which the interest expressed by PPGIS respondents is comparatively high relative to that reflected in the social media data. While groups 1 and 2 present touristic points of interest, group 3 includes wilder, forested areas which appear, from this preliminary data, to attract fewer SM users but more PPGIS respondents (i.e. local and assiduous hikers).

4.2. Features of the landscape

Fig. 3 illustrates how each site varies in terms of landscape elements of interest when assessed separately with the two methods. Mixed results emerge depending on the site. In Wadi Lotem and Givat Haizim, both methods reflect similar landscape elements of interest for the most part (note that for Wadi Lotem, the fauna that was mentioned in the interviews included mainly wild species, while social media users photographed mostly animals that can be found in the zoo, located on the upper part of the wadi). In other three sites, while some elements of interest are equally identified with both methods (e.g., flora in Wadi Ahuza and Wadi Siach, and landscape in Stella Maris), others are mainly or solely captured by one of the two methods. In the remaining two sites, the Bahai Gardens and Wadi Ahuza, the relative importance of specific elements, as derived from the two methods, is very poorly overlapping.

The characterization of each area based on the elements of interest in the landscape is further elucidated through the PCA presented in Fig. 4. In Fig. 4a, which shows the results of this PCA for the PPGIS method, the attractions of some of the sites are clearly linked to few and defining

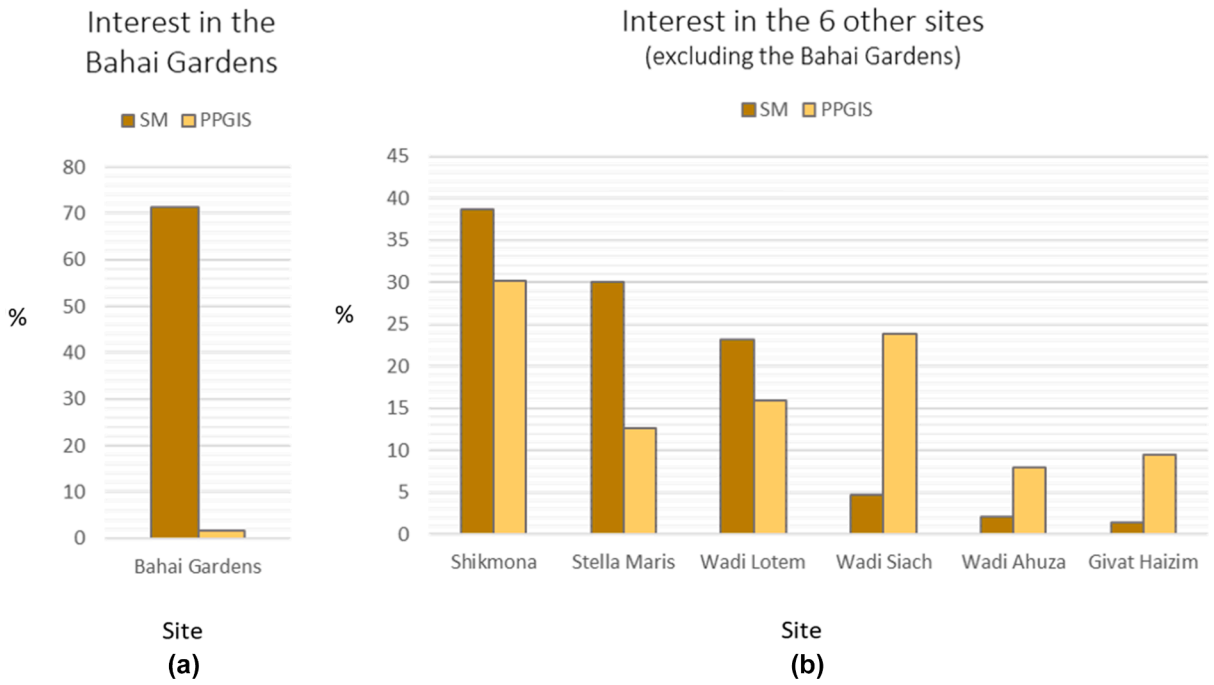

Fig. 2. (a) Interest in the Bahai Gardens expressed as a percentage relative to the total number of social media (SM) users and as percentage relative to the total number of times the site was selected by the PPGIS respondents for the seven areas. (b) Interest in the additional six sites expressed as the percentage of number of social media users for the six sites; and, for PPGIS respondents, as the number of times the sites were selected by respondents relative to the total times the six sites were selected overall.

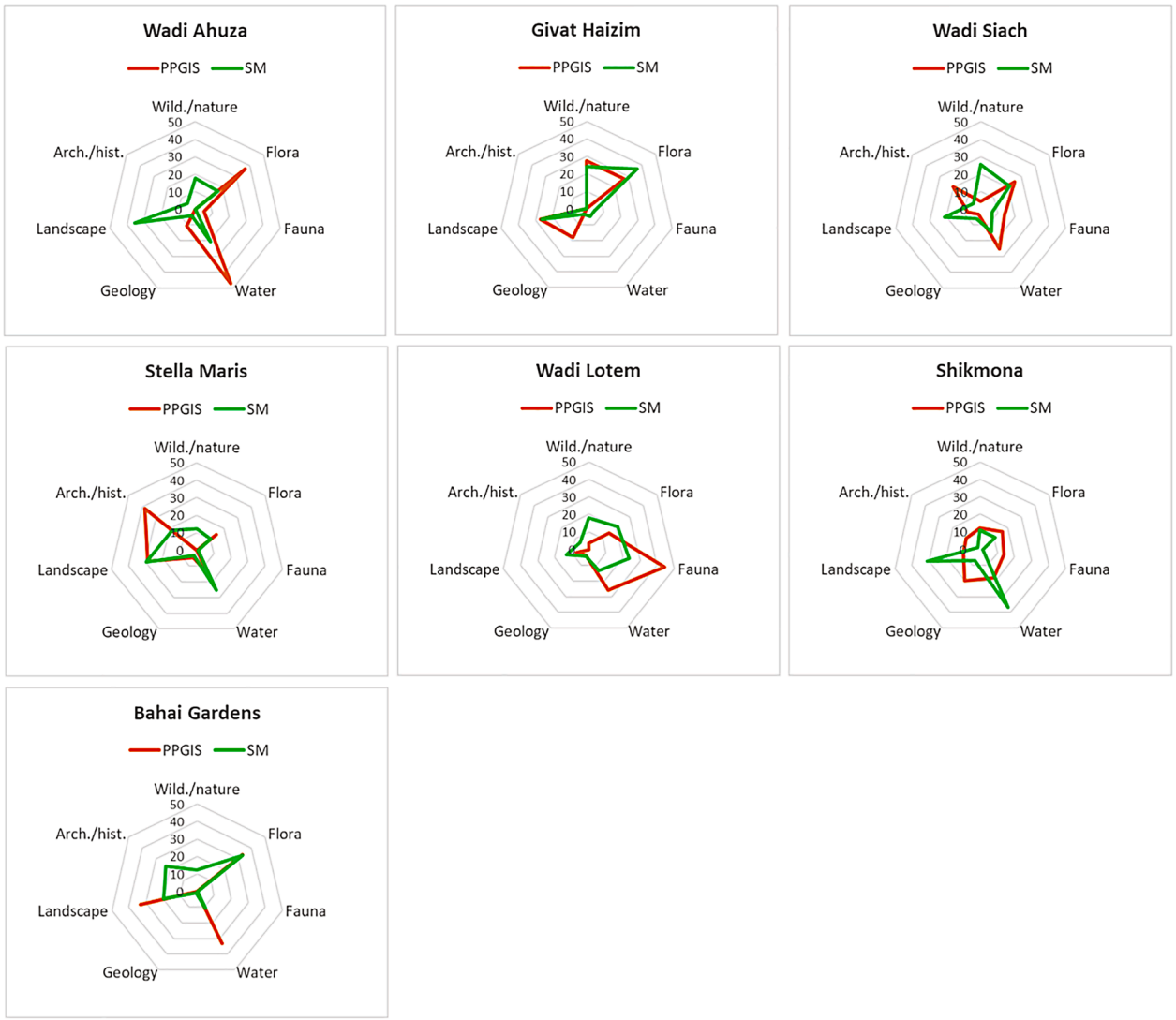

Fig. 3. PPGIS and social media-based (SM) assessment of the relative importance of each category of features of interest in the landscape, at each site and expressed in percentages over the total obtained for each method.

landscape feature (e.g., the architectural elements of the landscape for Stella Maris; wilderness and the geological elements of the landscape for Givat Haizim), while the other sites are characterized by a more diverse combination of features (e.g., geology, landscape, and wilderness in the case of Shikmona, and fauna and archeology in the case Wadi Siach). We note that only slightly more than 60% of the total variance in the data is explained in the PCA in this case.

The PCA performed on the data obtained with the social media-based method (Fig. 4b) provides some additional information, not reflected in the PPGIS results. We learn, for instance, that the element of water is important in the case of Shikmona and that the architectural and religious components are important in the case of the Bahai Gardens. In this PCA, the variance explained is close to 75%.

Additional comparative information can be deduced from Fig. 5a. Indeed, the Figure clearly reveals that categories such as wilderness and landscape are prominently captured with the social media-based method, while other elements, such as flora, fauna, and geology, are better captured by the PPGIS method.

4.3. Cultural ecosystem services types

Fig. 6 illustrates the frequency for which the four CES types considered are enjoyed at each site, based on the results obtained with the two methods. There is notable overlap in the results obtained in the cases of Givat Haizim, Wadi Siach, and, to a lesser extent, of Stella Maris and Shikmona. For the remaining sites, the overlap is minor.

According to the PPGIS, Wadi Siach, Givat Haizim, Wadi Ahuza and Wadi Lotem offer substantial recreational services. The aesthetic value appears as being particularly important in the case of Stella Maris and the Bahai Gardens. The discovery value (i.e., opportunities to observe and interact with elements of the biophysical system) is important for all the sites, except for Stella Maris. The educational service is recorded least often from among the various services provided by these sites.

Fig. 7a presents the results of the PCA performed on the data obtained through the PPGIS method for the four types of CES. The most touristic areas are in the upper quadrants of the graph, where discovery and aesthetic services are also more pronounced. The wilder areas, in contrast, are in the lower half of the graph, and are associated more closely with recreational and education services. These two types of CES are more frequently mentioned by the PPGIS respondents, which represent a group of users heavily engaged in outdoors activities and particularly interested in the wilder and less touristic green and blue areas of the city. The PCA, in this case, explained about 78% of the variance in the data.

The PCA exploring CES data obtained through the social media-based method (Fig. 7b) gives highly satisfactory results in terms of

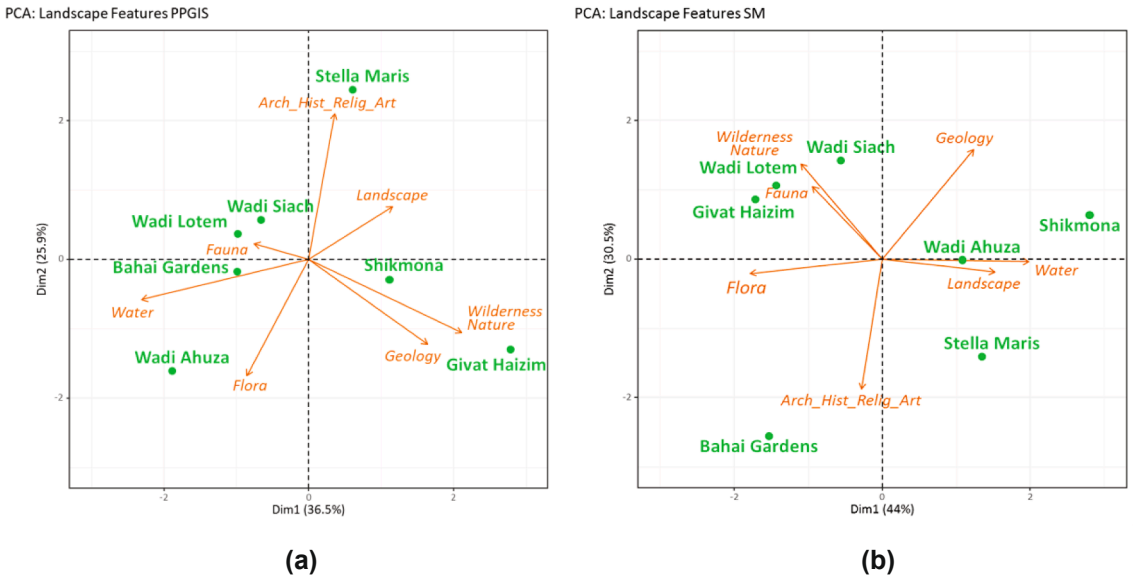

Fig. 4. Principal component analysis of landscape features of interest in the seven areas, as obtained with (a) the PPGIS method and with (b) the social media-based method.

Table 3
Number of social media users who uploaded photographs per site and number of respondents mentioning each site.

Site	Number of social media users per site	Number of PPGIS respondents mentioning the site
Bahai Gardens	1072	1
Shikmona	167	19
Wadi Lotem	100	10
Stella Maris	130	8
Wadi Siach	20	15
Givat Haizim	6	6
Wadi Ahuza	9	5

variance explanation (describing nearly 100% of the variance in the data). In this analysis, we see again a pattern with the group of more touristic sites offering primarily aesthetic and discovery services, but also educational services this time, and a group of sites which offer principally recreational services.

Fig. 5b summarizes the results obtained regarding CES in the seven selected sites, highlighting the strength of the social media-based method for the identification of the aesthetic value of a site, while suggesting that the PPGIS method allows to better identify the other types of CES analyzed (e.g., recreational services). Other services were identified through PPGIS but are not included in our comparative analysis since they were not to be easily and accurately discernible in the photograph content analysis. For instance, based on the PPGIS analysis, heritage and scientific value appeared to be very important in the case of Wadi Siach. Another service which was possible to assess only with the

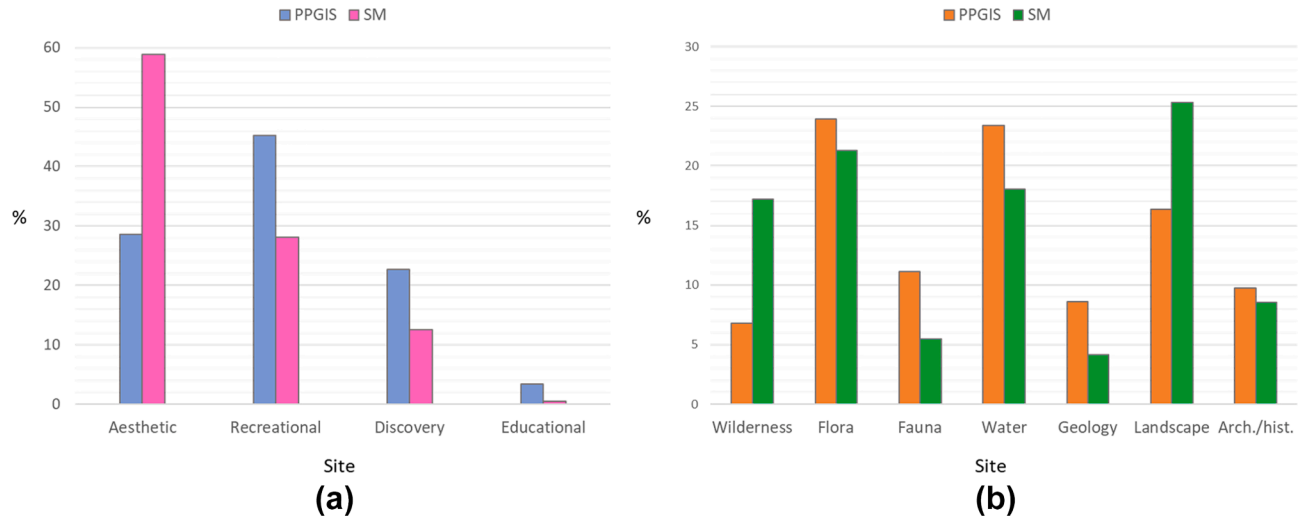

Fig. 5. (a) Summary of the landscape features of interest most often captured using the two research methods across the seven sites (SM stands for social media-based). (b) Summary of the percentage of mentions (PPGIS) or appearances (in the case of the social media-based method) of various CES types across all seven sites.

Fig. 6. Cultural ecosystem services types provided by each site in terms of percentages of total CES mentions as assessed with each method.

PPGIS method was the existence value, as some respondents mentioned the presence and importance of endemic species in the wadis.

4.4. Strength and weaknesses of the two methods

Table 4 summarizes the respective strengths and weaknesses of the two methods based on the results obtained in this study and as expressed in the literature. In sum, metadata (e.g., demographics) and qualitative information (e.g., rationales and perceptions) are more easily gathered with a PPGIS approach, while the social media-based approach improves upon PPGIS in the quantitative aspects, including amount of data and spatial and temporal scales. Through PPGIS one can define and control the target sample of users, tailoring it to research or planning needs, while this is harder to achieve with a social media approach. Information for a wide range of temporal and spatial scales can be captured by a social media approach, while the PPGIS approach generally allows for assessing values of a limited or specific area and for a specific time. Finally, the PPGIS facilitates capturing detailed information from a variety of users and for a variety of sites (touristic as well as non-touristic), while the social media-based assessment proved to be much more effective in the characterization of preferences in the most accessible and touristic sites of the city.

5. Discussion

This paper investigates and compares the application of two socio-cultural methods for the assessment of CES in seven green and blue sites of the city of Haifa: PPGIS, which relies on in-depth discussions with respondents regarding the identification and characterization of green and blue sites of cultural and recreational interest, conducted with a relatively small sample of participants; and social media-based assessment, which relies on analysis of a relatively large number of geolocated photographs loaded onto social media platforms by users. We compared the results obtained with the two methods to assess their relative benefits.

Overall, the results show that the two methods are complementary in the insights they provide, particularly regarding the qualitative information derived from each of them. In the following sections of the discussion, we highlight such differences, identifying applications for which each of the methods seems to be more advantageous.

5.1. Representativeness of the data regarding the population of users

The people we interviewed for the PPGIS study were local, current of past frequent users of Haifa's wilder urban green and blue areas. These

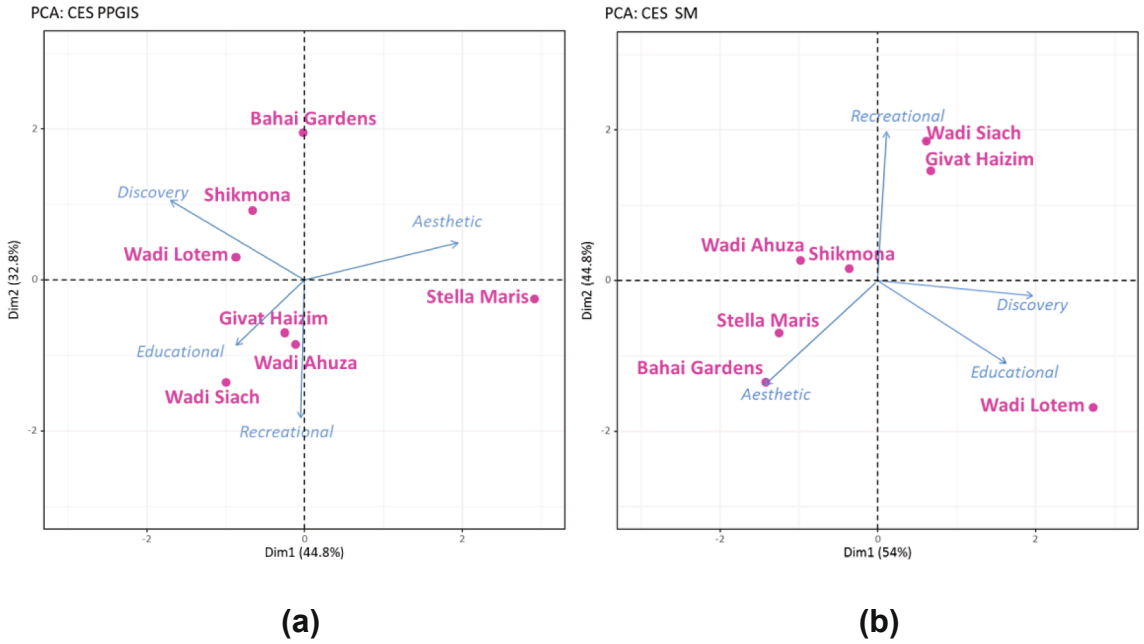

Fig. 7. Principal component analysis of the cultural ecosystem service types enjoyed at the seven sites as elicited with the PPGIS method (a) and with the social media-based method (SM) (b).

Table 4
Information obtainable using PPGIS and social media approaches for CES assessment, and the strengths and weaknesses of each approach. The table is based on our results and on the literature. + stands for "easily obtainable/strength"; +/− stands for "obtainable/strength under certain conditions"; − stands for "not obtainable/weakness".

Information	PPGIS	Social media
Knowledge and control of the representativeness of survey sample	+	−
Knowledge of the demographic profile of respondents	+	+/−
Overall reliability of the data	+	+/−
Estimate of the number of visits	+/−	+
Frequency and duration of the visits	+/−	+/−
Time dedicated to data gathering	−	+
Time dedicated to data analysis	−	+/−
Precision in the location of the points of interest	+/−	+
Broad spatial scale	−	+
Long temporal scale	−	+
Information on visitor activities	+	+/−
Identification of little known, poorly accessible, or new culturally important sites	+	+/−
Detailed characterization of biophysical elements of interest in the landscape	+	+/−
Description of feelings, of the perceptual and of evaluative aspects of the landscape, motivations, and values	+	+/−
Direct public participation	+	-

were relatively less represented quantitatively in terms of number users who uploaded photographs to social media platforms. Vice versa for the more touristic areas. Potentially linked to that, PPGIS also provided a qualitatively different set of preferences compared to the crowdsourced data. This suggests that the population that uploaded pictures of Haifa onto social media platforms (for which demographics are not available) is likely different than that represented by the sample interviewed. Similar to Sinclair et al. (2020), tourists likely made up a sizable fraction of the social media users in the study, while PPGIS specifically captured the preferences of locals.

As different users hold different cultural preferences, regardless of the method used (Moreno-Llorca et al., 2020; Sonter et al., 2016), caution should be taken when considering the representativeness of the social media-based method, which, due to the sheer amount of data, may be erroneously assumed to be representative of the entire population of users. Previous research has documented that the photo-sharing community is often not representative of the full diversity of community groups (Mellon and Prosser, 2017; Muñoz et al., 2020; Tenerelli et al., 2016). Thus, the adoption of a social media approach alone, although, in principle, a more "democratic" approach, carries the risk of overlooking important user groups (Heikinheimo et al., 2017). Distinguishing and separately analyzing the photographs uploaded by local, domestic, and international visitors (Ghermandi et al., 2020a, Sinclair et al. 2020), as well as combining data from a broad range of social media sources (Ghermandi et al., 2020b), may be crucial in ensuring that the perspectives and interests of all groups of users are properly captured. Despite this, due to lack of personal and demographic information regarding social media platforms users, it is often challenging to evaluate which of the user groups are over- or underrepresented in the assessments (Muñoz et al., 2019b). Complementing social media-based approaches with surveys or interviews can help ensure that the preferences of all stakeholders are adequately captured (Heikinheimo et al., 2020).

5.2. Touristic vs. Less known or less accessible sites

In this study, social media data appeared to primarily record information for the more touristic and more accessible sites and less for the little publicized and wilder sites. The availability of infrastructure, accessibility and abundant (tourist) information regarding the site, all seemed to correspond to the highest number of users and photographs. As such, in highly touristic sites, crowdsourced data may provide a good alternative proxy to visitor counts (Ghermandi et al., 2020b; Levin et al., 2017; Wood et al., 2020, 2013).

On the other hand, social media data appeared to under-represent areas that are not major landmarks or that are less known by the general public and/or are less accessible. Similar results were found by Wood et al. (2013) and by Muñoz et al. (2020). Tourist infrastructure and roads (i.e., accessibility) were the most important factors explaining the spatial distribution of photograph data from Flickr in protected areas in Southern Norway (Muñoz et al., 2020). Broad scale research has further documented that the interest expressed through social media is often directed to established touristic sites, like natural parks, national parks, rivers and lakes (Figueroa-Alfaro and Tang, 2017; Lotan et al., 2018; Martínez Pastur et al., 2016). Indeed, globally, infrastructure and accessibility are the main drivers of demand for recreational services (Heagney et al., 2018; Khadaroo and Seetanah, 2008; Su et al., 2016), leading international visitors to be more spatially concentrated around familiar, well-recognized sites, such as major urban centers and major roads (Muñoz et al., 2019a; Richards and Friess, 2015), or around popular places for leisure within urban parks (Heikinheimo et al., 2020). It is also plausible that self-reinforcing mechanisms within social media play a role in increasing visitation to popular sites, whereby sites that are marked by social media users through uploaded photographs are then more easily recognized, visted and appreciated by other social media users (Ghermandi and Sinclair, 2019).

Ease of access to a site is positively correlated with the quantity of the photos (Gosal et al., 2018; Richards and Friess, 2015). Richards and Friess (2015) suggest that, in little accessible, remote regions or in areas with a low market penetration of cameras with geo-referencing technology, social media-based assessments might be unreliable and miss important information about the value of places. At the scale of the city of Haifa, technological and network accessibility likely do not play a major role in determining the results obtained. Instead, our PPGIS analysis reveals that the preferences of intensive users of green areas for wilder, less touristy, and less accessible sites can simply go overlooked when adopting a social media-based method, due to the tendency of locals to upload few or no photographs onto the platforms. Local hikers are indeed more often associated with little publicized sites (see also Ghermandi et al., 2020a) and might not make frequent use of social networking services during their visits.

This may be influenced by various factors. For instance, the perceived value of a trip (in terms of effort, time or money) may affect whether or not an individual takes and shares photographs, resulting in a smaller number of images uploaded by visitors who travel short distances from home (Wood et al., 2013). Frequent visitors may be less inclined to take or share photographs of sites they routinely visit (Ghermandi, 2018; Wood et al., 2013). Overall, previous research has documented how collection bias, related to accessibility, proximity, or familiarity, strongly influence what people contribute to crowdsourced databases (Levin et al., 2017). These considerations might further help explain the rather low correlation of the social media-based method to capture the PPGIS respondents' preferences in Haifa. The two methods indeed appear to capture different "environmental worldviews" (Van Riper and Kyle, 2014).

We suggest some caution as grounding urban and environmental planning choices solely on preferences expressed through social media data, as this might lead to biased decision making towards the most known sites, overlooking equally valuable, although less known and publicized, sites (Komossa et al., 2020). Despite this the social media approach could precisely help identify these overlooked spaces to improve their planning. PPGIS offers a certain flexibility due to the possibility to actively determine the sample and to enquire about a broad range of sites, and might be used to supply some complementary information, based on in-depth, local knowledge (Fagerholm et al., 2016).

Overall, if the objective is to improve the management of known, easily accessible and popular areas, then social media-based assessments of data collected from popular platforms offer great potential. Moreover, within the boundaries of these more touristic sites, areas not represented by uploaded pictures, can inform about the lack of infrastructure to access points of potential interest (e.g., wildlife) (Figueroa-Alfaro and Tang, 2017). To capture more detailed knowledge about little know sites, one might instead need to resort to survey-based methods.

5.3. Landscape features of interest and cultural ecosystem services types as captured by the two methods

5.3.1. Landscape features of interest

Contrary to Muñoz et al. (2020) and Komossa et al. (2020), but similarly to Moreno-Llorca et al. (2020), we observed that the landscape features of interest across the seven sites only partially overlap when assessed using the two methods separately. From our analysis, the social media-based assessment is clearly more suitable for capturing broad elements of the landscape (e.g., landscape view, wilderness) as well as its overall value, rather than specific individual elements in it (Moreno-Llorca et al., 2020). There is in fact a difference between what people encounter and experience during a visit (e.g., wild animals) and what they can capture on camera (Komossa et al., 2020). Nonetheless, the propensity of the method to capture broad landscape values has previously been identified as a potential strength of the method, it being able to capture what one cannot put into words (e.g., a panorama) (Figueroa-Alfaro and Tang, 2017).

Through the PPGIS interviews, it was possible to gather more detailed information on specific species of flora and fauna of interest, the presence of rare or endemic species, as well as valued rock formations. Specific landscape characteristics, whose full appreciation seems to require a higher level of knowledge and expertise (e.g., wildlife and geological elements of interest), could be more readily elicited through the PPGIS method.

5.3.2. Cultural ecosystem services

Regarding the types of CES offered by the seven sites, the analysis of the photographs suggested strong aesthetic value provided by the sites, with less emphasis on discovery and recreational values, these being linked to the activities performed at each site. The tendency of the social media-based method to reflect aesthetic values was also found by Martínez Pastur et al. (2016), Dai et al. (2019), and Bernetti et al. (2019). Many of the nature and landscape photographs are indeed likely to be taken for aesthetic reasons (Richards and Friess, 2015). The content of online photographs is generally more biased toward unique and charismatic subjects and experiences (such as views on the landscape), at the expense of more common activities and other valuable elements of the landscape (Ghermandi and Sinclair, 2019; Wood et al., 2013). On the other hand, the capacity of photographs to capture the aesthetic value of a site may be considered as a specific strength of the social media method, as it may be challenging to translate the aesthetic perceptions and feelings into words (Martínez Pastur et al., 2016). In this sense, the approach offers important additional and complementary information to more traditional survey-based approaches (Heikinheimo et al., 2017; Levin et al., 2017; See et al., 2016), through which the precise location of the concentration of aesthetic value in a landscape is more difficult to determine.

Our results further confirm previous research suggesting that the social media approach is often limited regarding the accurate representativeness of the variety of activities taking place at a site (Ilieva and

McPhearson, 2018). The activities captured in photographs appear to be confined to a few types, such as the enjoyment of the view or the observation of the landscape. It is often challenging to associate the features of the landscape captured in the picture with a specific type of activity (Van Berkel et al., 2018), as there generally is some uncertainty with respect to why a picture was taken. Levin et al. (2017, p. 115) also suggested that the method is "an unreliable proxy for the full range of values and importance of protected areas, especially for non-use values such as biological conservation".

Our approach was based on the common interpretation framework of presence/absence of specific elements in the photographs (e.g., when a path appeared in the picture, we assumed that recreational activities, such as walking or hiking, were offered by the site). These paths were, in most cases, not the explicit subject of the photograph, and their categorization as suggesting opportunities for recreational activities required a degree of subjective interpretation (Angradi et al., 2018). This need for interpretation might still be associated to an underestimation of recreational value. It can in fact be assumed that people taking a picture in a park or a green and blue area are also benefiting from recreational services offered by that area. The analysis of additional qualitative information or of potentially available metadata (excluded in this study), would be needed to improve the identification of recreational activities performed at each site through a social media approach (Dai et al., 2019; Ghermandi et al., 2020a; Levin et al., 2017; Martínez Pastur et al., 2016; Richards and Friess, 2015; Wood et al., 2013).

Recreational and discovery values were extensively identified in the PPGIS interviews. The capacity of the PPGIS method to better capture the "who, what and why" in the context of urban park visitation was also found by Heikinheimo et al. (2020) and Cheng et al. (2019). Further, the PPGIS method allowed us to identify a broader range of types of CES, including the existence, heritage, and scientific values provided by the green and blue areas of Haifa. The cultural heritage and existence values have an important non-use component, which does not necessarily require a physical interaction with a landscape, and, insofar as their use component is concerned, such values are generally hard to extract from the analysis of social media photographs (Richards and Friess, 2015; Van Berkel et al., 2018). It is nonetheless important to note that these results can be affected by explicit or unconscious biases of the PPGIS facilitator or interviewer.

The possibility to identify only a limited number of types of CES with the social media approach was also found by Tenerelli et al. (2016), Oteros-Rozas et al. (2018) and Sonter et al. (2016). Other studies, similar to the one presented in this paper, have documented how stated preferences methods (including PPGIS) allow to better evaluate the whole, or a larger, range of cultural values offered by a landscape (Muñoz et al., 2020).

5.4. Specificity of the urban context

The differences observed between the information provided by the two methods might be partially attributed to the focus on the urban context and on the specific configuration of the city of Haifa. The social-ecological context can indeed lead to changes in the results obtained depending onthe method applied (Moreno-Llorca et al., 2020).

Our results indicate that, in the urban landscape of Haifa, green and blue areas with religious or historical significance were the most photographed sites by social media users. Similar results were found by Heikinheimo et al. (2020), who noted that in Helsinki (Finland), hotspots of interest captured through social media mostly concentrate near the city center and near popular sites. People generally do not visit cities to experience nature, as they would not expect to find any (the exception being, perhaps, iconic sites such as New York City's Central Park). Interest in landscape beauty or outdoor activities indeed increases on a urban-to-rural gradient (Baró et al., 2017), while heritage and inspiration decrease along the same gradient (Jaligot et al., 2019; Radford and James, 2013). Hamstead et al. (2018) analyzed preferences for more than 2000 parks in New York City using social media data, and found that cultural activity, even within urban parks, was positively correlated with proximity to public transportation, bike routes, water bodies, athletic facilities, and impervious surfaces, but was negatively associated with green space.

Haifa represents an extreme case in which vegetated, largely unmanaged areas are adjacent to, and intermingle with, the built-up area. This configuration is rather unique relative to other urban settings of medium-sized cities, particularly in Israel (Depietri and Orenstein, 2020). As it emerged in our study, locals, almost exclusively, are those aware of, and benefit from, these less publicized and largely unmanaged green areas.

Our case suggests that changes in perceptions between different groups of users might be accentuated in urban and peri-urban areas. Non-locals reflect appreciation of the local fauna and beauty of nature differently than that demonstrated by residents (Ghermandi et al., 2020a). In a natural park, plants, wildlife and rock formations, followed by scenic views, are generally the most photographed features by hikers (Dorwart et al., 2009). But these elements of the landscape are rarer in the urban context and might require a more constant and dedicated attention for their observation.

5.5. Instances of complementarity between the two approaches

We suggest that, in most cases, results obtained from the two methods considered in this study should be interpreted as capturing two unique aspects of the intangible benefits provided by urban green and blue spaces, emphasizing the complementarity of the two approaches and the potential benefits of combining them into a more thorough CES characterization. Complementarity of different methods to assess CES has been widely suggested in the literature (Brown and Reed, 2009; Cheng et al., 2019; Dunford et al., 2018; Gosal et al., 2018; Scholte et al., 2015; Wartmann et al., 2018). Ours and other recent studies suggest that this is true also in the case of social media and PPGIS approaches, and that it would be beneficial to combine these methods in order to capture a broad cross-section of CES offered by an area (Heikinheimo et al., 2020, 2017; Komossa et al., 2020; Martínez Pastur et al., 2016; Muñoz et al., 2020; Tenerelli et al., 2016).

For a comprehensive approach, we suggest that social media approaches be used first, to identify hotspots and coldspots of interest and aesthetic value which could then be analyzed more in-depth through a stated preferences method. In this phase, PPGIS could thus be used to collect more detailed information on elements of the landscape of interest and specific activities in which the visitors partake in each site, and, in this way, complement the social media-based analysis.

6. Conclusions

We assessed the features of the landscape which give value to seven green and blue areas of the city of Haifa as well as the CES enjoyed by visitors of these areas, by applying two different methods: PPGIS and geolocated social media-based assessment. We conclude that the two methods are complementary in many instances. For instance, we observe that, while it is possible to adequately identify preferences through both methods, the social media-based approach is particularly suitable to characterize sites with high visitation or high touristic value. Areas with landscape views, lookout points, and places where natural landscape elements are coupled with architectural, historical, and religious elements are well represented in geolocated, passive crowdsourced data. In contrast, urban green and blue areas that are less accessible, less known to the broader public, less publicized, but that are visited often and that are highly valued by local users, were better captured by the PPGIS method.

Social media assessments of CES, while having significant advantages and while providing important additional information to survey-based methods, should be considered as a tool within a more holistic

framework, rather than an all-in-one solution (Richards and Friess, 2015; Richards and Tunçer, 2018). The use of one or the other method will also depend on the policy objective (e.g., managing existing well-known sites vs. the identification of locally highly valued, little touristic sites), the target audience for research, and the desired spatial scale of analysis. Overall, we advocate the application of multiple methods, whenever possible, to exploit the synergies and capture a wide spectrum of urban CES.

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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