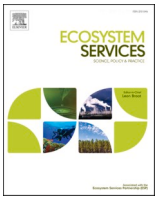
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The future of crowd-sourced cultural ecosystem services assessments

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1. Introduction

Cultural Ecosystem Services (CES) represent one of the primary interactions between humans and ecological systems, with implications for environmental stewardship and awareness of environmental issues. CES include the physical, experiential, intellectual and representative interactions we have with nature, our social relations within it, as well as spiritual and symbolic attachments (Andersson et al., 2015; Chan et al., 2012; Huynh et al., 2022). Consequently, the relationships that result from CES is a key motivation for caring for the environment (Dutcher et al., 2007). Yet, while material ecosystem services (provisioning and regulating services) have been mainstreamed into sustainability policies and landscape planning arenas in recent years, CES are missing from many ecosystem service assessments (Nowak-Olejnik et al., 2022; Kosanic and Petzold, 2020). Challenges related to the recognition and quantification of CES have raised concerns about a lack of consideration of CES in decision making at local to global scales (IPBES, 2018).

Recently, however, there has been renewed interest in CES, with a focus on relational values (Chan et al., 2016; Chan et al., 2018; IPBES, 2022). Relational values of CES create additional incentives to care for the environment (e.g. Langemeyer et al., 2018) in ways that complement utilitarian motivations (Himes and Muraca, 2018). There are also important methodological advances that support the wider consideration of CES in ecosystem services assessments. New advances in social-environmental research based on passively crowd-sourced digital data, notably from social media platforms, has led to novel empirical approaches to assess CES (Ghermandi and Sinclair, 2019; van Zanten et al., 2016) that overcome some of the limitations of time- and resource-intensive methodologies, including surveys, interviews and workshops (Kosanic and Petzold, 2020).

With more than half of the world's population active on social networking sites (Statista, 2022), new opportunities are opening up for the study of human-nature relationships through an unprecedented amount of user-generated social media data (Ghermandi et al., 2023). As such, the analysis of geo-located social media content has become a promising method for assessing and mapping CES at scale (Ilieva and McPhearson, 2018; Ghermandi and Sinclair, 2019) and to gain insights into the relationship between humans and nature, crucial for incentivising and improving global environmental stewardship and nature conservation (Spotswood et al., 2021).

This Special Issue includes 16 individual contributions that showcase cutting edge research in the use of crowd-sourced social media approaches, including: 1) *novel assessment opportunities* for studying CES; 2) *methodological advances* through semantic analyses, automated image content analyses, and validations; and 3) *conceptual advances* to better understand the representation of CES and creation of relational values within virtual social-media communities. This Special Issue overview provides critical reflection and future direction on the potential of social media analyses for CES assessments, including specific limitations, key assumptions and biases, and remaining methodological, theoretical, and interpretive challenges. In the following sections we highlight insights from the assembled papers and present ideas on the future of crowd-sourced cultural ecosystem services research.

2. Novel assessment opportunities

When combined with geolocated social media data, advances in the quality, resolution, and availability of remotely sensed data can enhance understanding of the distribution and value of CES. In Karasov et al. (2022), the authors leverage high-resolution land cover models and digital elevation models from state-of-the-art Earth observation data to investigate patterns in the distribution and content of geolocated photo data in Estonia. The authors also demonstrate how researchers are increasingly relying on platforms such as Google Earth Engine and advanced statistical models to analyse datasets with high levels of spatial heterogeneity and spatial autocorrelation. As the global availability of remotely sensed data and geolocated social media data advances, the Special Issue papers demonstrate the potential for high resolution monitoring of the status and trends in CES at different scales.

Two papers in this Special Issue explore the application of social media data to non-market, economic valuation of ecosystem services. In an investigation of recreational activities in the entire network of national parks in Germany, Sinclair et al. (2020) demonstrate how crowd-sourced travel cost models result in consumer surplus estimates that are highly correlated with those generated by more resource-intensive on-site surveys. Kolstoe et al. (2022) perform a discrete choice experiment

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concerning recreational access to the Waikamoi Preserve on the island of Maui, Hawai'i. Comparison of the results obtained from a convenience sample of *Facebook*, *Instagram* and *Twitter* users to those of a representative sample highlights systematic differences in the distributions of Willingness To Pay (WTP), and provides technical guidance on how to correct for sample selection bias.

The Special Issue also highlights novel opportunities for CES assessments emerging from the use of crowd-sourced social media data, and with these advances, uncovers numerous methodological challenges. For instance, Zapata et al. (2022) apply a crowd-sourced photo-interpretation approach to assess CES in the city of Cali in Colombia. Although hampered by the limited use of *Flickr* in the Latin American context, the study clearly outlines the potential for social-media based assessments in data-sparse urban contexts. Richards and Lavorel (2022), use a machine learning approach, supported by automated object identification by *Google Cloud Vision*, to analyse landscape appreciation in New Zealand. The novelty in their approach is to estimate CES under future reforestation scenarios. The authors project the impact to CES provisioning given planned changes (i.e., spatial configuration) based on a spatial analysis of CES occurrence in relation to different social and environmental variables.

3. Methodological advances

3.1. Semantic analyses

While early social-media based CES assessments have broadly relied on the interpretation of an image's content (Ghermandi and Sinclair, 2019), an important frontier in current research is the additional consideration of social media text. Schirpke et al. (2021) use a text analysis of tags linked to photographs from *Flickr* in order to access CES from mountain lakes across the European Alps. The study provides a means to compare CES across large and remote region region while identifying the importance of small lakes for aesthetic experiences. Following a similar approach, applied to a *peri*-urban park in Barcelona, Spain, Calcagni et al. (2022) combined manual content analysis of *Flickr* pictures with the coding of titles, tags and text into nine CES categories. The studies by Schirpke et al. (2021) and Calcagni et al. (2022) highlight the capacity to identify a wider spectrum of CES, including cognitive and spiritual CES, when combining picture content with semantic (text) analyses.

The broader range of CES that can be assessed through semantic analyses is also explored by Kong and Sarmiento (2022), who differentiate eight CES by means of natural language processing (NLP) and text-mining techniques to examine reviews derived from *TripAdvisor* and *Google Reviews*. This study capitalizes on web-based travel apps that are promising social media data sources but still rarely used in CES research. The automated approach based on a phrasal lexicon (in contrast to single word lexica) was applied to the El Cajas National Park, Ecuador, and further underlines the potential for future applicability and refinement of semantic analyses for CES.

3.2. Automated image content analysis

Another critical research frontier in social-media based CES research is the automated image content assessment based on artificial intelligence. Cardoso et al. (2022) explore the potential of deep learning for automated analysis of crowd-sourced social media data through the training of neural networks. Applying this deep learning approach to the comparative case studies of Peneda-Gerês, Portugal, and Sierra Nevada, Spain, the authors highlight that the automated identification of CES is not straightforward. While the study notes challenges distinguishing specific CES categories, the ability to identify the biophysical nature attributes that underpin the generation of CES is real. The authors also found that their own models, trained on purposely developed and manually pre-coded data-sets, perform less well than established models, trained on larger but not location — or CES — specific classified pictures (e.g., ImageNet, Places365).

Fox et al. (2021), Lee et al (2022) and Kaiser et al. (2021) use automated text annotation based on supplied image tags (using the *Google Cloud Vision label detection,* and *Clarifai general image recognition* tools). Fox et al. (2021) apply this approach to the social-media platform *Reddit*, a social news aggregation and discussion orientated social media platform. Comparing their results with data from *Flickr*, the authors find the automated, machine-based annotation approach is promising for identifying recreational activities. While *Reddit* presents a novel data source for CES assessment, there are difficulties in geo-locating these posts when compared to other social media data sources.

Similarly, Lee et al (2022) applied *Clarifai* to *Flickr* photographs taken in the Mulde basin in Germany to identify CES related to landscape aesthetics (i.e. scenic landscapes) and existence values. While the authors similarly acknowledge the promise of machine learning to quickly and accurately analyse image content, they agree that this may not indicate the true motivation for the photograph. The need to "translate" identifiable features and objects to CES is common in automated approaches, suggesting the need to develop models more specifically tailored to CES assessment.

Kaiser et al. (2021) apply automated labelling of *Instagram*, *Flickr* and *VKontakte* via *Google Cloud Vision* and cluster analysis to investigate the CES provided by a prominent river restoration project in Israel. The authors highlight the potential of this novel data source to reveal previously unrecognised instrumental and relational values associated by visitors to the ecosystem restoration project, but also acknowledge that photo content does not capture the full range of recreational activities that are known to take place at the site.

3.3. Validation

As a nascent field of research, many approaches to assess CES from social media data are still in an exploratory stage that requires evaluation of their efficacy. Validation of results is therefore a current focus in social-media based CES research. The work by Dai (2022) refines our understanding of potentials and limitations in automated semantic analysis by comparing two social media data streams, i.e., reviews from *Dianping* and location-based text posts from *Weibo*, with face-to-face surveys in urban parks in Shanghai, China. While the results based on *Dianping* showed low reliability, strong discrepancies were also observed between revealed (*Weibo*) and stated CES (survey). These discrepancies were particularly related to spirituality, inspiration, and knowledge, and indicate the need to further understand reporting biases on social media platforms. For example, social media might reveal different CES than surveys, but particular platform do match specific CES.

Depietri et al. (2021) address the case study of green and blue areas in the city of Haifa (Israel). As in the above mentioned study by Dai (2022), the validation is conducted through the comparison of the results obtained with social media data streams to those from more established and more broadly tested methodologies. The authors compare the distribution of seven different CES obtained from the analysis of photographs from three social networking sites (*Flickr*, *Panoramio* and *VKontakte*) to those from a public participation mapping (PPGIS) exercise. The results of this study also point to complementarity in the insights that can be obtained with the two methods. The combination of research approaches and ancillary data sources requires further research as it helps to understand and overcome particular biases related to social media-based assessments that might allow for their systematic accounting in the future.

4. Conceptual advances

The infancy of using social media for the study of CES means that there are still few conceptual frameworks with which to orient and place the innovative work being conducted (Havinga et al., 2020).

Langemeyer and Calcagni (2022), aim to remedy this, conceptualising 'digital relational values' connecting the concept of relational values in ES with these new digital spheres. Their framework distinguishes three phases. With 'Seeding' describing the sharing of CES within virtual communities as the digital expression of relational nature-values; 'spreading' considering the deliberation and multiplication of relational values within and across virtual communities; and 'grounding' as the creation of environmental stewardship agency triggered by digital relational values. Establishing the hypothesis for virtual communities to — at least partly — counteract the 'extinction of experiences' of nature (Miller, 2005), the authors call for the analysis of inherent dynamics within virtual social media communities, in order to understand digital value shaping processes in relationship with the representation of CES on social media and global environmental stewardship.

5. Outlook

This Special Issue demonstrates how recent advances in analytical techniques, including artificial intelligence, have allowed researchers to move beyond simple counts of media posts, tweets, or photos, which dominated early research in this field, to the analysis of the content of the images or text, enabling thus a differentiated understanding of CES provided. Ultimately, however, more remains to be done before research in this field translates into actionable results for decision and policy-makers. Crowd-sourced CES assessments will require a stronger standardization, with harmonized protocols, established ethical standards, and including widely agreed upon categories of CES, which allow for comparison between different case studies — such standardization is currently lacking. Furthermore, broadly tested methodological approaches, including the systematic validation of assessment qualities across data streams, including both social media and other empirical assessments, are necessary. The Special Issue includes several studies that are providing empirical insight into this representation bias — however, a stronger standardization and guidelines for validation are urgently needed to enhance the scientific robustness of crowd-sourced CES assessments. Cooperation between social-environmental and data scientists could aid in developing new ethical and technical standards.

The exploration of novel social media data streams that are not yet widely tested for studying CES are crucial in this context. Most studies in this Special Issue as well as in the wider research field (Ghermandi et al., 2023), are still relying on data from *Flickr* and, to a lesser extent, *Twitter* data, due to the ease of data accessibility and the availability of spatial *meta*-data. With the waning popularity of *Flickr* and *Twitter*'s uncertain future, our ability to use social media for CES assessment, and other sustainability research, is in jeopardy (Ghermandi et al., 2022). Studies in this special issue have highlighted potential alternative crowd-sourced data streams, such as *Dianping*, *Reddit*, *TripAdvisor* and *Google Reviews*, while other data sources, especially video content (e.g. *TikTok*, *YouTube*) have not yet received wide attention. However, the opening of novel data streams raises important challenges for CES assessments, including challenges with the lack of spatial *meta*-data and the difficulty of data integration and analysis in data mashups (Fleming et al., 2014). To maintain access to this valuable data for CES and sustainability research will require high ethical standards on the part of researchers to ensure the public that their data is being handled ethically and for the common good (Ghermandi et al., 2023). We also acknowledge that insights derived from crowd-sourced social media data will omit values and perspectives from communities without access to these technologies or who chose not to participate in social media platforms. Much of our current insights into the nature and value of CES are derived from ethnographic and qualitative scholarship, often through deep engagement with local stakeholders, including indigenous communities (Satterfield et al., 2013, Gould et al., 2015). A desire to scale integration of CES into policy at local and global scales may be enhanced by use of mobile technologies and data from web-based applications. However, these novel methods need to be considered as part of a diverse and pluralistic portfolio of valuation methods that includes local, contextual, and ethnographic data if we are to truly characterize the breadth and depth of CES.

The articles in this Special Issue provide evidence of the importance of crowd-sourced social media for understanding people's appreciation and relationship with nature across different spatial and temporal scales (Bubalo et al., 2019; Lu et al., 2021). Crowd-sourced assessments are showing that CES are no longer 'intangible', as they have often been described in the past and crowd-sourced social media assessments constitute an important opportunity to further reverse the lack of visibility and relevance of CES in research and practice. Thanks to the relative ease with which social media-based CES analyses can be scaled up and updated in a timely fashion, there is a great potential for crowd-sourced data to support, for instance, the ongoing efforts to extend the current systems of national accounts to adequately reflect changes in natural capital and ecosystem services (e.g., UN SEEA). Yet, to unfold this potential a conceptual adaptation of the understanding of CES seems necessary (Havinga et al., 2020). Technical feasibility should not overrule conceptual advances, where it is important to maintain a continued communication with the broader CES-research community, and a stronger engagement with parallel developments for instance within IPBES. In particular, the emerging field of relational values constitutes a window of opportunity to further foster the visibility of CES; it also opens a new research frontier. Crowd-sourced assessments embed important potentials for the observation of digital value-shaping processes (Calcagni et al. 2019; Ghermandi et al., 2023). Novel methodological approaches developed for CES assessments, such as semantic analyses, will, in combination with other methods such as social networks analysis, likely underpin the empirical development of the novel field of research on *digital relational values* (Langemeyer and Calcagni, 2022).

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.

Data availability

The authors do not have permission to share data.

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