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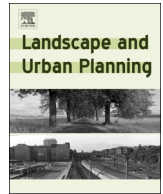
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Review Article

Crowdsourcing geo-information on landscape perceptions and preferences: A review

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ABSTRACT

This paper offers a summary of different crowdsourcing modes to collect geo-information on landscape perception & preferences and cultural ecosystem services. Crowdsourcing modes range from harvesting information passively transmitted by large groups on the web to actively engaging the crowd to generate data by using dedicated mobile apps and web-platforms. The latter, active crowdsourcing projects, were described in more detail by analysing the organizational variables of the twelve projects that were identified. Crowdsourcing has great potential to advance the field of landscape perception & preference research as it enables the *in-situ* collection of real-time, location-based data. One of the main limitations of reviewed active and passive crowdsourcing modes, lies in the fact that sample selection bias easily occurs and sample representativeness of any target population has been proven hard to achieve. Often crowdsourcing projects are implemented with a strong focus on technical aspects and content, but with insufficient attention for participant engagement. Projects would benefit from more inter- and transdisciplinary approaches and professionalizing campaigns, and thereby bringing participant engagement to the heart of the project. We recommend more attention to be placed towards awareness raising, diversification of formats and activities to reach a larger diversity of participants, structured tracking of performance indicators and learning from participants' feedback. Such strategies aim at enhancing participation and reducing bias in participant selection, which constrains the usefulness of the results for research, planning and policy.

1. Introduction

Significant technological advances during the last decade have resulted in momentous changes in different aspects of human life, leading society to redefine the role of public information (Goodchild, 2007; See et al., 2016). The emergence of Web 2.0 and the release of public application programming interfaces (APIs) for online mapping tools and sites that enable uploading georeferenced content, together with the proliferation of mobile devices able to record the location, allowed non-expert users to quickly and easily display geographical information on shareable maps (See et al., 2016; Turner, 2006). Consequently, spatial data collection and mapping has shifted radically from the exclusive domain of highly-trained experts, to increased engagement of the public. Turner (2006) terms this novel set of techniques and tools that fall outside the scope of traditional Geographic Information Systems (GIS) as *neogeography*. Aligning with the concept of neogeography, a wide range of new approaches and terms has been introduced in the

literature to highlight the changes in the forms of spatial information that are available, and in the processes through which they are created and used (Elwood, 2008). The term volunteered geographic information (VGI) refers to intentionally created and shared data. In contrast, data collected without awareness or permission of data “producers” are often labelled as contributed geographic information (CGI) (Goodchild, 2007; Elwood, 2008; Elwood, Goodchild, & Sui, 2012; Fischer, 2012; Harvey, 2013). Broader terms such as crowdsourcing, citizen science and user-generated content (UGC) are also used extensively in the literature to describe this new phenomena. Brabham (2013) has defined crowdsourcing more narrowly, as “...an online, distributed problem-solving and production model that leverages the collective intelligence of online communities (i.e. crowds) to serve specific organizational goals”, stressing that crowds are *given* the opportunity to contribute by organizations. To be more inclusive in this paper, we adopt a definition of crowdsourcing that extends beyond Brabham's definition, including both VGI and CGI. For a further discussion of the use of the

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crowdsourcing concept in relation to VGI and CGI see [See et al. \(2016\)](#).

Crowdsourced geo-information has been used to visualize how people perceive and interact with landscapes ([Dunkel, 2015](#)). Crowdsourcing perceptions on landscapes can be used to mobilize public engagement in land use planning ([Seeger, 2008](#)) and advocate incentives to maintain and increase landscape quality ([Martínez Pastur, Peri, Lencinas, García-Llorente, & Martín-López, 2015](#)). Also, crowdsourced CGI from social media has become a significant source for mapping cultural ecosystem services and landscape values ([Casalegno, Inger, Desilvey, & Gaston, 2013](#); [Dunkel, 2015](#); [Tenerelli, Demšar, & Luque, 2016](#); [van Zanten et al., 2016](#)). The applications listed above indicate that crowdsourcing is increasingly harnessed to collect geographic information to support research on landscape perception and preference (LP&P) and cultural ecosystem services (CES). This type of geographic information is inherently subjective: it summarizes emotions, opinions, views and values of people in relation landscapes and/or ecosystems, often motivated by direct use (e.g. recreational activities), aesthetics, sense of place and belonging or existence values of biodiversity. As a result, quantifying landscape preferences and associated ecosystem services requires large scale public consultation and sophisticated methods to ensure representative views and inclusive research outcomes ([van Zanten, Verburg, Koetse, & van Beukering, 2014](#)). In theory, employing crowdsourcing techniques allows reaching a large number of people in a relatively short time frame at limited costs. Also, the volume and near real-time nature of crowdsourced geo-information enables inference of subtle spatial and temporal variations of the perception and preferences in landscapes. Measuring such spatio-temporal variations is a particularly challenging and time-consuming task to achieve with traditional methods, such as field observations or questionnaires. In addition, crowdsourcing enables *in-situ* collection of geographic information using mobile devices, which is deemed particularly important to capture the aesthetic value of landscapes ([Gobster, Nassauer, Daniel, & Fry, 2007](#)) and other CES ([Plieninger, Dijks, Oteros-rozas, & Bieling, 2013](#)).

Still, several challenges are apparent in crowdsourcing applications in general. One of those is recruiting and retaining participants in different crowdsourcing modes. In a review addressing recruitment and retention of participants in citizen science, [West and Pateman \(2016\)](#) coupled key theories found in volunteering literature with examples from the environmental volunteering and citizen science literature. They identified three key points project facilitators need to take into account when developing strategies for participant engagement: (I) the motivations of potential participants, (II) their personal circumstances and demographics, and (III) how they will become aware of the project. It is important to have in mind that not all societal groups have equal access to Web 2.0 or the interest in generating content, either online or through a mobile application. Hence, insights in the socio-demographic characteristics of participants and individual motivations underlying their willingness to participate could give directions for improving future crowdsourcing design and enhancing participant engagement. Also, such information can provide a base for developing strategies for reaching out to diverse demographic groups that are often under-represented ([Seeger, 2008](#)).

The main objectives of this paper are twofold. First, we aim to create a comprehensive overview of different crowdsourcing modes used to collect and use volunteered and contributed geographic information in the domain of LP&P and CES based on a literature review ([Section 2](#)). This is done by i) describing and classifying different types of crowdsourced geo-information, ii) discussing the approach and output of active crowdsourcing projects based on relevant publications and iii) discussing the approach and output of research that harnesses passively crowdsourced geo-information. Second, following the need to investigate the incentives for participating in crowdsourcing projects ([See et al., 2016](#)), this paper aims to identify best practices and lessons learnt to guide strategies for participant recruitment and retention in such projects ([Section 3](#)). In the discussion, we reflect on our findings and

present a set of recommendations. Throughout this paper, we will use the term crowdsourcing to describe the process of collecting and utilizing geo-information produced by the crowd to support research on LP&P and CES with relevance to landscape planning and policy.

2. Crowdsourcing geographic information for landscape perceptions and preferences and cultural ecosystem services – current state in the field

To provide an overview of current use of crowdsourcing for collecting geo-information on LP&P and CES, we searched the Google Scholar and Web of Science for peer-reviewed articles using the combinations of terms *crowdsourcing*, *social media*, *volunteered geographic information* AND *landscape*, *environment* AND *perception*, *value*, and *cultural ecosystem services*. This search yielded in total 587 results. After screening the titles and abstracts, we included only those studies aiming to demonstrate how crowdsourcing techniques can be applied to collect geo-information with a focus on landscape perceptions and preferences or cultural ecosystem services.

To review crowdsourcing through dedicated mobile applications and online platforms, we also examined two inventories of crowdsourcing projects in landscape research ([Draux, 2014](#); [Tisma, De Weerd, & Riemsdijk, 2015](#)), a recent handbook in crowdsourcing, citizen science and VGI ([Capineri et al., 2016](#)), and consulted with experts in the field. Twelve relevant crowdsourcing projects were identified ([Section 2.1](#)) supported by the same number of publications discussing these projects and/or using the collected data. All twelve crowdsourcing projects in this review are situated in Europe. Additionally, a snowball search method was applied by examining reference sections of collected articles resulting in 25 additional publications that used crowdsourced geographic information from different social media sites and online repositories.

Relevant articles were classified as having either a conceptualization, system or application focus, as proposed by [Zhao and Zhu \(2014\)](#). First, studies with a conceptualization focus explore what crowdsourcing is and how it differs from other similar concepts. Second, studies with system focus examine the different constituents of the crowdsourcing system: Organizations benefitting from crowd input, individuals and communities forming the crowd, and intermediation platforms building a link between the assigners (organizations) and the input providers (crowd). Third, studies with application focus aim to explore the use of crowdsourcing as a tool or a method to address different real world problems. Most of the studies were in the latter category describing the use of crowdsourcing to capture the perception and emotional responses in relation to landscapes (e.g. [Huang et al., 2014](#); [Klettner, Huang, Schmidt, & Gartner, 2013](#)), and to assess landscape preferences and cultural ecosystem services associated with landscapes on different spatial scales, ranging from local to continental ([Casalegno et al., 2013](#); [Dunkel, 2015](#); [Tenerelli et al., 2016](#); [van Zanten et al., 2016](#)). Application focus studies in this review either describe (the use of geo-spatial data obtained through) active crowdsourcing projects ([Section 2.2](#)) or research projects that harness passively crowdsourced geo-information ([Section 2.3](#)). Studies with a system focus – the second category – served to provide foundation for discussing participants' engagement in crowdsourcing projects ([Section 3](#)). Before describing applications, the next section characterizes different types of crowdsourced geo-information.

2.1. Types of crowdsourced geo-information for LP&P and CES research

In their typology of VGI, [Craglia, Ostermann, and Spinsanti \(2012\)](#) consider two dimensions: (I) the way information was created and (II) the geographic nature of the information. Both of these dimensions can be either explicit or implicit. As for II, a piece of information is explicitly geographic if it describes characteristics of a certain place, while a piece of information that is not specifically about a place, but still

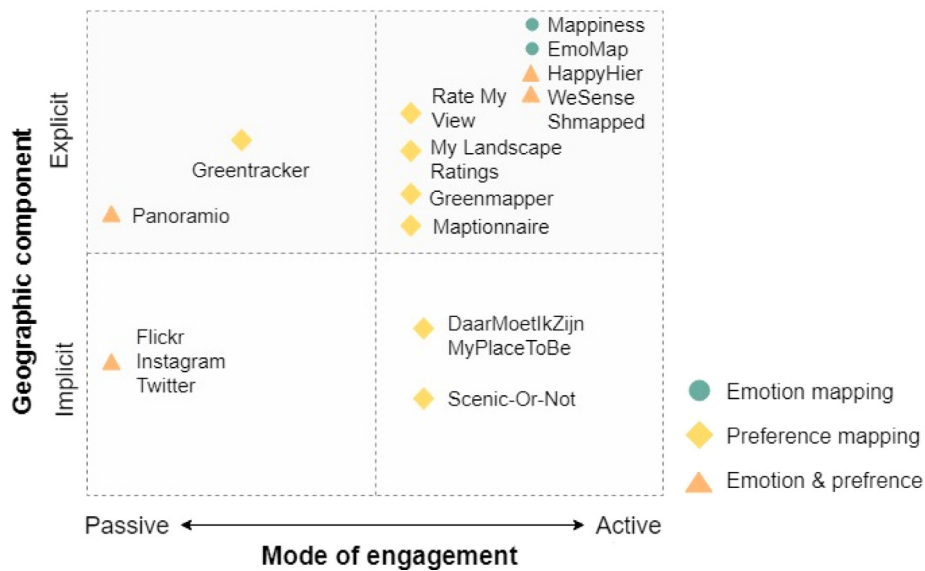


Fig. 1. A typology of crowdsourced geo-information (dedicated apps, platforms and social media/photo repositories) with regards to the geographic component (Y-axis) and engagement of data produces (X-axis).

includes a geo-reference, can be considered implicitly geographic. Gliozzo, Pettorelli, and Haklay (2016) use the same terminology to distinguish crowdsourced data sources as having either an explicit or implicit geographical component. For example, Panoramio can be considered as the example of the former as users are explicitly requested to include geographic location for each uploaded image, while Flickr and Instagram are examples of implicit geographic information since their geo-tags serve only as an optional, accompanying information. We build on these distinctions by classifying the detected crowdsourced data sources in this review as either implicitly or explicitly geographic (Fig. 1). In this paper, explicitly geographic crowdsourced information requires manual upload of the geo-location, such as for Panoramio, mobile applications which require users to be in the environment while recording information (e.g. Mappiness, Rate My View), and web-platforms which require positioning locations on a map (Greenmapper) (Fig. 1). On the other hand, implicitly geographic information is obtained through social media where geo-locating posts is optional and/or automated (Flickr, Instagram, Twitter), and platforms where users are asked to state their preference for landscape elements (DMIZ, MPTB) or landscape scenes (Scenic-Or-Not) without having to record location.

The second axis of the typology by Craglia et al. (2012) describes two ways information is created. If a piece of information was made publicly available by the author and contributed with a specific purpose in mind, it is considered explicitly volunteered. On the other hand, the information made public by the author, but not provided for the specific purpose is qualified as implicitly volunteered. Corresponding with the explicitly and implicitly volunteered information, See et al. (2016) classified crowdsourced geographic information depending on the nature of the contributions as either active, implying contributions were made actively as a part of a crowdsourcing system/campaign, or passive suggesting it was generated for another purpose (e.g. sharing location-based content with other users on social media) and then mapped.

The distinction between active and passive contributions suggests different engagement levels within different crowdsourcing modes. Gomez-Barron, Manso-Callejo, Alcarria, and Iturrioz (2016) further elaborate on this by distinguishing contributory, collaborative or participatory processes of crowdsourcing which imply different levels of participants' engagement ranging from passive contributions or basic participation through independent tasks, across more complex contributions involving group communication and relationships, to

proactive participation with the possibility of involvement in steering the project (Haklay, 2013; Gomez-Barron et al., 2016). None of the crowdsourced data sources in this review did involve projects based on proactive participation, therefore they were positioned on a spectrum from passive to active depending on the mode of engagement (Fig. 1).

The crowdsourced geo-information of sources presented in Fig. 1 was used to capture (1) the perception and emotional responses in relation to landscapes, (2) to assess landscape preferences and cultural ecosystem services, or (3) a combination of the former and the latter (Fig. 1). From an environmental psychology perspective, person-environment relationships are shaped by several factors including objective attributes of the environment, the way these objective attributes are cognitively perceived, the way it is affectively evaluated and the activities carried out in that environment (Aiello, Grazia, & Scopelliti, 2010). In the case of Mappiness, EmoMap and HappyHier, the crowdsourced geo-information includes self-reports on affective responses to the different types of landscapes – and was subsequently used to map how the landscape influences emotional states of people. Hence, this category of crowdsourcing is termed emotion mapping. Crowdsourced geo-information collected in the projects such as DaarMoetkZijn, Rate My View and Scenic-or-Not was applied to map landscape preferences and cultural ecosystem services, labeled here as landscape preference mapping. Finally two of the detected active crowdsourcing projects (WeSense and Shmapped) collected data on both self-reported affective responses and preference scores, while passively crowdsourced data was employed to capture both location-based emotions (Hauthal & Burghardt, 2013; Huang, Gartner, & Turdean, 2013; Klettner et al., 2013) and map landscape preferences (Casalegno et al., 2013, Tenerelli et al., 2016, van Zanten et al., 2016).

In the following sections, we describe the different types of crowdsourced geo-information (Fig. 1) in more detail. Except for social media (i.e. Instagram, Flickr and Twitter), photo-sharing platform Panoramio and Greentracker, all crowdsourced geo-information presented in Fig. 1 stems from active crowdsourcing projects (Section 2.1). Research that harnesses geo-information originating from photo-sharing and social media platforms is reviewed in Section 2.2.

2.2. Active crowdsourcing projects

The information on the twelve active crowdsourcing projects, all expert-facilitated, was sourced through official websites and promotional materials, as well as from publications in which the projects were

discussed (SM A).

A first group of three projects focused on assessing how the environment affects people's emotional states by collecting geo-located self-reports on the levels of happiness (Mappiness, HappyHier) and affective (i.e. emotional) responses to environment (EmoMap). Mappiness, the most successful project in terms of number of users, in its' six year of existence managed to collect over million observations from 66,621 participants. Participating in the project required to install the mobile application, record socio-demographic data and general satisfaction with life, and continuously report the happiness levels when notified by answering a short questionnaire. The campaign was initially run in the UK, and became globally known through extensive media coverage including press, television and radio, and thousands of mentions on social media sites such as Facebook and Twitter (MacKerron & Mourato, 2013). More than a million geo-located responses from 21,947 UK participants collected during a six-months long active campaign, were subsequently associated with objective spatial data showing people are on average happier in natural than in urban environments, and once more proving the relationship between exposure to nature and well-being (MacKerron & Mourato, 2013).

A similar project was carried out in the Netherlands under the name HappyHier. During a three-month campaign, project was extensively featured in both traditional and social media, resulting in more than 6000 app downloads, with 4000 sustained participants contributing close to 100,000 observations. Regular feedback on the project's progress was provided during the course of the campaign in a form of summary statistics published on the projects' social media sites. The HappyHier app functionalities are similar to those of Mappiness. Users were required to create a profile and fill in a short questionnaire once or more a day after receiving a notification. The results of the HappyHier project were not yet available at the time of writing this paper. Finally, EmoMap, a two-years long project, which ended in 2013 gathering 3200 observations from 193 participants, also involved a mobile app where users were asked to rate the experienced levels of comfort, safety, diversity, attractiveness and relaxation in their environment, and record contextual information such as familiarity with the place and company (Klettner et al., 2013). The collected data was subsequently used to enhance route-planning services (Huang et al., 2014).

A second group of seven projects aimed to assess preferences and values of cultural ecosystem services associated with landscapes and their features, namely Maptionnaire, Greenmapper (earlier versions are known as HotSpotMonitor; Fig. 2), DaarMoetIkZijn and MyPlaceToBe, Scenic-Or-Not, Rate My View and My Landscape Ratings. A cloud service called Maptionnaire in an example of a crowdsourcing tool which enables researchers to collect data from a large number of residents with regard to their insights on the environment. The collected data is subsequently applied as a knowledge base for discussing spatial planning options (López-Aparicio, Vogt, Schneider, Kahila-Tani, & Broberg, 2017). Here, we will further discuss the application of Maptionnaire to capture people's use and preferences for green spaces in Renfrewshire, Scotland and Helsinki, Finland as designed by Richard le Brasseur from the University of Edinburgh. In this project, participants were asked to annotate their favourite green spaces on a map and report on how they use them. The generated data has been utilized to inform the management of green space systems in Finland and Scotland.

Similar to the Maptionnaire projects in Finland and Scotland, Greenmapper, is a crowdsourcing platform developed by researchers from the University of Groningen, Netherlands with the main aim of collecting information on the natural areas people perceive as attractive or valuable while building an online community of nature lovers. The predecessor of Greenmapper is a Google Maps-based tool HotSpotMonitor (HSM), which asked respondents to annotate attractive places on a map and answer several additional questions explaining their selection (Sijtsma, Daams, Farjon, & Buijs, 2012). So far, data collected through HSM was analysed to measure the attractiveness of nature in Dutch Wadden Sea area (Sijtsma et al., 2012), as well as the

attractiveness of Dutch landscapes on a national scale (de Vries et al., 2013). Furthermore, Davis, Daams, Hinsberg, and Sijtsma (2016) conducted a content analysis of answers provided by HSM respondents to extract the subjective experiences associated with natural areas in the Netherlands. A recent study by Bijker and Sijtsma (2017) demonstrated, through using Dutch, Danish and German Internet panel respondents, how HSM data can be used to compare the appreciation and use of green space by urban residents at four different spatial levels: neighbourhood, region, national, and global. Expanding the HSM to the Greenmapper project, a new function was added to the standardized online survey allowing users to register as "fans" of different landscapes and enabling them to get in touch with other users who share their interests as well as with land use management organisations. To support both of the described Greenmapper functions, two other applications were developed – Greentracker, which allows users to record and share their favourite tracks in natural areas, and Greenmapper Daily, which can be considered as a mechanism to stay engaged with the Greenmapper platform as it provides daily suggestions on natural areas worth visiting.

Another contributory crowdsourcing project originated in the Netherlands is DaarMoetIkZijn, a website released in 2006 with the aim to collect data on landscape preferences. Based on the preference scores respondents assign to different landscape features, they are presented with a map indicating areas that match their "ideal" landscape. In 2011, a mobile app was released having the same functionalities as the original webpage, while also displaying information on landscape characteristics in the perimeter of 5 km from user's location. Information collected through both app and website was employed to analyse perceived attractiveness of landscapes in the province of South-Holland for informing landscape planning and management decisions (Goossen, 2017). A Dutch version of the website was extended to a similar tool for the European scale, called MyPlaceToBe, which enables Internet users to discover potential travel destinations in Europe based on their preferences for different landscape types as well as the activities they like to engage in during their holidays (Goossen, Franke, Meeuwse, & de Jong, 2012).

Scenic-Or-Not is a web-based crowdsourcing project originally developed by a non-profit UK-based organization mySociety to quantify scenic quality of UK landscapes. Today the website is being managed by researchers at Data Science Lab of Warwick Business School interested in exploring the relationship between scenic quality and human well-being. The Scenic-Or-Not website works by displaying geo-tagged landscape photographs from the Geograph online photo repository, and asking respondents to rate each image on a scale from 1 (not scenic) to 10 (very scenic). Up to now, over 1.5 million ratings have been recorded for over 200,000 locations in the UK (Seresinhe, Moat, & Preis, 2017). Empirical applications with the project data included relating it to census data on citizen-reported health (Seresinhe, Preis, & Moat, 2015) and employing it to verify findings obtained from Flickr and OpenStreetMap data (Seresinhe et al., 2017). Also, Chesnokova, Nowak, and Purves (2017) have used the Scenic-Or-Not dataset to develop a predictive map of landscape preference. The use of online visual preference surveys, such as the above described Scenic-or-Not project, often raises the question of what is the best approach to analyse the data collected in such a manner. A recent research note by Goodspeed (2017) provides a constructive effort to answer that question by comparing the suitability of three potential metrics (i.e., Win Ratio, Q score and Elo algorithm) on a dataset of 103,200 votes collected in a visual preference survey conducted for the streets of Philadelphia in which the participants were presented with a pair of images and asked to select the one they considered more beautiful. The results suggest that, while all three applied metrics demonstrate high correlation, the Elo algorithm provides a more discerning measure for those images that stimulate strong responses (Goodspeed, 2017).

The last two projects described in this group are Rate My View and My Landscape Ratings: Mobile applications developed with an aim to

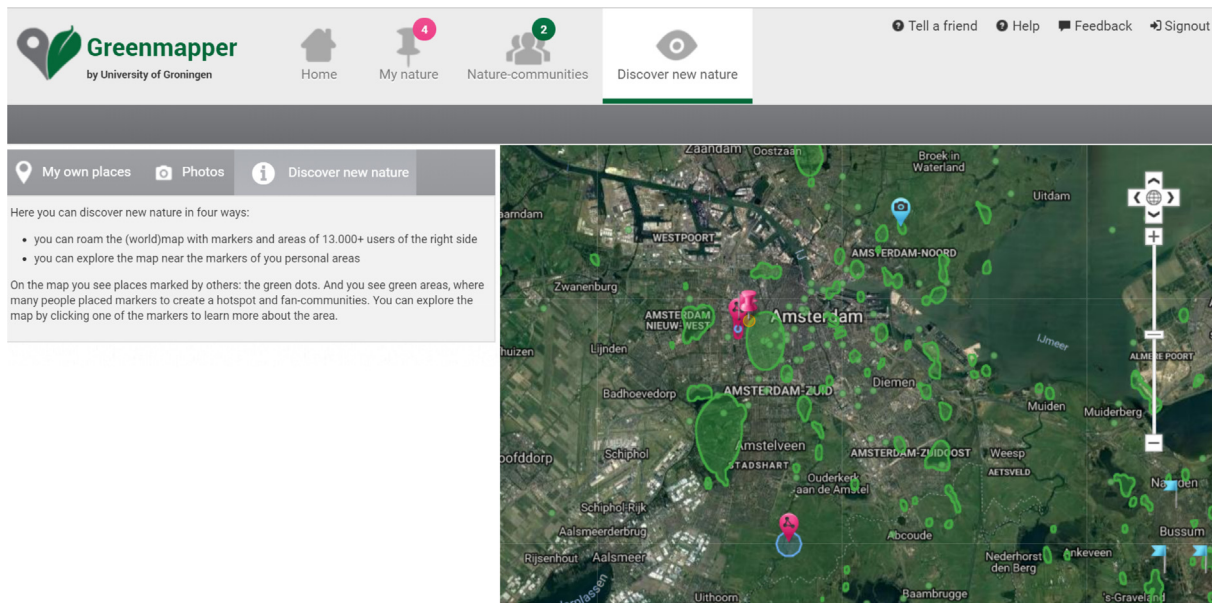


Fig. 2. A screenshot of the Greenmapper 'discover new nature' page. Greenmapper allows you to define your favourite green spaces or nature at neighbourhood, regional, national and global level. Based on the features of these favourite places, Greenmapper Daily provides users with suggestions of places to visit. In this map, the pin shows the location of residence of the user. The red marker nearby represents the favourite neighbourhood green space and the red marker outside the city of Amsterdam shows the favourite regional green space of the user. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

collect geo-information on landscape preferences. Rate My View was initiated in 2015 by the Plymouth University and the South Devon Area of Outstanding Natural Beauty (AONB) to capture the personal views and perceptions of landscape users in South Devon, UK. Users are asked to take a photograph of a landscape scene of their own choosing, rate it (1–5) and describe the captured scene using three phrases. So far, 437 observations were collected in the UK and all of the entries can be accessed on a shareable map featured on the project's official website. A very similar set of functionalities to those of the Rate My View app was featured in the My Landscape Ratings app developed in 2015 within the HERCULES project (<http://www.hercules-landscapes.eu/>). According to the project description, the main aim of the application was to engage the people in collecting georeferenced observations (photographs), and gather additional information on how landscapes are being perceived for a European-scale survey on landscape practices. However, the number of downloads indicates that the application has not been widely used, and no information was found on the course of the campaign or the engagement strategies employed. Therefore, this project was not included in the subsequent analysis of engagement strategies.

A third group includes two mobile applications, Shmapped and WeSense, designed to collect the data on both emotional responses and preferences people have for different types of natural areas in cities. The former has been developed as a part of IWUN (Improving Wellbeing through Urban Nature) project run by the Universities of Derby and Sheffield which aims to better understand how different aspects of public spaces affect resident's wellbeing in the study area of Sheffield, UK. Users are asked to participate in the study by continuously using the application in the period of one month. While the Shmapped campaign is still running, so far over 830 participants actively used the app (Kirsten McEwan, personal communication, November, 27, 2017). A second application in this group is the WeSense app developed by the researchers of the Urban Landscape Architecture Research Group at Delft University of Technology. The main aim of this research project is to explore how people perceive urban green areas in the study area of Amsterdam, The Netherlands. WeSense app works on a similar principle as the earlier described Mappiness and HappyHier apps. After receiving a notification, users are asked to give their input

by filling in a questionnaire on how they perceive and interact with their immediate surroundings, followed by an option to upload a geo-located photograph. According to the statistics on the project's website (accessed 20th of Nov 2017), 442 responses were collected so far. For the two described projects, no peer-reviewed publications are available.

2.3. Research projects using passive crowdsourced geo-information

Online photo repositories and social media are becoming increasingly used to extract geo-information on LPP and CES. As Dunkel (2015) stated, "if multiple people take photographs at a certain location, those photographs might be linked to a specific visible or associated characteristic (or absence of characteristics) that initiates the same decision process for that place or area" (p. 177). The same relation is applicable to the use of tags as semantic descriptors of an experienced scene. Building on that premise, Dunkel (2015) argues that maps generated from such crowdsourced data can visualize perception and cognition-based decision processes.

So far, geo-referenced social media data have been explored to assess and map people's activities (and variations over time and space), preferences for urban landmarks (Jankowski, Andrienko, Andrienko, & Kisilevich, 2010), to visualize the characteristics of both urban and natural environments as perceived by the public (Dunkel, 2015), and to assess visitation rates and perceived importance of protected natural areas (Levin, Mark, & Brown, 2017). While LP&P research often tends to reveal commonly liked aspects landscape photos, a study by Lovato et al. (2013) takes an opposite direction by attempting to discern individual aesthetic preferences of 200 Flickr users by analysing colour, textures, edges, regions, objects, faces and scenes present in the images users themselves marked as their "favourites" (Lovato et al., 2013). The results demonstrate that, based on their aesthetic preferences, different users can be identified with high level of precision. These findings may, therefore, prove valuable for future advancement in employing crowdsourced images to extract landscape preferences, especially as these studies are often criticized for providing limited, if any, insight in the individual traits of data producers.

Finally, online photo repositories have been particularly popular data source for quantifying and mapping cultural ecosystem services

(CES). Here, majority of research efforts was put in crowdsourcing information on recreation and nature-based tourism (Keeler et al., 2015; Upton, Ryan, O'Donoghue, & Dhubhain, 2015; Willemen, Cottam, Drakou, & Burgess, 2015; Wood, Guerry, Silver, & Lacayo, 2013), and/or aesthetic value (Casalegno et al., 2013; Figueroa-Alfaro & Tang, 2016; van Zanten et al., 2016; Yoshimura & Hiura, 2017). Some studies expanded CES selection to include educational and existence value, local identity, as well as cultural heritage, social and spiritual value (Richards & Friess, 2015; Tenerelli et al., 2016; Martínez Pastur et al., 2015; Oteros-Rozas, Martín-López, Fagerholm, Bieling, & Plieninger, 2017). The potential of crowdsourced geo-information has also been explored to capture the way people interact with urban green spaces. For instance, (Kothencz, Kolcsar, Cabrera-Barona, & Szilassi, 2017) utilized Flickr images to reveal human perception of urban green spaces. Similarly, Guerrero, Møller, Olafsson, and Snizek (2016) used geo-tagged Instagram photos to map citizens' uses and perceptions of urban nature.

While the majority of studies focused on analysing user-generated photographs, either by examining their locations, content or both, we have also detected several applications of text-based analysis. For example, geo-located Twitter posts were analysed to extract information on the patterns of use and physical activity in a number of city parks in Birmingham (Roberts, 2017; Roberts, Sadler, & Chapman, 2017). Finally, several studies have applied natural language processing techniques to the tags and descriptions of Flickr and Panoramio images in order to study location-based emotions (Hauthal & Burghardt, 2013; Huang et al., 2013; Klettner et al., 2013). The majority of the data collected from social media is implicit in terms of its geographic component collected using a passive mode of engagement (Fig. 1). However, we found one example of a campaign held among Instagram users in Copenhagen who were explicitly asked to upload geo-tagged photographs of urban nature while using a specific hashtag (Guerrero et al., 2016). This example illustrates how targeted campaigns can be used to actively engage the existing crowd on social media in generating content for a specific purpose.

3. Engagement and motivations to actively participate in crowdsourcing

While the previous sections portrayed different modes of crowdsourcing and their current use in landscape research, this section focuses on engagement strategies used in active crowdsourcing geo-information for LP&P and CES. The willingness to volunteer is conceptualized by Penner (2002) as a relation between attributes of project organization (organization variables) and attributes of individuals (dispositional variables). In the context of crowdsourcing VGI, this means that "if motivations are aligned with a VGI project, then volunteers will be more likely to participate, less likely to get demotivated and have interest in providing better and more complete data" (Antoniou, Fonte, Minghini, See, & Skopeliti, 2016, p. 1). In the following sections we further explore this relation by summarizing the engagement strategies adopted by twelve reviewed projects and analyse those dimensions of engagement specific to LP&P and CES.

3.1. Engagement strategies in active crowdsourcing

In any crowdsourcing project, engaging participants consists of two stages: recruitment and retention (Crall et al., 2017). Recruitment refers to the motivation underlying individual's decision to take part in the project, while retention stands for the motivation to continue participating. Depending on the main goals, crowdsourcing projects can be based either on one-time contributions or require a sustained participation. Only one of the analysed projects (Shmapped) requires a sustained engagement, by asking participants to make contributions at least every other day throughout the course of one month. While several other projects did encourage multiple contributions, this was not a

prerequisite for successfully completing the participation. Four projects (Mappiness, HappyHier, WeSense, Shmapped) included a request-driven workflow, meaning participants were asked to give their contributions upon receiving a notification once or multiple times a day, while for the remainder of the projects contributions could be made at any time relying on participant's own initiative.

To achieve the desired levels of engagement, the benefits arising from participation should be presented in a clear and comprehensible manner. Based on their evaluation of citizen science projects, Gommerman and Monroe (2012) distinguished the following four benefits for volunteers: (1) increased knowledge and understanding of the scientific process, (2) deeper understanding of natural phenomena and issues of local importance, (3) strengthening attitudes toward their natural environment, and (4) participation in making science-based recommendations. These four categories were based on the citizen science projects deviating from the thematic focus of this review: collecting objective data such as water quality parameters or occurrence of bird and animal species (Gommerman & Monroe, 2012). These relate to topic areas that are very focussed and tangible. The broader and less tangible nature of landscapes provides a challenge in this respect.

In order to assess which benefits participants may receive through engaging in projects crowdsourcing geographic LP&P and CES data, a content analysis of promotional material, official web-pages and application interfaces of twelve projects was conducted. The benefits of active engagement were communicated in ten out of twelve investigated projects. In three cases (Mappiness, HappyHier, WeSense), this was done in a very direct manner by featuring *what's in it for you* segment on the project's homepage. The other projects incorporated such information in a general description or under FAQ section. Other organizational variables including tasks, types of data collected, and mechanisms used to provide feedback, are summarized in Table 1, while additional information on the reviewed projects can be found in the SM 1.

Six benefits of active engagement in crowdsourcing subjective data are summarized in Table 2. The first one, presented across all twelve cases, is the contribution to scientific research. Strengthening attitudes towards the (natural) environment also emerges as potential benefit of active engagement in all twelve projects, as participants are prompted to record various aspects of their interaction with the surroundings. A third benefit, found in eight cases, involves receiving a personalized feedback based on user's contributions. Applications focused on collecting emotional responses (Mappiness, HappyHier, EmoMap) provided access to information on own emotional states and levels of happiness across time and space. This personalized feedback mechanism is also applied in the WeSense project by providing users with information on daily patterns of satisfaction with their surroundings in the form of charts showing when, where and with whom they are most satisfied. With an increasing number of completed surveys, participants could gain access to more detailed personal statistics. Lastly, a form of personalized feedback was utilized in both DaarMoetIkZijn/MyPlace-ToBe and Greenmapper to enable users to discover new landscapes. The former provide users with a map showing the landscapes worth visiting based on expressed preferences. Similarly, the latter offers tips on places to visit based on the previous entries and HSM data. Besides personalized feedback, another benefit for participants may be the opportunity to compare their own experience or opinion with others. This is enabled in seven projects which provide an overview of all contributions, either on map or as descriptive statistics.

Following the findings of Davis (1989), importance of the fun element was recognized in the DMIZ and MPTB applications which were constructed in a way to deliver the users the outcome of their participation right away (Goossen, Meeuwssen, Franke, & Kuyper, 2009). Gamification and conversational user interface (UI) can be considered mechanisms to increase the fun component of participation. The former one was featured in the case of Scenic-Or-Not through leaderboards showing 5 prettiest and 5 ugliest places in UK. These leaderboards serve

Table 1
Organizational variables of twelve crowdsourcing projects (where Greenmapper is considered a single project).

Project	Smartphone app/ website	Request- driven	Tasks		Types of data collected		Feedback mechanism
			Giving opinions or ratings	Taking geo-tagged photographs	Taking part in outdoor activities		
Mappiness	Smartphone app	X	X		Self-reports + photo	Website/map/personal statistics	
EmoMap	Smartphone app	X	X	X	Self-reports	Website/map/personal statistics	
HappyHier	Smartphone app	X	X	X	Self-reports + photo	Twitter/personal statistics	
Shmapped	Smartphone app	X	X	X	Self-reports + photo	Map/personal statistics	
WeSense	Smartphone app	X	X	X	Self-reports + photo	Website/map/personal statistics	
Mappionnaire (user-centric green space management app)	Website	X	X	X	Self-reports + points	N.A.	
My Landscape Ratings	Smartphone app	X	X	X	Preference scores + photo	Website/map	
Rate My View	Smartphone app	X	X	X	Preference scores + photo	Website/map	
Greenmapper Project							
HotSpotMonitor	Website	X	X	X	Points + preference scores	Website/map	
Greenmapper	Smartphone app and website	X	X	X	Points + preference scores + photo	Website/map	
Greentracker	Smartphone app			X	GPS tracks	Map	
Greenmapper Daily	Smartphone app	X				Map	
Scenic-Or-Not	Website		X		Preference scores	Leaderboard/statistics of other entries	
DaarMoetikZijn	Smartphone app and website	X	X		Preference scores	Map	
MyPlaceToBe	Website	X	X		Preference scores	Map	

to encourage respondents to vote if they disagree with the selection. Also, respondents are able to see how close their aesthetic judgment is to an average of all votes. Conversational UI was introduced in the Shmapped application in a form of a character who guides participants through the study. This feature should help to sustain user engagement throughout a lengthy period. Shmapped users could also join guided group walks in the study area to learn more about the green spaces as well as the research behind the app. In the case of Shmapped a monetary reward was used as an incentive for participants to stay continuously engaged through a one month period. Another example of monetary incentive for the participants was detected in the Maptionnaire green space management app.

4. Discussion

This paper reviews the current use of crowdsourcing for the collection of geographic information in LP&P and CES research. As envisioned by Daniel (2001) nearly two decades ago, technological advances in GIS and data visualization can now support an ‘ecosystem services based’ management of landscapes by improving our understanding of the effects of (changing) spatio-temporal patterns of landscape features. *In-situ* crowdsourcing tools, for example, now help to understand relations between landscape features and LP&P and CES and are gradually replacing and complementing traditional questionnaires and field observation-based tools and methods.

Aesthetic values, and arguably other CES that often spatially coincide with aesthetics, are best captured on-site. Given the importance of a (i) sensory experience of landscapes and an (ii) accurate representation of the perceived scale of landscapes, on-site evaluation has clear advantages. The perception of aesthetic values and other CES in landscapes is often conceptualized by having a component of direct ‘biological’ sensory perception and a perceptual component that is mediated by cognitive factors that often can be explained by the cultural background of an individual or group (Farina, Bogaert, & Schipani, 2005; Gobster et al., 2007; Lothian, 1999; Zube, Sell, & Taylor, 1982). Farina et al. (2005) refer to the sensory component as the ‘individual-based landscape’ and to the cultural component as the ‘observed-based landscape’. In their model of human-environment interactions, Gobster et al. (2007), conceptualize the relation between landscape patterns or processes and the perceptual process, where they highlight the importance of recognizing the spatial scale of landscape perception for understanding aesthetic values people assign to landscapes: this perceived scale is referred to as the perceptual realm.

The crowdsourcing examples included in this review resonate with the concept of *citizens as database*. This concept was introduced by Richter and Winter (2011) in their outlook on the development of crowdsourcing, in which users provide their ‘image of their city’ through a common data structure. They ultimately foresee a state of *conscious ubiquity* of data collection through crowdsourcing, in which citizens function as a database. To achieve this state, however, Richter and Winter list a number of criteria, indicating that crowdsourcing technologies should be “smart enough to collect sensor observations, provide disappearing interfaces for collection of semantic information, report to the user on request and in critical situations, contribute the collected observations to a content platform, and smoothly integrate these observations into the platform’s databases” (Richter & Winter, 2011, pp 4).

4.1. Strengths and weaknesses of different crowdsourcing approaches to assess LP&P and CES

Depending on the research questions posed in the specific study using crowdsourced geo-information, crowdsourcing modes range from harvesting information passively transmitted by large groups on the web to actively engaging the participants in supplying information through dedicated mobile apps and web-platforms. The former

Table 2
Engagement strategies in ten analysed projects with regard to benefits of active engagement.

Project	Contributing to scientific research	Strengthening attitudes towards the (natural) environment	Receiving personalised feedback	Comparing own contributions with others	Fun component	Monetary Reward
Mappiness	X	X	X	X		
HappyHier	X	X	X	X		
EmoMap	X	X	X	X		
WeSense	X	X	X	X		
Shmapped	X	X	X	X	X	X
Maptionnaire (green space application)	X	X				X
Rate My View	X	X		X		
Greenmapper	X	X	X	X		
DaarMoetIkZijn	X	X	X		X	
MyPlaceToBe	X	X	X		X	
Scenic-Or-Not	X	X		X	X	

Table 3
Strengths and weaknesses of active crowdsourcing and the use of passive crowdsourced geo-information. C1, C2 and C3 are the main challenges identified for active crowdsourcing projects in this review.

Using passive crowdsourced geo-information on LP&P and CES	Active crowdsourcing projects to collect geo-information on LP&P and CES
<p><i>Strengths:</i></p> <ul style="list-style-type: none"> ● Large numbers of observations ● Large spatio-temporal coverage ● No selection bias because of interest in project (i.e. nature/landscapes), <p><i>Weaknesses:</i></p> <ul style="list-style-type: none"> ● No information on background of the contributors ● Dependence on lifecycle of platform (e.g. Twitter, Panoramio, Instagram) ● Dependence on technical infrastructure of platform ● Selection bias as a result of no access to technology or no interest/access to platform 	<p><i>Strengths:</i></p> <ul style="list-style-type: none"> ● Controlling the content of the app/platform ● Campaign transparency and monitoring ● Monitoring demographic and other background information participants <p><i>Weaknesses/challenges (C):</i></p> <ul style="list-style-type: none"> ● Resource intensive: technical infrastructure and campaign to engage participants ● Problems to achieve sufficient participant engagement (C1) ● Problems to achieve sufficient participant retention (C2) ● Selection bias as a result of campaigns targeted at participants with an interest in nature or landscapes (C3)

approaches – tapping into existing data streams from social media platforms – allow researchers to relatively easy reach large quantities of geo-information on different spatial and temporal scales, but often at the expense of not knowing the background of the data producers. On the other hand, approaches found on the active side of crowdsourcing spectrum integrate traditional survey research with novel technologies to collect location-based self-reports or preference scores. These active approaches can also be utilized on various spatial scales from local (e.g. Shmapped, WeSense) to national (e.g. Mappiness, HappyHier), and allow collecting more targeted information in comparison to passively crowdsourced geo-information. However, active crowdsourcing is more resource intensive, as it requires developing a technical infrastructure and engaging a sufficient number of users. Table 3 summarizes the key strengths and weaknesses (or challenges) associated with the two different approaches. The key challenges for active crowdsourcing projects (Table 3: C1, C2, C3) are described in the next sections of this discussion.

4.2. Challenge 1: participant engagement

We analysed approaches to engage participants in twelve active crowdsourcing projects to identify if LP&P and CES applications of crowdsourcing use specific approaches for engagement. Engagement with crowdsourcing activities can be characterized by three factors that are elaborated in this section: (1) awareness that the opportunity for participation exists, the (2) appropriateness of such opportunity, and (3) sufficient motivation to take part (Hobbs & White, 2012).

Any recruitment phase of participant engagement should start with an awareness raising campaign. The examples of Mappiness and HappyHier projects illustrate how an extensive coverage in both traditional and social media may attract a large number of people to initially engage. On the other hand, the low number of downloads and contributions to My Landscape Ratings campaign may be a result of limited awareness raising activities. Therefore, we argue that it is

necessary to extend future crowdsourcing projects towards evaluating the effectiveness of awareness raising activities by defining and tracking performance indicators (e.g. number of (social) media mentions, number of app downloads, etc.) during the course of the project. Awareness raising for LP&P and CES crowdsourcing projects can benefit from leveraging awareness for ongoing processes and/or third party campaigns, focused (foreseen) landscape changes.

The appropriateness of the opportunity for participation in a crowdsourcing project may depend on the aim of the project, complexity of the tasks, as well as the context in which contributions are made (i.e. on-site or distant mapping). We did not find examples of applications that were related to active planning projects: e.g. the renovation or design of new green spaces. Such a project would provide a good opportunity for engagement as foreseen changes may motivate the willingness to express opinions. LP&P and CES studies using survey-based and PPGIS techniques found that the relation to potential planning was a strong motivation to contribute (Scholte, van Zanten, Verburg, & van Teeffelen, 2016; Soliva, Bolliger, & Hunziker, 2010; van Berkel & Verburg, 2014).

The benefits that participants receive from active engagement are closely linked to the participants’ motivations to take part and could influence how appropriate they find the participation. Opportunities to contribute to science and to strengthen the attitudes towards landscapes or ecosystems were the most prominent benefits across all projects (Table 2). Further, receiving feedback on both individual and aggregated contributions was also presented as a potential benefit in majority of cases. However, only two of the analysed projects explicitly featured a fun component either by introducing a game element (Scenic-Or-Not) or conversational user interface (Shmapped). Iacovides, Jennett, Cornish-Trestrail, and Cox (2013) showed that game elements may not be necessary for attracting volunteer participants, but game elements do help to sustain engagement over time (retention) as they can enable social interaction and volunteers derive satisfaction from recognition or achievements. Following the example of Scenic-Or-

Not, we suggest a wider application of game elements in the active crowdsourcing of landscape perception, for example by incorporating leader boards of ‘prettiest’ or ‘most popular’ sites, which could in return boost the participation by creating a ‘competition’ between locations. Gamification might also contribute to engaging a younger audience. Landscape preferences are not normally a topic directly appealing to a younger generation. At the same time, as landscape processes are generally leading to a long lasting change it is important to engage the younger generation. Methods that engage the younger generation with the landscapes (of the future) are therefore highly important.

4.3. Challenge 2: participant retention

In addition to review of the twelve active crowdsourcing projects (Table 1, SM 1), we conducted an exploratory analysis of participant motivations for two projects based on an e-mail survey to achieve more insight in the participant retention. In spite of a relatively low response numbers some interesting insights were obtained (full results are in SM 2). When it comes to the challenge of retention, the survey results indicated that participants who repeatedly contribute have higher levels of familiarity with the project’s goals. Therefore, in order to design a successful crowdsourcing system, project facilitators must first ensure that people understand what to do and why. As pointed out by Gomez-Barron et al. (2016), facilitators should carefully construct an engagement plan to assure participants’ emotional commitment over time. The guiding questions when constructing such a plan could involve the following:

- What kind of behaviour are we expecting from the participants?
- What could be the potential motivations for them to behave in such a way?
- What would we like them to experience while participating?

One-time assessments of participants’ motivations may provide useful insights in sample demographics and contributory behaviour, as well as serve as a basis for developing more refined instruments to be used in future studies. However, in order to timely answer to the potential shifts in participants’ motivations, project facilitators should consider introducing iterative assessments of motivations throughout the course of the project. Furthermore, we propose introducing a learning component or gradually increasing task complexity to keep participants interested in the project. Finally, we advise project facilitators to provide regular feedback on the project’s progress and to establish a direct communication channel between participants and project organization.

4.4. Challenge 3: sample selection biases associated with active crowdsourcing approaches

The survey results from the two investigated projects (SM 2) suggest that there is an overrepresentation of older, highly-educated male participants. Other studies investigating participation in crowdsourcing projects also revealed overrepresentation of older, highly-educated men (Brown, Kelly, & Whittall, 2014; Wright, Underhill, Keene, & Knight, 2015). The results also showed that the most prominent motivational factor in both projects was interest in nature. These motivational factors cause a sample selection bias, which poses a challenge for the validity of crowdsourcing in investigating LP&P and CES when the project aims to draw a representative sample of the general population. For example, a study by Brown, Weber, & de Bie (2015) observed preferences for bio-centric conservation and preservation values from a crowdsourced VGI sample, while for the general population these outcomes were not expected.

LP&P and CES studies often aim to summarize public opinions to inform policy and should, therefore, rely on a representative sample. As noted by Jarvis, Breen, Krägeloh, and Rex (2016), it likely that “the

motivations of a voluntary sample would be different to those of a random household sample” (p. 613). Findings from our preliminary analysis of participant’s motivations (SM 2) also point in this direction. Still, we stress the need for more studies comparing and cross-validating the outcomes of using different data collection methods (i.e. crowdsourcing vs. surveys vs. field observations) to properly capture or triangulate LP&P and CES. Furthermore, for (future) evaluation purposes it is essential that project facilitators should monitor and report on the socio-demographic characteristics of participants and, depending on project aims, target campaigns to engage underrepresented groups using stratified sampling. One way to reach out to different groups, as proposed by Domroese and Johnson (2017), is to implement crowdsourcing projects in a curriculum-based context. This was also recognized by Fritz, See, and Brovelli (2017) who described two Italian cases of successful implementation of VGI in the educational program in both elementary and high schools. Integrating a variety of activities for participants to engage in could increase the project’s chances of appealing to a broad audience and thus reduce selection biases.

Another option is to explore post-processing, such as resampling or using statistical weights. Different approaches exist to weigh observations in order to correct for selection biases. In public opinion surveys, weighing approaches are widely applied (Pew Research Center, 2018; Stuart, 2010). (i) Raking is an approach where weights are assigned based on a number of key variables (e.g. gender, age, education level) that are known from a representative population; (ii) matching is an approach where weights are assigned based on a discrete-variable based comparison to a representative sample, for example using machine learning techniques; (iii) propensity weighting is an approach where the probability of selection (or opt-in) of a respondent estimated and weighed by the inverse of this probability (Pew Research Center, 2018). These weighting approaches – especially those that harness machine learning techniques (Zhao, Su, Ge, & Fan, 2016) – have great potential value for passive and active crowdsourcing applications in LP&P and CES research.

5. Conclusion

This review describes the potential value and the challenges of crowdsourcing LP&P and CES geo-information. Clearly, there are trade-offs among different modes of crowdsourcing. On the one hand, various social media sites offer an abundance of readily available data to assess revealed landscape preferences and CES. Applications of these data are abundant in the literature. The limitations of these approaches, however, include drawing assumptions on the reasons why the users generate and share the content, as well as not knowing the socio-demographic structure of the sampled geo-information (Tieskens, Van Zanten, Schulp, & Verburg, 2018). On the other hand, active crowdsourcing approaches are emerging as a promising technique to collect real-time, location-based data to describe LP&P and CES, while also allowing to record demographic information of the participants. Active crowdsourcing approaches face different challenges: engaging sufficient number of participants and the issue of sample representativeness – for example due to access to technology and/or a specific interest in nature – need to be addressed more explicitly to ensure usefulness of the results from a public policy perspective.

Based on the review of approaches, we presented some recommendations in the discussion section for the design and implementation of active crowdsourcing projects that focus on LP&P and CES. We stress that these recommendations are preliminary as the evidence base is too small and too geographically skewed for the identification of generic rules of thumb for project design and implementation (in particular with regard to participant engagement and retention). Often crowdsourcing projects are implemented with a strong focus on technical aspects and content, but with insufficient attention for the three steps of participant engagement. On a higher level, we conclude that projects would benefit from more inter- and

transdisciplinary approaches, professionalizing campaigns and bringing participant engagement to the heart of the project.

On a final note, this review showed that crowdsourcing projects may generate biased results as participants often have a strong interest in nature and landscapes. This affects the type of conclusions that can be drawn from crowdsourced data, and limits the capacity to capture views and opinions of the general public. Studies and research projects aiming to utilize active crowdsourcing should, therefore, be aware of the motivations of different societal groups whose views they aim to capture, be responsive to the potential changes in participant's motivations over time, and work towards further developing strategies for the inclusion of various societal groups. Such strategies aimed at enhancing participation and reducing bias in participant selection will improve relevance of findings for planning and policy.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.landurbplan.2019.01.001>.

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