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Plural relational green space values for whom, when, and where? – A social media approach

Fulvia Calcagni [a,b], James J.T. Connolly [c], Johannes Langemeyer [a,d,*]

[a] Department of Geography, Humboldt Universität zu Berlin, Germany
[b] Department of Natural Resources and Environmental Management, University of Haifa, Israel
[c] University of British Columbia, School of Community and Regional Planning, Vancouver, Canada
[d] Institute of Environmental Science and Technology (ICTA), Universitat Autònoma de Barcelona (UAB), Edifici Z (ICTA-ICP), Carrer de les Columnes s/n, Campus de la UAB, Cerdanyola del Vallès 08193, Spain

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ABSTRACT

The values people ascribe to their interactions with and within the environment are essential to inform justice and sustainability transformations. The development of many of these values unfolds through enjoying so-called cultural ecosystem services (CES) such as outdoor recreation, landscape aesthetics or environmental education. A growing body of literature is improving the assessment of the multiple ways that people value human and non-human relations arising when enjoying CES. Yet, the geo-temporal-demographic patterns of values distribution and the lessons that can be derived are to be consistently analysed within this relational framework. Building on a visual and textual content analysis of social media (SM) data geotagged in a peri-urban park of Barcelona, Spain, this research explores the potential of analysing the associated metadata (such as geotag, timestamp and social media users' demographics – i.e., performed gender and residency) in order to develop a better understanding of the linkages between people's values and the situated context of their construction. Our results show trends in relational CES values distribution along and between the analysed spatial, temporal, and demographic dimensions. In particular, despite there being a multiplicity of values revealed across the whole case-study area, to enjoy contemplative CES, such as *spiritual* or *cognitive value*, people need to move away from highly frequented areas and prefer specific times of the day, respectively evening or afternoon. Locals show a higher preference to visit the park on weekends compared to non-locals, while women-performing users show a significantly higher drop in their CES benefits uptake compared to men-performing users at night. In addition to providing novel and fine-grained information for transformative practices toward justice and sustainability, this study highlights the importance of complementing CES studies employing SM with metadata analysis to improve our understanding of the relationship between the real and the more-than-real.

1. Introduction

Understanding people's social-ecological interactions and related benefits uptake is pivotal to the development of pathways to sustainable futures that accounts for the role of underlying value structures in shaping outcomes (Arias-Arévalo, Gómez-Baggethun, Martín-López, & Pérez-Rincón, 2018; Guo, Zhang, & Li, 2010; Ilieva & McPhearson, 2018; Kremer et al., 2016; MEA, 2005; Plieninger et al., 2015; Riechers, Barkmann, & Tscharntke, 2016; Stålhammar, 2021). This notion is well-developed within the ecosystem service (ES) scholarship, a now long-standing effort to comprehensively account for the biophysical structures, processes, and functions from which people derive multiple material and non-material benefits that they value and, in turn, contribute to produce (Dickinson & Hobbs, 2017). As a result, ES is an established framework for integrating numerous social and environmental factors into decision-making (European Commission, 2020; Plieninger, Dijks, Oteros-Rozas, & Bieling, 2013) and is increasingly gaining importance in fostering just and sustainable planning agendas (Ernstson, 2013; IPBES, 2018; Langemeyer & Connolly, 2020). This role for ES analysis highlights the importance of measuring differential access to and uptake of ES benefits, especially in ever-denser and increasingly ethnically and linguistically diverse metropolitan areas (Amorim-Maia et al., 2020; Andersson et al., 2019; Baró, Langemeyer, Łaszkiewicz, & Kabisch, 2021; Calderón-Argelich et al., 2021; Danford,

* Corresponding author at: Institute of Environmental Science and Technology, Autonoma University of Barcelona
E-mail addresses: fulvia.calcagni@gmail.com (F. Calcagni), james.connolly@ubc.ca (J.J.T. Connolly), johannes.langemeyer@uab.cat (J. Langemeyer).

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Strohbach, Ryan, Nicolson, & Warren, 2014; Hamstead et al., 2018). Yet, accounting for ES benefits that people actually experience and value remains an open challenge. These benefits are possible expressions of the situated and subjective "view from the body" advocated by Haraway, 1988 (pg. 589), elements of a dynamic and relational processes through which they construct their sense of belonging in space (Beebeejaun, 2017), and descriptive of current states of social values key to informing pathways toward sustainable transformations (Stålhammar, 2021). This is especially the case for those benefits ascribed to so-called cultural ecosystem services (CES), which are less tangible and objective (e.g., landscape aesthetics, cultural heritage, or simply the appreciation for the existence of a natural resource).

In addition, measuring uptake and access to the specific range of CES benefits that people value because contributing to individual wellbeing or to collective flourishing can be seen as an essential "technology of participation" needed to increase public acceptance, equity and reflexivity in planning and transformative measures (Angradi, Launspach, & Debbout, 2018; Ilieva & McPhearson, 2018; Pascual et al., 2017; Tadaki, Sinner, & Chan, 2017). Therefore, for the purpose of value-informed decision-making toward justice and sustainability, scholars from different fields (e.g., environmental science, digital critical geography, feminist digital nature and urbanism) call for consideration of the multiple and intersecting factors influencing the ways in which we value ecosystems, and encourage the measurement of the spatial, temporal and demographic variability in the benefits gained from CES (Beebeejaun, 2017; Blicharska et al., 2017). From this perspective, a special stress is placed on acknowledging the plural – and often conflicting – valuation languages and priorities we associate with social-ecological interactions (Arias-Arévalo et al., 2018; Himes & Muraca, 2018; Jacobs et al., 2018; Pascual et al., 2017; Small, Munday, & Durance, 2017; Tadaki et al., 2017).

Yet, CES values assessments are straining to meet emerging demands for more plural and relational information, in part because they are mostly conducted through traditional data collection methods, such as interviews, surveys, focus groups or participatory mapping (Arias-Arévalo et al., 2018; Dickinson & Hobbs, 2017). While these approaches do offer important insights, they are time- and resource-intensive, and thus heavily conditioned by their spatial, temporal, and demographic scale and sensitivity (Milcu, Hanspach, Abson, & Fischer, 2013; Riechers et al., 2016). Traditional data collection approaches also express systematic biases as a result of research design and operation (Derungs & Purves, 2016; Lopez, Magliocca, & Crooks, 2019; Pastur, Peri, Lencinas, Garcı-Llorente, & Martìn-Lopez, 2016; Tadaki et al., 2017), likely only reflecting a partial memory of the stated values, more conditioned by normative understanding of values, and falling short in uncovering the benefits experienced at the actual site and moment of realization. With this study, by employing social media data and metadata, we aim to assess the fine-grained spatial, temporal and demographic variation of a broad scope of revealed relational CES values relevant to environmental justice and sustainability in decision-making. We do so by, first, defining the values that we specifically focus on; then outlining the data and methods chosen to assess them; and, finally, describing the results from a case study application that relates the findings to possible insights for planning.

1.1. Notions of value in the ES framework

The value ascribed to ES is understood as the relative importance individuals assign, either individually or through group negotiations, to the several, interdependent benefits the ecosystem provides (Chan, Satterfield, & Goldstein, 2012). Reflecting a dichotomous understanding of society and nature as separate and independent ontological domains, and an epistemological distinction between the subject and the object of valuation drawn from market theories rooted in political economic thought of the eighteenth century (Harvey, 1996), ES values were initially translated into mainly economic terms. However, scholars have recently pointed at the multiplicity of ways and plurality of subjectivities from which individuals value social-ecological interactions, raising the need to include a wider range of socio-cultural values into ES accounting beyond only economic terms (Andersson, Tengö, McPhearson, & Kremer, 2015; Arias-Arévalo et al., 2018; Chan et al., 2012; Chan, Satterfield, & Goldstein, 2012; Díaz et al., 2015; Dickinson & Hobbs, 2017; Fischer & Eastwood, 2016).

1.1.1. Values for sustainability

ES functions become services when people, through their system of situated knowledge, beliefs and practices, value the benefits they provide (Calderón-Argelich et al., 2021; Chan, Satterfield, & Goldstein, 2012; Dickinson & Hobbs, 2017). In other words, ES benefits uptake is always dynamically produced and negotiated in space (Beebeejaun, 2017), as well as heavily mediated by human values and the cultural, historical, spatial and political context in which humans live and build their capabilities and identities (Fischer & Eastwood, 2016; Fish et al., 2016; Harvey, 1996). In line with this thinking, we assume that cultural ecosystem services (CES) are not just a subset of ES, as commonly assumed (MEA, 2005). Rather, CES provide irreplaceable access to and operationalisation of the non-material, intangible, and incommensurable benefits arising from social-ecological interactions and, in turn, from ES functions (sensu Andersson et al., 2015). Values ascribed to CES benefits are, thus, regarded as essential and pervasive inputs to, both, the realization of those same benefits and the valuation and consequent production of the underlying ES (Dickinson & Hobbs, 2017; Fischer & Eastwood, 2016; Langemeyer & Connolly, 2020), pointing toward an important set of motivations that serve as a driver for ES conservation (Andersson et al., 2015; Dickinson & Hobbs, 2017; Stålhammar, 2021). Mapping, monitoring and assessing CES has proven critical to define sustainable use of natural resources and restoration targets (European Commission, 2020) as well as to perform impact and strategic assessments (*namely* Environmental Impact Assessment and Strategic Environmental Assessment) (Geneletti, 2016). Including CES values in decision-making is, thus, essential to foster sustainability and resilience in transformative practices.

1.1.2. Values for justice

The way to incorporate distributive, procedural, and recognition justice into decision-making is starting to be explored. For example, building on precedents from non-ES studies (see Currie, Lackova, & Dinnie, 2016; Krange & Skogen, 2007), some authors find that socio-economic factors influence the uptake of CES. Fortnam et al. (2019) look at gender differences in CES perceptions; Martinez-Harms et al. (2018) reveal differential socio-economic impact on visiting protected areas; and Plieninger et al. (2013) stratify their analysis of CES perceptions by socioeconomics.

A full understanding of the range of benefits, and multiple value systems for defining those benefits, associated with CES is an important element of social-ecological justice (Calderón-Argelich et al., 2021; Grossmann, Connolly, Mattioli, & Nitschke, 2022). This is the case because, firstly, the uptake of CES benefits depends more strictly on the actual occurrence of and access to social-ecological interactions than is the case for other types of ES (e.g. climate regulation, carbon sequestration, rainwater runoff, etc.), which can be supplied by distant ecosystems (Martinez-Harms et al., 2018). Secondly, because values ascribed to CES benefits have recently been defined as inherently relational (Chan et al., 2016; Chan, Gould, & Pascual, 2018).

1.1.3. Relational CES values for transformations

Relational values are described as socio-cultural, anthropocentric, yet non-instrumental values rooted in social-environmental relations that people seek to maintain and find desirable for individual and collective flourishing (Himes & Muraca, 2018), linking them with core social values such as justice, care, and reciprocity (see Chan et al., 2016). Relational values ascribed to CES (hereafter referred to as relational CES

values for the sake of emphasizing this link) point toward a nuanced middle ground of human and non-human relations (Dickinson & Hobbs, 2017; Fish, Church, & Winter, 2016; Muraca, 2016; Panelli, 2010; Stålhammar & Thorén, 2019) and are at the centre of any dynamic process of space and time construction, negotiation and signification (Beebeejaun, 2017; Harvey, 1996; Massey, 1994). In addition, besides being important components of human wellbeing, relational values are also thought to enable plural and subjective languages of valuation, so that their consideration in transformative practices improves inclusivity and recognition of different people's claims and needs (Chan et al., 2018; Díaz et al., 2015; Himes & Muraca, 2018; Pascual et al., 2017) allowing to expand the conceptualization of justice toward a less top-down and more crowdsourced form.

Relational values' space- and time-dependency, collective negotiation, and expressions of people's plural conception of a meaningful community life within nature, make their assessment well-suited to meeting the complex demands of value-informed transformative practices devoted to justice and sustainability (Blicharska et al., 2017; Himes & Muraca, 2018; Pascual et al., 2017; Tadaki et al., 2017), being not only key drivers for environmental stewardship and for advancing sustainable and just transformative agendas as we know them, but also a marker for a different pathway of development for these agendas.

In addition, building on the branch of feminist urbanism scholarships focusing on the right to the everyday life (Beebeejaun, 2017), we argue that the analysis of relational CES values engendered over embodied tactics of benefits realization at the fine-scale of the "everyday" could provide novel insights into questions of social-ecological justice and sustainability transformations, especially in the urban context.

However, despite a steadily growing body of literature, the attempts to empirically assess and interpret the meaning of relational values remain limited. Most studies use qualitative research approaches alone or mixed methodologies, through open-ended questions with a non-predefined analytical framework (Arias-Arévalo et al., 2018; Jacobs et al., 2018; Schulz & Martin-Ortega, 2018). In addition, recent studies have highlighted research gaps in addressing questions of justice within ES assessments, highlighting the particular need to focus on relational values, conduct analyses across spatial scales and along inter- and intra-generational temporal scales, include gender and intersectional perspectives, and combine the different dimensions of distributive, procedural and recognition justice (Calderón-Argelich et al., 2021; Langemeyer & Connolly, 2020).

1.2. The potential of using social media metadata

Social media (SM) is emerging as a novel approach to eliciting a fine-grained assessment of multiple relational CES benefits in the place and at the moment of their realization (Calcagni, Amorim Maia, Connolly, & Langemeyer, 2019; Calcagni, Nogué Batallé, Baró, & Langemeyer, 2022; Ghermandi et al., 2023; Ruiz-Frau et al., 2020). Unsolicited pictures, texts, and videos portraying social-ecological interactions shared on SM, joined with the digital network's inherent "observer effect" (Ghermandi & Sinclair, 2019; Lazer, Hargittai, Freelon, Gonzalez-bailon, & Munger, 2021) and presentational (Meikle, 2016) purpose, reveal the relationship-laden nature of the values expressed therein (Leszczynski, 2019). The act of sharing is the central aspect that makes SM content meaningful and material to people (Leszczynski, 2019). It generates a link to what they find, and believe observers to find, desirable or just. This reading of the digital as a place for novel encounters between humans and non-humans, fertile for caring and cultivating shared eco-centric goals for collective flourishing, is also gaining momentum within the emerging digital ecology scholarship (Büscher, Koot, & Nelson, 2017).

Based on the assumption that people use SM platforms to express and negotiate individual opinions on what they value (Amorim-Maia et al., 2020; Calcagni et al., 2019), SM data arguably expose "situated" relational CES values through people's outward expression of ongoing relations with people and nature that they benefit from (thus value and benefit are tightly interlocked and both terms are used throughout the article). These data, thus, as crowdsourced and unsolicited "view from somewhere", can substitute the "view from nowhere" provided by authoritative and official data – to which access and availability for research is also decreasing (Shelton, 2023) – away from the objectivity guise and in the sake for different, even if yet partial, categories and methods for assessing spatial and social truth and justice (Shelton, 2022). Further, this expression of value can be measured in terms of a continual spatial and temporal pattern due to the ongoing log formed by social media data (Ghermandi & Sinclair, 2019). Thus, by revealing preferences expressed in different 'languages' and formats (e.g. through pictures, texts, "likes", etc.) that are freely shared and unbiased by researcher intervention, and including metadata such as geotags, time stamps and demographics, SM offer promising opportunities for relational CES values assessment to explore a broader epistemological plurality (i.e. recognition justice) (Armstrong, Derrien, & Schaefer-Tibbett, 2021; Barry, 2014; Calcagni et al., 2019; Ernstson, 2013; Leszczynski & Elwood, 2015; Martinez-Alier, Kallis, Veuthey, Walter, & Temper, 2010) and inquire into the differential patterns (i.e. distributional justice) (Ilieva & McPhearson, 2018; Martinez-Harms et al., 2018) of benefits access and uptake.

SM metadata are increasingly available at an unprecedented rate and scale (Ilieva & McPhearson, 2018), allowing for (near) real-time, high resolution, spatially explicit and, sometimes, global analyses (Huang, Gartner, & Turdean, 2013; Tieskens, Van Zanten, Schulp, & Verburg, 2018; van Zanten et al., 2016). This data helps explain the values at the moment and site of their realization (Ghermandi & Sinclair, 2019). Besides CES studies, geodemographic analyses of SM data have proved useful in assessing how demographic factors relate to human mobility patterns (Luo, Cao, Mulligan, & Li, 2016), activity spaces (Shelton, Poorthuis, & Zook, 2015), neighbourhoods' available facilities (Quercia & Saez, 2014), as well as to landscape appreciation and accessibility (Martinez-Harms et al., 2018). Among the wealth of empirical studies using SM data for CES assessment, the majority use the attached geotag – or location-related tags (Alieva et al., 2021; Bernetti, Chirici, & Sacchelli, 2019; Gosal & Ziv, 2020) – for inferring the spatial distribution of CES values (Calcagni et al., 2019; Hamstead et al., 2018; Havinga, Bogaart, Hein, & Tuia, 2020; Wood, Guerry, Silver, & Lacayo, 2013) and some others also use the timestamp (Barros, Moya-Gómez, & García-Palomares, 2019; Crampton et al., 2013; Gosal, Geijzendorffer, Václavík, Poulin, & Ziv, 2019; Mancini, Coghill, & Lusseau, 2018; Shelton et al., 2015; Sonter, Watson, Wood, & Ricketts, 2016; Walden-Schreiner, Rossi, Barros, Pickering, & Leung, 2018) and show the validity of this data in approximating visitation rates and temporal patterns by comparing them to official statistics (Tenkanen et al., 2017). Finally, some studies associate SM data to demographic information at several scales (Hamstead et al., 2018), some cluster the users based on their pictures content (Gosal, Geijzendorffer, Václavík, Poulin and Ziv, 2019), some others extract user demographics through deducing them from available information (e.g. language spoken) (de Juan, Ospina-Álvarez, Villasante, & Ruiz-Frau, 2021) or through algorithms which calculate their most frequented locations and either correlate the result to census data (Martinez-Harms et al., 2018) or validate it through a survey (Lenormand et al., 2018). Yet, only a few CES studies have started to explore metadata other than the geotag, such as place of residence (Bandara & Bandara, 2019; Cao, Wang, Su, & Kang, 2022; Ghermandi, Camacho-valdez, & Trejo-espinosa, 2020; Hamstead et al., 2018; Huai, Chen, Liu, Canters, & Van de Voorde, 2022) and/or gender included in or inferable from the user profile (Angradi et al., 2018; Ding, Yang, & Luo, 2021), despite the explicit recognition of this methodological gap in the context of social-ecological sustainability research to inform decision-making (Alieva et al., 2021; Blicharska et al., 2017; Clemente et al., 2019; Gliozzo, Pettorelli, & Haklay, 2016; Ilieva & McPhearson, 2018; Oteros-Rozas, Martín-López, Fagerholm, Bieling, & Plieninger, 2018; Ruiz-Frau et al., 2020; Tadaki et al., 2017).

Table 1
Relational CES values coded in (Calcagni et al., 2022), respective description, examples of annotation and number of corresponding entries.

Coding categories	Description	Examples of the annotation for both textual and visual content	Nr. of entries (% of the total)
Physical recreation	The engagement, use or enjoyment of the biophysical characteristics or qualities of species or ecosystems in ways that require physical and cognitive effort. It denotes an active involvement with nature.	Bikes, walking or running gear, horsing facilities, biking, walking, riding or running activity	476 (28%)
Experiential recreation	The engagement or enjoyment of the biophysical characteristics or qualities of species or ecosystems through passive or observational interactions. It is an experiential use of plants, animals, and landscapes. It denotes a passive engagement.	Observational or passive activities: relaxing, observing, thinking, taking artistic pictures of nature (close-up pictures of species were categorized also as *Existence value*)	642 (37,9%)
Existence value	Characteristics or features of living systems that have an existential value. The things in nature that people seek to preserve because of their non-utilitarian qualities and that want to be kept for future generations.	Close-up pictures or common names of (animal or vegetation) species	582 (34,4%)
Cognitive value	Intellectual interactions with the natural environment that foment scientific investigation, the creation of traditional ecological knowledge, education or training. It is the in-situ research and study of nature.	Knowledge transmission activities, studying outdoors, taking samples	183 (10,8%)
Natural cultural heritage	Intellectual interactions with the natural environment that help people identify with the history or culture of where they live and come from.	Natural landmarks with symbolic significance, iconic	858 (50,7%)
Landscape aesthetics	Intellectual interactions with the natural environment that enable aesthetic experiences. It is the appreciation of the inherent beauty of the biophysical characteristics or qualities of species or ecosystems. It is the beauty of nature.	Pictures with a wide landscape framing. Tags related to landscape scenic value.	665 (39,3%)
Spiritual value	Elements of living systems that have sacred or religious meaning. Things in nature that have spiritual importance for people.	Expressions of attachment to religious values, relating to or involving spiritualism, denoting a spiritual state or relating to sacred matters.	21 (1,2%)
Social relations*	Pictures and text capturing social interactions in the engagement or enjoyment of the biophysical characteristics or qualities of species or ecosystems.	Images of or tags related to people sharing time and activities in nature.	237 (14%)
Built cultural heritage*	Intellectual interactions with the built environment that help people identify with the history and culture of where they live and come from. Cultural heritage or historical knowledge.	Built human infrastructure and landmarks	983 (58,1%)

* Note: Coding categories not included in the CICES reference system (v. 5.1) (Haines-Young & Potschin, 2018).

Accounting for the composition of SM data producers and content is a necessary step for relating the fine-scale patterns of social-ecological interactions that this specific kind of data reveal to the subjectivities behind them (Arts, Fischer, Duckett, & Wal, 2021; Elwood & Leszczynski, 2018). In addition, apart from leveraging SM data for investigating dynamics of social-ecological justice on the ground, in this study we also look at SM as subject of study. Drawing on considerations attempting to overcome the dichotomic understanding of digital spaces - and inherent dynamics - as "non-real" and opposed to the "real" of the non-digital world, we adopt the more-than-real alternative conceptualization (McLean, 2020) and recognize its role in co-constructing social-ecological interactions along dimensions of gender, age, race, class, etc. In so doing, we respond to a recent call to foster a dialogue between the scholarships of digital geography, digital natures and feminist political ecology, differently engaging with the interactions between the digital, environmental and social domains (Nelson, Hawkins, & Govia, 2022). The use of these data as both object and subject of study, as fostered in the digital geography literature, allows for transformative practices to unfold in the assessment of both situated and plural relational CES values ascribed to everyday experiences and their geo-temporal-demographic distribution, and in understanding the role of the more-than-real in the co-construction of the real, by challenging official data positivist biases and embracing the fuzziness of the crowdsourced. Therefore, by combining SM data and metadata, such as the geotag, timestamp and demographic information, and conducting a "reality check" with ground data, this study aims to unveil useful insights for just and sustainable transformative practices. This is accomplished through (i) fine-scale mapping of the distribution of multiple relational CES values, (ii) evaluating how selected spatial, temporal, and demographic predictors help explain the distribution of relational CES values, and, finally, (iii) examining qualitative and distributional social inequities in the uptake of CES benefits across space and time.

2. Data and methods

2.1. Study case and data

This study is based on the case of Collserola, a large peri-urban park located north of the highly densified city of Barcelona, Spain. Covering an area of almost 8.300 ha, Collserola is the central greenspace in the Barcelona Metropolitan Area. Declared a protected Natural Park in 2010, Collserola is home to numerous environmental education and recreation activities. It includes two natural reserves, La Font Groga and La Rierada-Can Balasc, and it has been the object of several studies and management plans. Such efforts have tried to monitor and manage the visitation flow in order to maximise the benefits uptake for park users and, at the same time, minimise their impact on both the vital ES benefits supply and the potential crowd effect in specific areas, such as the area surrounding the Tibidabo mountain, where visitor crowding may prevent an enjoyable use of the park (Comissió institucional del Pla especial de Collserola, 2019; Farías-Torbidoni & Morera Carbonell, 2020).

This study builds on the data and outcomes of a preceding analysis conducted by (Calcagni et al., 2022) in the same case study area and using social media data to assess the multiple relational values attached to the CES benefits provided by this specific greenspace (see Table 1).

For said study the authors retrieved a total of 5170 pictures on the photo-sharing platform Flickr using the Application Programming Interface (API). The pictures were uploaded between 2004 and 2017 and geotagged within the boundaries of Collserola. The assessment was performed by three different researchers looking at either or both the visual and textual content of the retrieved data and coding each item of data with as many CES as those identified. The non-exclusionary nature of the assigned codes explains why the percentages of data per category in the last column of Table 1, as well as in the graphs showing relative proportions below, does not sum to 100. The codes were assigned using CICES as a reference system for CES assessment, leveraging the

Table 2
Data source and calculation of the geo-temporal-demographic predictors used in the analysis.

	Predictors	Relation	Type	Source/calculation
Spatial	Touristic amenities	Planar distance	Continuous	Department of Territory and Sustainability of the Catalan Government (Generalitat de Catalunya)
	Bus/train stations	Planar distance	Continuous	
	Walking paths	Planar distance	Continuous	Extracted from the topographic map (scale 1:5000), available for download at the website of the Cartographic and Geologic Institute of Catalonia (ICGC, http://www.icgc.cat/es/)
	Picture Hotspots	Planar distance	Continuous	Calculated performing an Optimized Hot Spot analysis across the full sample of relevant pictures (Aggregation Method: count incident within fishnet polygons; Bounding Polygon: Collserola; Cell Size: 400 m)
Temporal	Time of the day	1/0	Categorical	Morning: when pictures "data taken" indicate a time between 06:00 and 12:00
		1/0	Categorical	Afternoon: when pictures "data taken" indicate a time between 12:00 and 18:00
		1/0	Categorical	Evening: when pictures "data taken" indicate a time between 18:00 and 24:00
		1/0	Categorical	Night: when pictures "data taken" indicate a time between 00:00 and 06:00
	Day of the week	1/0	Categorical	Weekday: when pictures "data taken" indicate either Mondays, Tuesdays, Wednesdays, Thursdays or Fridays
		1/0	Categorical	Weekend: when pictures "data taken" indicate either Saturdays or Sundays
	Season	1/0	Categorical	Summer: Pictures "data taken" between 22/06 and 23/09
		1/0	Categorical	Autumn: Pictures "data taken" between 24/09 and 21/12
		1/0	Categorical	Winter: Pictures "data taken" between 22/12 and 20/03
		1/0	Categorical	Spring: Pictures "data taken" between 21/03 and 21/06
Demographic	Performed gender	Woman-performing/ Man-performing	Categorical	Retrieved manually from Flickr user pages based on first names and/or profile pictures (as in Angradi et al., 2018)
	Residency	Local/Non-local	Categorical	Retrieved manually from Flickr user pages (where given)

versatility of this system to adapt the coding to the crowdsourced and passive nature of the data under study (i.e., not dependent on the study design but rather on the collective choices of social media users). For instance, we added or merged categories when needed. Coders iteratively checked their agreement through the Cohen's kappa indicator and co-developed a protocol for increasing the consistency and replicability of the analysis. By looking at SM metadata, this study complements the understanding of the multiplicity of relational CES values unveiled in (Calcagni et al., 2022) and, in so doing, leverages SM data potential for addressing justice and sustainability questions in the assessment of relational CES values.

2.2. Geo-temporal-demographic analysis of CES uptake

Building on the same dataset used and analysed in (Calcagni et al., 2022), constituted by a total of 1692 relevant pictures, we explored the potential of SM metadata by correlating the multiple relational CES values assessed therein (see Table 1) to the geo-temporal-demographic variables elicitable from Flickr.

To analyse the spatial distribution of relational CES values, we first aggregated the data by creating a grid of 124 cells of 1 km^2 each through the open-source software QGIS 3.10.10-A Coruña[1]. Then, we computed the sum of the observations for each relational CES value category per grid cell. Subsequently, to understand the correlation between this distribution and a set of chosen spatial predictors (see Table 2 and Fig. 1), we used ArcGIS (10.6) to determine the planar distance from the location of each sample point to the closest elements of the spatial predictors. While touristic amenities, bus/train stations and walking paths represent the park's facilities and accessibility factors that have been widely used in similar studies (Hamstead et al., 2018; Richards & Friess, 2015; Vaz et al., 2020), pictures hot spots (i.e. spatial clusters of images posted to Flickr) comprise an innovative factor introduced in this study. We assumed hotspots function as a proxy for the most frequented places, interpreted as those where people feel safe, which attract them, or are better suited for seeking social approval by sharing them on SM.

Following evidence from other studies (see Plieninger et al., 2013), all spatial predictors have been extracted using a 1 km buffer from the Collserola boundaries. Acknowledging that CES benefits can be derived at some distance from where they are generated (e.g. aesthetic benefits), the buffer takes into account the CES whose benefits uptake is enabled by the park even when associated with features outside of its administrative boundaries (e.g. the Tibidabo mountain).

In addition, we assume that not only the location but also the time in which a picture is taken is an essential characteristic related to the content and the photographer (e.g. location, user's performed gender, CES valued) that helps to analyse the pictures' content variety, and relative CES benefit uptake over time (Blicharska et al., 2017; Vaz et al., 2020). Therefore, using the pictures' entry for the field "date taken" provided by the Flickr API, we determined the corresponding time of the day, day of the week and season in which they were taken (approximating the same date for summer and winter solstices and spring and autumn equinoxes for every year) (see Table 2).

Finally, we accounted for two main demographic characteristics, namely gender and residency, which were found to be determinant of differential landscape perception and use in previous studies (Plieninger et al., 2013). Regarding residency, people declaring that they currently live within the nine municipalities enclosing Collserola Natural Park (namely, Sant Cugat del Vallès, Molins de Rei, El Papiol, Barcelona, Cerdanyola del Vallès, Sant Feliu de Llobregat, Sant Just Desvern, Montcada i Reixac, Esplugues de Llobregat) were coded as 'local', all others were coded as 'non-local'. While residency is provided by the Flickr API, since the 2017's redesign of the Flickr Profile page, gender ceased to be collected among the personal information and was deleted from existing profiles, leaving to each user the only option to share it in the description box. Therefore, not being included in the information retrievable through the API, we assumed gender manually from Flickr users' page (Hamstead et al., 2018; Martinez-Harms et al., 2018; Wood et al., 2013) by looking at their names and/or profile pictures and excluding those ambiguous or unclear. Given the interpretation based on users' appearance online and not on their biological traits, here we refer to gender – not to sex, as approximated elsewhere (Wilkins, 2004) –, understanding it as a social construct which underlies norms, expectations, attitudes and behaviours related to the different combinations of what is regarded as feminine and masculine (Rogg Korsvik & Rustad, 2015). For urban studies in particular, gender assumptions by gender presentation are considered a valid methodology for determining policy implications for public space. This is because, within public spaces, all users are either consciously or subconsciously assuming gender via gender presentation and therefore their interaction with the space or with others (e.g., fearing dark areas, trusting or aggressive attitudes) are

[1] https://qgis.org/en/site/

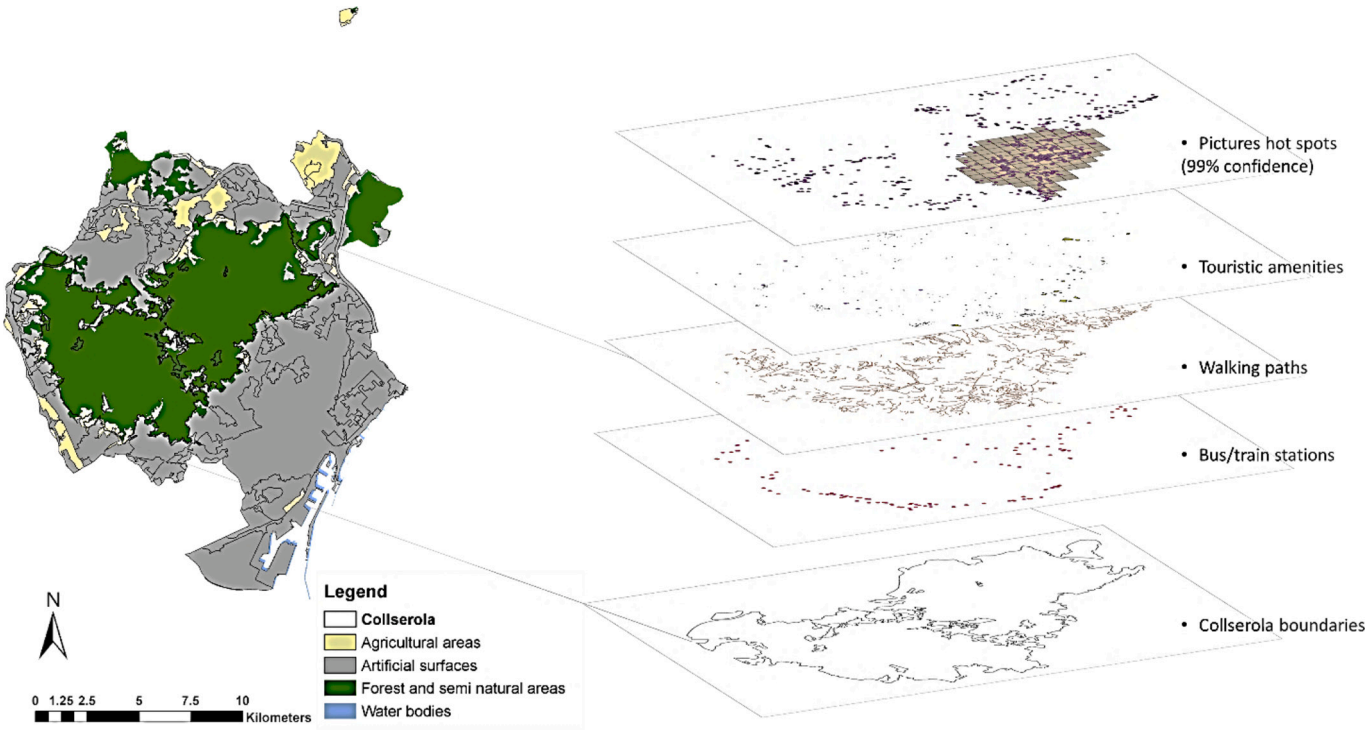

Fig. 1. Case study area of Collserola park, surrounded by the 9 neighbouring municipalities, including Barcelona. On the left, land cover map; on the right, chosen spatial predictors within 1 km buffer from the park boundaries.

dictated as such (Valera & Casakin, 2022). We argue that a similar assumption can be made for social media environments, understood here as virtual spaces of daily life performance and social interaction in which people negotiate their identities (e.g., through freely choosing their username and profile picture) (van Doorn, 2011).

Therefore, while observatory methods in public space rely on gender presentation, we argue that on social media we observe gender performance (van Doorn, 2011). However, despite the liberation potential sometimes ascribed to SM, allowing dissident and non-normative subjectivities to "think/do/be otherwise" (Byron, 2020; Elwood, 2021; Pilcher, 2017; Solombrino, 2018), and probably due to the above mentioned "observer effect" (Ames & Naaman, 2007; Ghermandi and Sinclair, 2019) relating people's behaviour on SM to the perceived presence of – mostly unknown – others (Meikle, 2016), studies show the predominance of heteronormative gender performativity online (van Doorn, 2011). Thus, for this reason, and for the purpose of our study to understand how gender performance (not identity) online weights on and relates to people's experience of real and more-than-real public spaces, we believe that the binary assumption of SM users' gender by interpreting the – non-ambiguous – chosen username or appearance on profile pictures that they feel comfortable in showing publicly (van Doorn, 2011), is acceptable.

2.3. Descriptive statistics and analysis

In order to check the statistical significance of the relationships between the analysed predictors and the relational CES values' geo-temporal-demographic distribution, having both categorical (e.g. demographics, time predictors) and continuous (e.g. distance from spatial predictors) variables, we performed a set of Exploratory Data and Spatial Data Analyses (EDA and ESDA) with R and Geoda[2] (version 1.14) respectively to select the adequate descriptive statistical tests.

In particular, in R we plotted histograms and performed the Shapiro-Wilk's test for normality. All predictors showed a non-normal distribution and, more precisely, a positively skewed histogram. Consequently, we conducted Chi-Square tests of independence between categorical variables and Kruskal-Wallis tests between categorical and continuous variable, as a non-parametric method for the analysis of variance for $k \geq 2$ levels of a factor. Then, in order to calculate pairwise comparisons between group levels with corrections for multiple testing, we used the Wilcoxon rank sum test.

In addition, we used the Geoda software to detect spatial outliers through box and scatter plots. Across all predictors, outliers are mainly located in the area surrounding the Tibidabo mountain, the most touristic and panoramic section in the study area because of the historical amusement park located on its summit. Therefore, since we believed that their presence did not depend on poor experimental design but, instead, revealed local patterns of CES access, we did not dismiss outliers from further analyses. Of note, observations for *spiritual value* had a relatively low sample size and the results should thus be interpreted as preliminary.

Finally, we were able to validate SM data through comparison with data available from other studies: a survey to Collserola park users conducted between 2017 and 2019 (Farías-Torbidoni & Morera Carbonell, 2020), and another conducted by the municipal government of Barcelona in 2016 about gender violence (Adjuntament de Barcelona, 2018).

3. Results

3.1. Spatial distribution

Through the geotag, we categorized the spatial distribution of multiple relational values ascribed to CES in the study area (Fig. 2). In addition to the variety of relational CES values showed by the pie chart, the amount of SM content shared in each cell is represented by the corresponding graduated colour. The south-western area is, thus, where most of the SM activity takes place. Interestingly, the amplitude of the values spectrum per standard area grid cell appears to be linked to the

[2] See https://geodacenter.github.io/

respective amount of SM data: the fewer the SM posts, the lower the variety of CES benefits uptake. One way of understanding this trend is to see it as reflecting a circumstance where, more people go to areas with a wider variety of CES benefits. Overall, frequent values include *built cultural heritage, natural cultural heritage, physical recreation* and *landscape aesthetics*.

3.2. Statistical correlation between geo-temporal-demographic predictors and CES uptake

3.2.1. Spatial predictors

The distance that people are willing to walk from the spatial predictors listed in Table 2 (i.e. touristic amenities, bus/train stations, walking paths, and picture hotspots) varies, reflecting different spatial patterns associated with the various CES benefits that people pursue. Through the Kruskal-Wallis test (see Appendix A), we were able to understand the statistical relevance of the relationship between the occurrence of SM data coded with the different relational CES values and the respective distances to spatial predictors. Then, the Wilcoxon rank sum test (see Appendix B) allowed us to understand the relationship between relational CES values in their distance from each spatial predictor. Between the relational CES values that proved relevant in explaining their distance from touristic amenities (see Fig. 3), the relatively longer distance that people walk on average to enjoy *physical recreation* and *existence value* compared to enjoying *cognitive value* and *built cultural heritage*, resulted statistically relevant. Similarly, there is statistical significance in the longer average distance walked from bus and train stations to enjoy *physical recreation*, *natural cultural heritage* and *social relations* compared to that covered to benefit from *experiential recreation* and *built cultural heritage* (see Fig. 3). Distance from walking paths is statistically explained by the enjoyment of *spiritual value* (*p*-value = 0.006275), *built cultural heritage* (p-value = 0.0007478) and *physical recreation* (p-value = 4.772e-05), being the respectively decreasing average distance walked for their enjoyment also relevant (see Fig. 3). Finally, the longer distance walked from hotspots to enjoy *spiritual value*, *cognitive value*, *social relations*, and *existence value* compared to that covered to benefit from *built cultural heritage* showed to be statistically relevant as well (see Fig. 3).

3.2.2. Temporal predictors

Temporal factors also seem to have an influence on the distribution of the access to CES benefits. Most of the relational CES values which present a statistically significant correlation with the time of the day (see Appendix C), namely *physical recreation* (*p*-value = 2.84e-05), *experiential recreation* (p-value = 0.007496), *existence value* (p-value = 0.04913), *natural cultural heritage* (p-value = 3.68e-10), *landscape aesthetics* (p-value = 0.01897), and *built cultural heritage* (p-value = 3.147e-05) seem to be enjoyed either in the morning or, mostly, in the afternoon (see Fig. 4), as confirmed by other studies (cfr. Bandara & Bandara, 2019).

Noticeably, and probably due to the relatively smaller sample of data coded as *spiritual* (*p*-value = 0.002116) and *cognitive value* (p-value = 0.009655), a different timespan is preferred for their uptake, the former being the most enjoyed during evenings and nights and the latter showing comparable benefit uptake during mornings and afternoons.

Moving up the temporal scale of the week, there is statistical significance (see Appendix C) in people's preference to enjoy *experiential recreation* (p-value = 0.0001113), *cognitive value* (p-value = 7.719e-05), *natural cultural heritage* (p-value = 1.138e-05), *social relations* (p-value = 0.006018) and *built cultural heritage* (p-value = 0.05525) over the weekend. Interestingly, the slightly higher enjoyment of *landscape aesthetics* on weekdays than on weekends is statistically relevant (p-value = 5.066e-07) (see Fig. 4).

Looking at seasonal distribution, unexpectedly, CES depicting SM pictures are taken mainly in autumn and spring, fewer in winter and even less in summer (see Fig. 4). This general trend is reflected in the annual distribution of the relational CES values statistically correlated with seasonality, with *physical recreation* (p-value = 0.01088) and *social relations* (p-value = 0.001312) mainly enjoyed during autumn, while *landscape aesthetics* (p-value = 0.01931) mainly in spring (similarly to Cao et al., 2022).

3.2.3. Demographic predictors

Finally, we assessed demographic differences in the uptake of CES benefits. Out of the 471 unique users in our sample, we determined the performed gender of 433 (92%): 55 (13%) performed as women and 376 (87%) as men, in similar proportions to other studies (see Angradi et al., 2018). Two Flickr accounts are shared among a couple and were not included in demographic analyses. In relation to the number of photos per performed gender category, out of the total 1617 pictures uploaded by photographers whose performed gender we could assign, 92% (1482) were taken by men-performing and 8% (135) by women-performing people. Thus, woman-performing people posted proportionately less pictures-per-capita to the platform (i.e., they comprise 13% of the users but posted 8% of the pictures). Among the 232 unique users (50% of the total) that shared residency information on their profile, 109 (47%) were coded as "local", which amounted to 57,6% (514) of the total pictures tagged with residency (892), while the remaining 53% as "non-local", contributing to 42,4% (378) of the pictures.

The chi-square test (see Appendix C) shows that the differences in relational CES benefits uptake based on performed gender and residency are not random for some CES (see Figs. 5 and 6).

As expected, people performing as men appear to benefit at a significantly higher rate than those performing as women from all the services which showed statistical correlation with this demographic variable (see Appendix C and Fig. 5): *physical recreation* (*p*-value = 0.01392), *experiential recreation* (p-value = 0.03862), *natural cultural heritage* (p-value = 0.0001271), and *social relations* (p-value = 0.01641). In relation to place of residence, instead, relational CES benefits uptake reveals a more equal distribution (see Fig. 6), with locals taking a higher number of pictures categorized as *existence value* (p-value = 0.004107), *cognitive value* (p-value = 0.0001788), *natural cultural heritage* (p-value = 2.8e-13), and – even if slightly – *built cultural heritage* (p-value <2.2e-16) compared to non-locals who, in turn, primarily appreciate *landscape aesthetics* (p-value <2.2e-16) and *social relations* (p-value = 3.077e-08).

3.2.4. Geo-temporal-demographic cross-analysis

After analysing how relational CES values distribution can be explained by the different predictors taken singularly, here we want to understand their combined effect. Statistically relevant correlations between seasons and performed gender (p-value = 0.0007301, see Appendix D), for example, show more nuanced relational CES benefit distribution, than the two predictors analysed separately (see Figs. 4 and 5 respectively).

In particular, summer and autumn seem to be the best or the worst seasons to enjoy both *physical recreation* or *social relations* depending on whether you are a woman-performing or man-performing user respectively (with the only exception for *physical recreation*, which woman-performing users enjoy at relatively high rate in autumn as well). Similarly, woman-performing users show a preference for winter over spring activities, as opposed to man-performing users mostly enjoying springtime (see Fig. 7).

Given the statistical correlation between the weekly distribution of relational CES values and residency (p-value = 2.441e-07), we notice that both locals (more evidently) and non-locals seem to prefer to enjoy time in the natural settings of Collserola during weekends, regardless of the relational CES benefits enjoyed within those that showed statistical correlation with both residency and day of the week (see Fig. 8 and Appendix C). The only exception is given by non-locals, who seem to benefit more from *landscape aesthetics* and *built cultural heritage* during weekdays than weekends.

The daily distribution of CES uptake is statistically correlated with both residency (p-value = 2.657e-09) and performed gender (p-value =

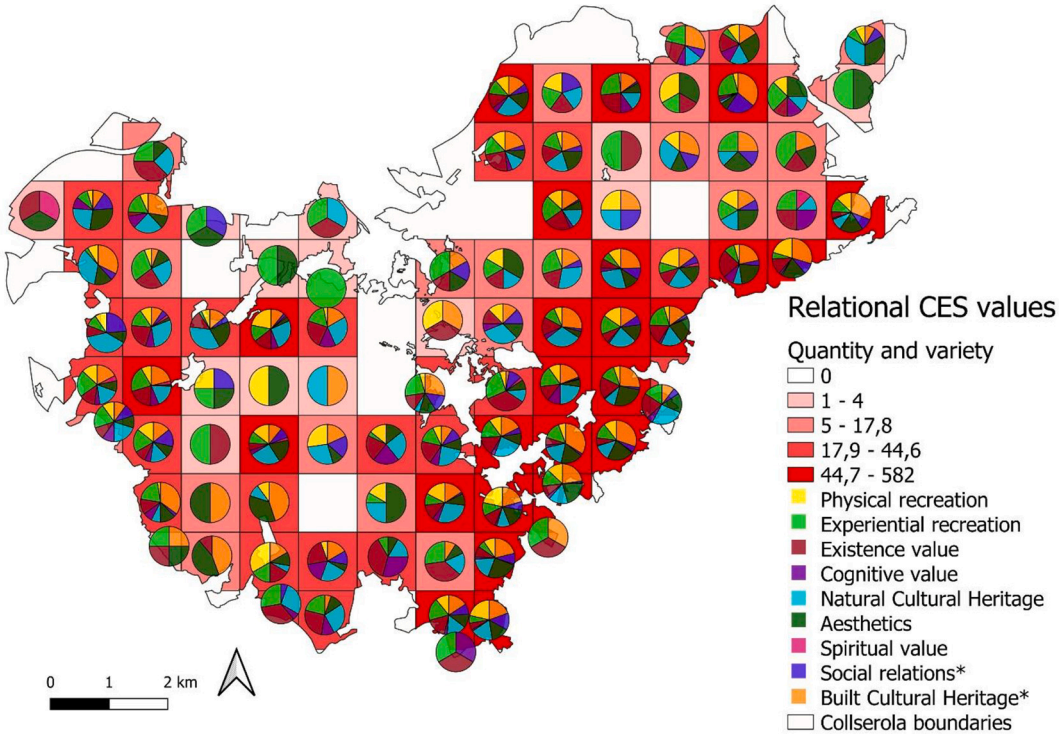

Fig. 2. Distribution of relational Cultural Ecosystem Services (CES) values in Collserola park, Barcelona. Each pie chart shows the values distribution within the 124 grid cells in which the study area has been divided. The red graduated colour of each grid cell indicates the total amount of pictures geocodedwithin it. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

0.01027)(see Appendix D). Both locals and non-locals mostly enjoy relational CES benefits in the afternoon. A clear increase in benefits uptake from morning to afternoon is evident for all the relational CES that showed statistical correlation with both residency and time of the day (see Fig. 9 and Appendix C) except for *cognitive value*, which locals experience either in the morning or in the afternoon likewise, while non-locals seem to slightly prefer during mornings. Moreover, on average, non-locals seem to dedicate proportionally more evening- and night-time than locals to the uptake of relational CES benefits.

Physical recreation, experiential recreation and *natural cultural heritage* resulted statistically correlated with both daytime and performed gender (see Fig. 10 and Appendix C). While the relational CES benefits uptake revealed by woman-performing users decreases smoothly from mornings to evening and presents a steep decrease at night, man-performing users' enjoyment of relational CES benefits mostly happens in the afternoon and at a lowering rate during mornings while decreasing consistently during evening and night, but never reaching the drop experienced by people performing as women.

Finally, we analysed the interplay of all the different factors at once. Being both residency (p-value = 0.001856) and daytime (p-value = 2.346e-10) statistically correlated with distance from hotspots, we analysed the daily patterns of locals and non-locals' uptake of the relational CES values which resulted statistically correlated with the combination of these geo-temporal-demographic variables, namely *existence* and *cognitive value*, and *built cultural heritage* (see Fig. 11 and Appendix A and C). In general, locals experience *existence* and *cognitive value* (apart from evenings for this latter) at shorter distances from hotspots than non-locals throughout the day. Finally, on average, locals and non-locals move similar distances from hotspots to enjoy *built cultural heritage*, with non-locals reaching further distances than locals in absolute terms, especially during mornings and nights.

Distance from bus and train stations correlates with performed gender (p-value = 0.02073) and daytime (p-value = 0.001052) for the uptake of *physical* and *experiential recreation*, and *natural cultural heritage*, with seasons (p-value = 1.248e-05) for the enjoyment of *physical recreation* and *social relations* (see Figs. 11 and Appendix A and C). While performed gender does not seem to have an influence on the average distance walked, man-performing users reveal to walk a wider range of distances from bus and train stations than woman-performing users to enjoy every relevant relational CES benefits and during the whole day, with this difference being most visible at night. A similar result is shown by the distance walked to access relational CES benefits correlated with the seasonal distribution, in this case performed gender-based difference are mostly evident in autumn.

3.3. Reality check

Even though the number of respondents to the survey conducted in Collserola ($n = 1922$) is significantly higher than the SM unique users in this study, and the study design substantially different (no assessment of relational CES benefits uptake in the survey), the general trends and comparable. The survey, in accordance with our results, reported the highest frequency of visits in the south-western fringe of the park along the famous walking path named Carretera de les Aigües, and mostly during spring and autumn, with a significant drop in summer. Weekends are also preferred by both survey respondents and SM users, but, according to the survey, people mostly visit the park in the morning (72%) while SM shows a stronger preference in the afternoon. Among the survey respondents, 75,2% would be coded as locals according to our classification, against the 47% found in our SM data sample, while regarding gender, the survey shows a similar but less stunning disproportion (67% men vs 33% women) to that encountered in this study (87% men-performing vs 13% women-performing). Also, when asked about their habits in sharing their park experience on SM, they mostly mention tracking apps, such as Strava or Wikiloc, while Flickr does not appear to be a frequently used app.

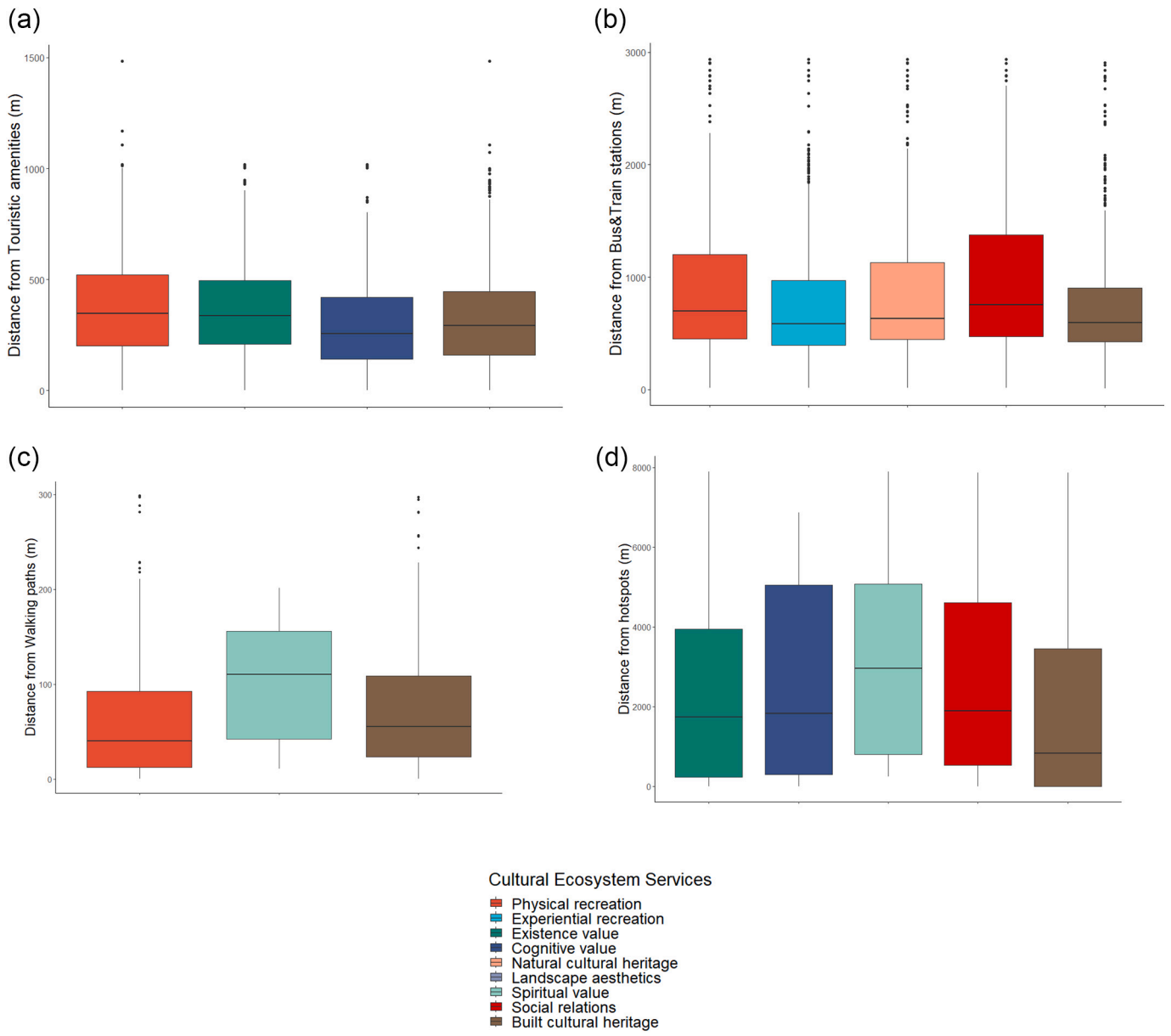

Fig. 3. a) Distance (m) between touristic amenities and geotagged SM data coded with statistically relevant explanatory relational CES values. b) Distance (m) between bus and train stations and geotagged SM data coded with statistically relevant explanatory relational CES values. c) Distance (m) between walking paths and geotagged SM data coded with statistically relevant explanatory relational CES values. 4) Distance (m) between hotspots and geotagged SM data coded with statistically relevant explanatory relational CES values.

4. Discussion

This study aims to leverage the potential of SM data to generate "*snapshots of the city* as a functioning system" (Crooks et al., 2010) and to gain novel insights into complex phenomena in social-ecological systems (Lopez et al., 2019) to inform justice and sustainability transformations. These aims speak to the CES community's need to understand the actual and fine-grained distribution of multiple and plural benefits and ascribed relational values in space and time, and to the feminist and digital geography community's urge to investigate social phenomena by blurring public/private and rean/more-than-real boundaries, politicizing life at the scale of the everyday and sensing public embodied and situated perceptions through access to individuals' ideas and opinions (Koblet & Purves, 2020; Leszczynski, 2019; McLean, 2020; Morrow, Hawkins, & Kern, 2015). In the name of speaking to both of these communities, we target our discussion of the results presented above toward unearthing the relational dimensions of CES that are exposed and toward looking at the digital as both object and subject of inquiry (Elwood & Leszczynski, 2018).

4.1. *Digital fine-scale traces of differentiated relational CES benefits uptake*

The analysis of social media metadata within the boundaries of the peri-urban park of Collserola offers a privileged view of the relationship between multiple relational CES values and the differentiated distribution across the several groups of urban dwellers interacting with and within green spaces in the surroundings of densely populated cities.

Spatial analyses confirm intuitive expectations that link the enjoyment of some relational CES benefits to specific spatial needs (e.g., walking relatively long distances from hotspots to enjoy *social relations, spiritual*, *existence* and *cognitive value* as well as moving further from

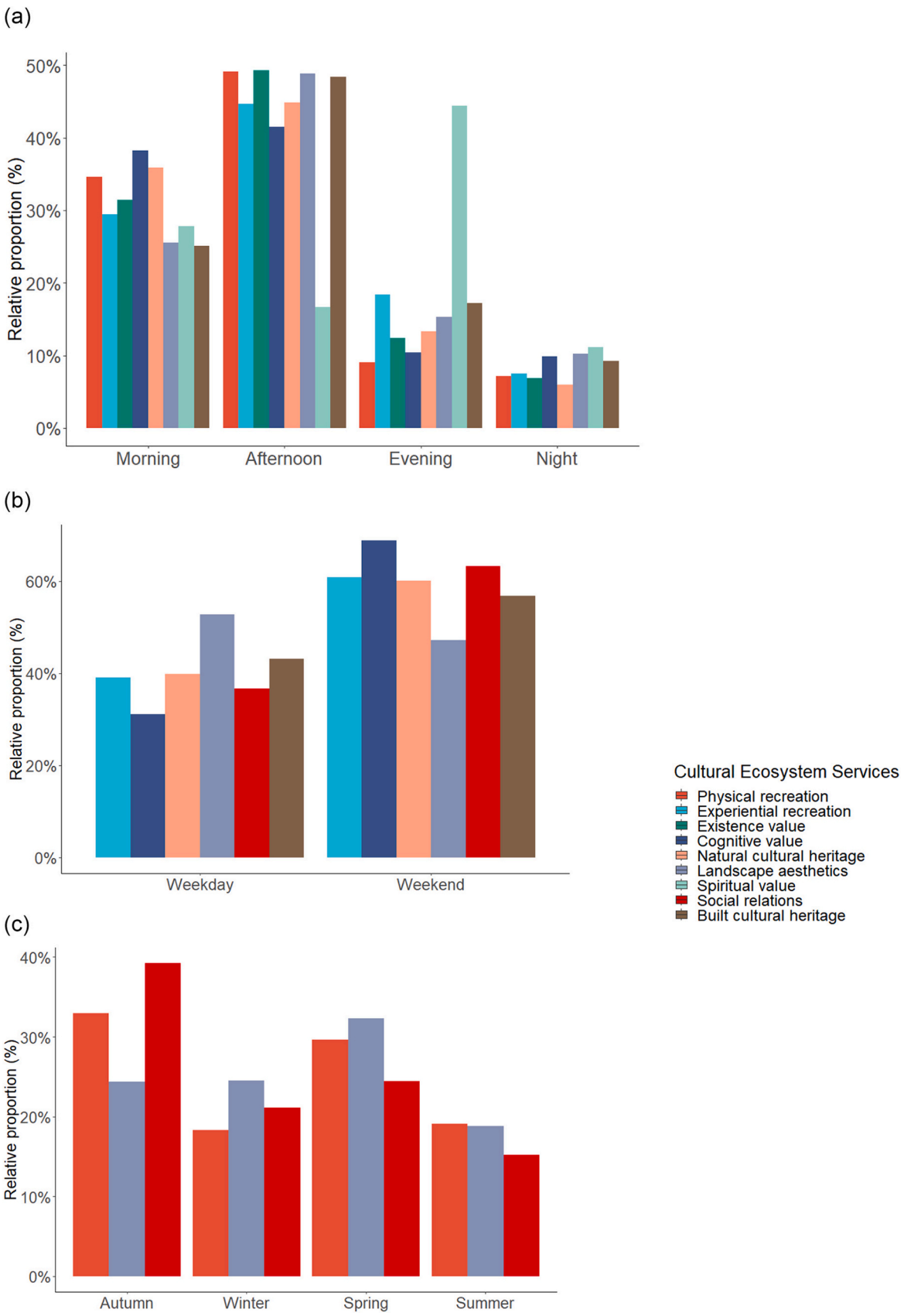

Fig. 4. a) Percentage of daily variation in the statistically correlated uptake of relational CES benefits. b) Percentage of weekly variation in the statistically correlated uptake of relational CES benefits. c) Percentage of seasonal variation in the statistically correlated uptake of relational CES benefits.

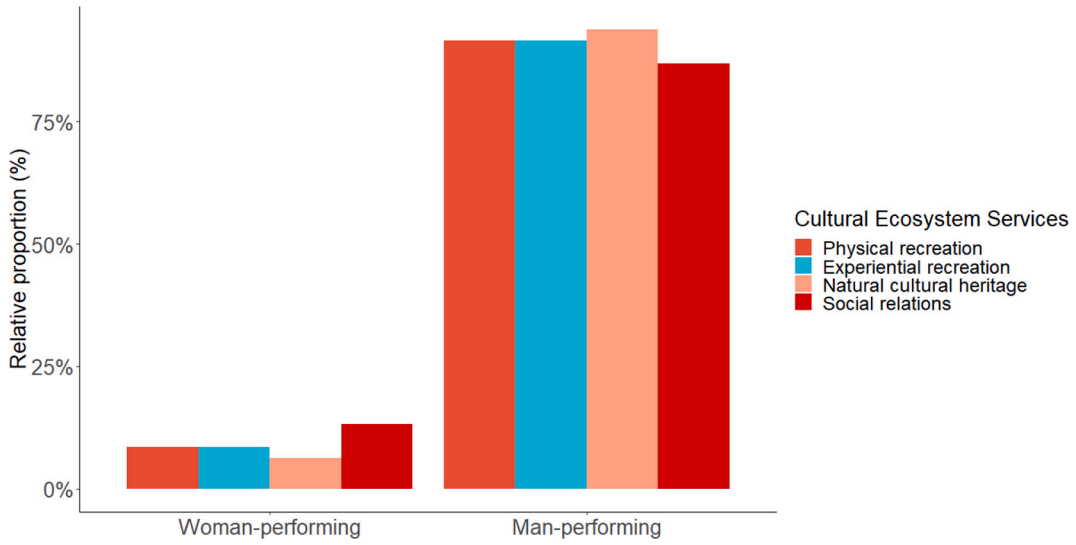

Fig. 5. Relative percentage of pictures distribution per performed gender and correlated relational CES values.

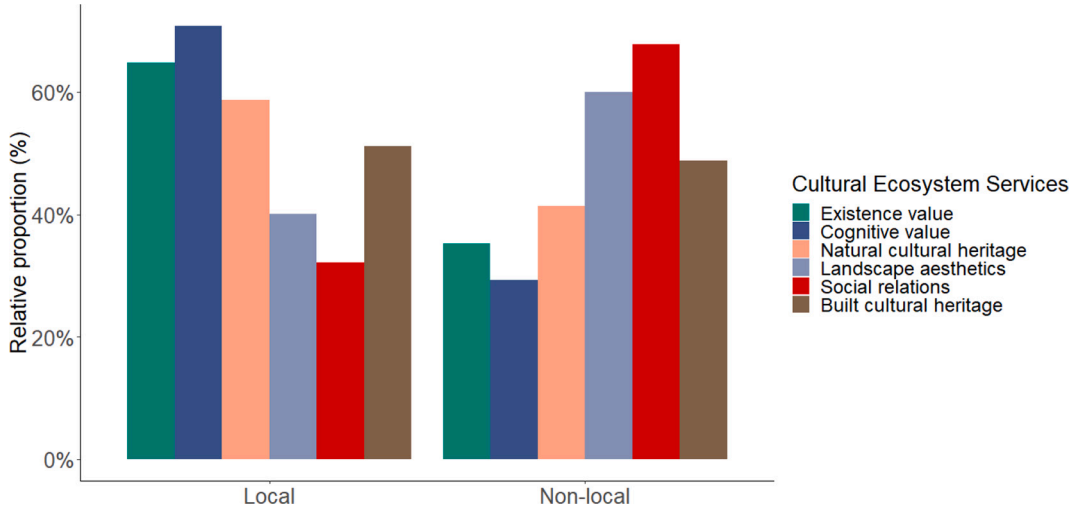

Fig. 6. Relative percentage of pictures distribution per place of residence and correlated relational CES values.

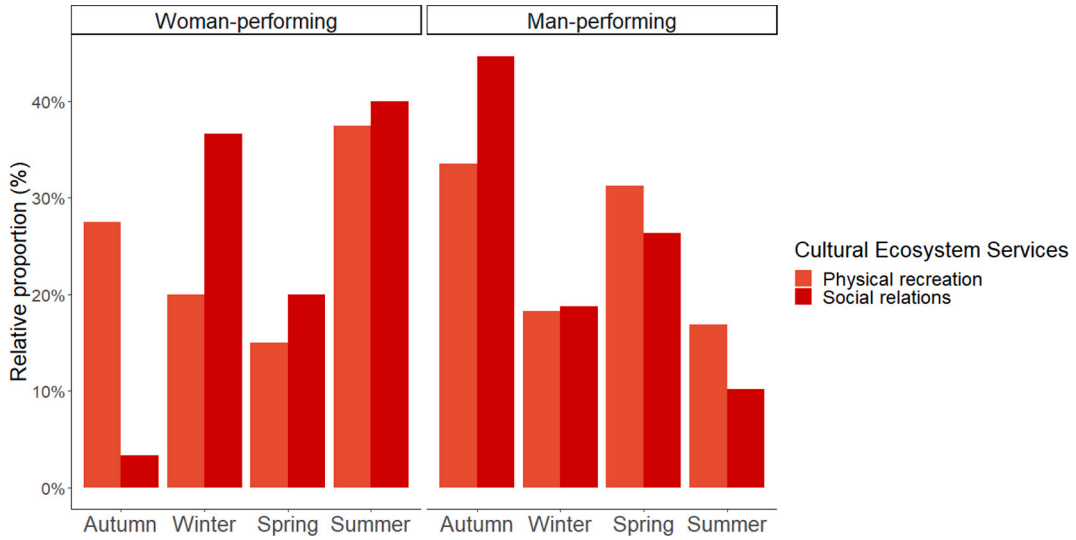

Fig. 7. Relative percentage of pictures seasonal distribution per performed gender and statistically correlated relational CES values.

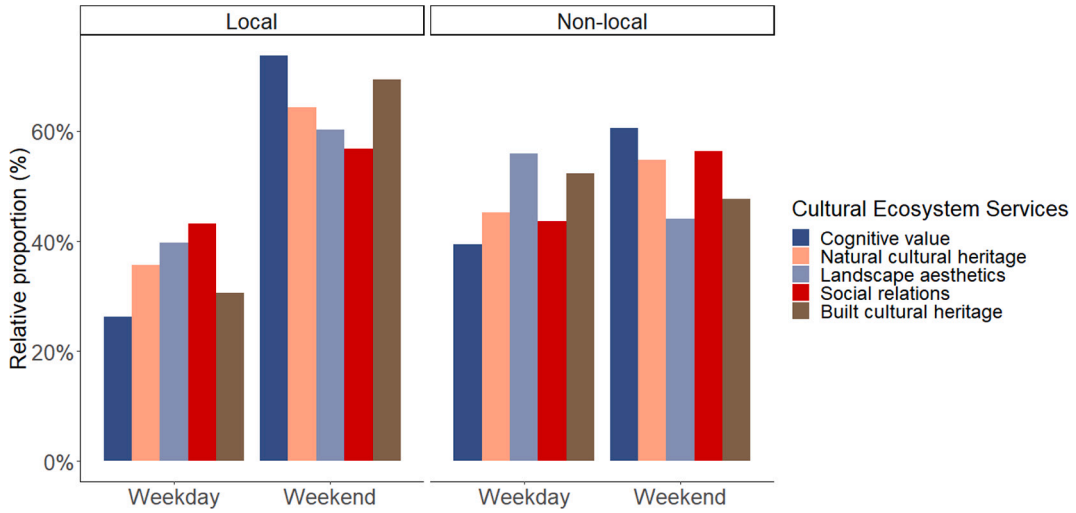

Fig. 8. Relative percentage of pictures weekly distribution per residency and statistically correlated relational CES values.

touristic amenities and bus and train stations but closer to walking paths for the uptake of *physical recreation* than for other benefits). The relatively little distance travelled from walking paths and touristic amenities (on average, <100 and 350 m respectively) confirms other studies findings (see Cao et al., 2022) and can be linked to several factors. First, given the mainly forestry cover, the enjoyable share of the park is of relatively small size and, as expected, closely linked with paths and amenities. As well, the significantly dense network of walking paths that eases access to the touristic amenities, especially Tibidabo mountain, attracts both locals and tourists to the area.

Temporal analyses, in line with other studies, show predictable trends of CES enjoyment during the day (e.g. most of the CES valued in the morning and in the afternoon, fewer at evening and night) (cfr. Bandara & Bandara, 2019) and the week (e.g. overall, higher uptake over weekends than weekdays) (cfr., Havinga, Marcos, Bogaart, Hein, & Tuia, 2021), but rather surprising seasonal variability given the low number of pictures taken in summer (differently from what found by da Silva Lopes, Cadima Remoaldo, & Ribeiro, 2018; but confirming findings by Bandara & Bandara, 2019). This might be explained by the relatively close beachline that could work as a higher attractor for both tourists and local people in hot weather conditions.

Finally, the fine-scale demographic characterization of SM data and the multi-variate cross tabulation analyses performed in this study open a new frontier for SM research, reflecting specific spatial and temporal needs in relation to the social groups analysed (e.g., non-locals evading from crowded areas more than locals; reverse seasonal and daily preferences in accessing relational CES benefits between woman- and man-performing users).

However, the different proportion in data availability per CES (e.g. see Calcagni et al., 2022) and per predictor variable (as also warned in Shelton, 2022), may explain the lack of statistical significance for some of the relationships between the chosen variables and might have hampered the full potential of the proposed methodology, for instance neglecting the peculiar spatial, temporal, and demographic patterns of some relational CES values.

4.2. *Embracing the fuzziness and challenging the boundaries of the more-than-real*

As feminist digital geography has recently asserted, local knowledge cannot be separated from the situated, embodied positionality of the individual who produces or interprets it (Elwood, 2008; Leszczynski & Elwood, 2015). Consequently – and in contrast to the objectivity, neutrality and universality often ascribed to SM data by contested algorithmic epistemology principles (Crawford, Miltner, & K., 2014; Leszczynski & Elwood, 2015; Shelton, 2022) – we acknowledge that the

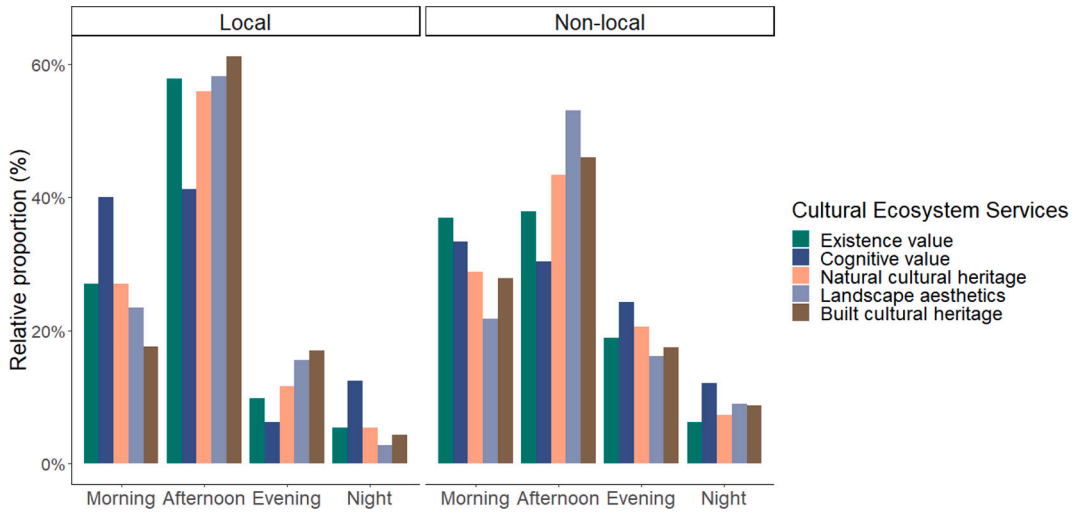

Fig. 9. Relative percentage of pictures daily distribution per residency and statistically correlated relational CES values.

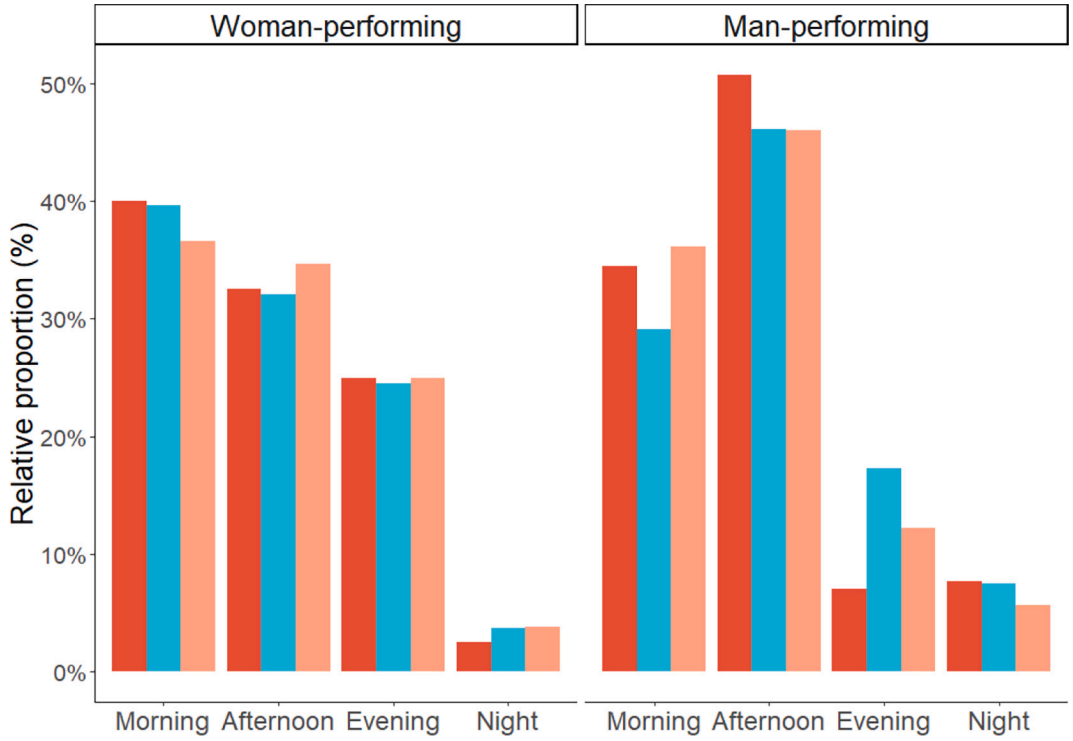

Fig. 10. Relative percentage of pictures daily distribution per performed gender and statistically related relational CES values.

production of this data does not occur in a social vacuum, and that the digital environment is a place where subjectivities, everyday life and perceptions of space are negotiated and forms of power reproduced (Armstrong et al., 2021; Elwood & Leszczynski, 2018; Stephens, 2013), in a tangled process of online-offline behavioural and affective co-production of space and benefits uptake (Armstrong et al., 2021). In this vein, scholars call for a feminist digital epistemology and methodology aimed at accounting for those processes, usually invisible in SM data assessment (Elwood & Leszczynski, 2018; Leszczynski & Elwood, 2015).

To address the issue of SM data representativeness, mixed-method approaches have been proposed, using both SM and traditional data (Ghermandi & Sinclair, 2019; Oteros-Rozas et al., 2018) or conducting surveys to social media users – although with fairly low response rates (Lenormand et al., 2018). In our study, we relied on shared or revealed information, which are also limited because contributed only by a portion of the SM users or assumed by the researcher. Procedure for assessing representativeness may either reveal a general bias in SM data, and thus confirm other evidence (Crampton et al., 2013; International Telecommunication Union, 2016; Stephens, 2013), or unveil ground-level spatial, temporal, and social structures and processes causing inequalities in the case study area. In order to address aspects of injustices in relational CES values and respective benefits access and uptake, those structures and processes need to be analysed as well (cf. Fortnam et al., 2019).

For example, not accounting for the gender-imbalance found in both SM and survey data might, on the one hand, underestimate the gendered geo-temporal patterns of access to relational CES benefits revealed by this study while, on the other, possibly neglect the effect of analogous differences in the predisposition of men and women (whether appearing or performing) to either respond to a survey or post on SM. This difference can potentially be explained as fear for gender violence, which in Barcelona showed to mostly occur in public places for leisure and in the cyberspace (Adjuntament de Barcelona, 2018). Despite other studies that used different sources of socio-demographic information obtained gender-neutral patterns of CES uptake (Martinez-Harms et al., 2018) or reached conclusions different from this study, (e.g., Oteros-Rozas et al., 2018 find SM to be mostly used by women), taking the context-specific dynamics revealed by SM data seriously, in a way that accounts for the data shortcomings without dismissing the imbalances exposed, is essential to furthering goals outlined in feminist cartography and data visualization agendas (Braidotti, 2005; D'Ignazio, 2015).

4.3. *Opportunities and limitations*

As seen, SM offer promising opportunities for studying the co-evolution of relational CES values and the ecosystem structures and functions to which they are ascribed (Blicharska et al., 2017). However, the availability of SM data is dwindling and unstable. Platforms can shut down for changing users demand, and access to data can be restricted due to data protection regulations (*General Data Protection* Regulation, 2016) or changed platforms' Terms and Conditions of Use[3], or denied to avoid data manipulation in the corporate and political interests (Richterich, 2018). In addition, SM platforms access is unevenly distributed across social groups. This can be due to continued issues of digital divide regarding the access to devices, technologies, infrastructures and skills needed to make proper use of them (Ghermandi and Sinclair, 2019), or, as suggested here, to the sense of safety felt by groups in cyberspace (Adjuntament de Barcelona, 2018).

Therefore, warranting ethical and inclusive practices in data use and platform accessibility is essential to recover public trust and legitimacy in SM data research (de Juan et al., 2021; Ghermandi et al., 2023; Hausmann et al., 2020).

In addition, we do not aim here to target or solve binary and heteronormative biases related with gender assumptions and inherent to observatory methods (Fontán-Vela et al., 2021; McKenzie, Cohen, Sehgal, Williamson, & Golinelli, 2006; Sebo, 2021) – and not yet sparing active data collection methodologies either (see Valera & Casakin, 2022; Farías-Torbidoni and Morera Carbonell, 2020) – but this study is a first

[3] For Flickr see https://www.flickr.com/help/terms

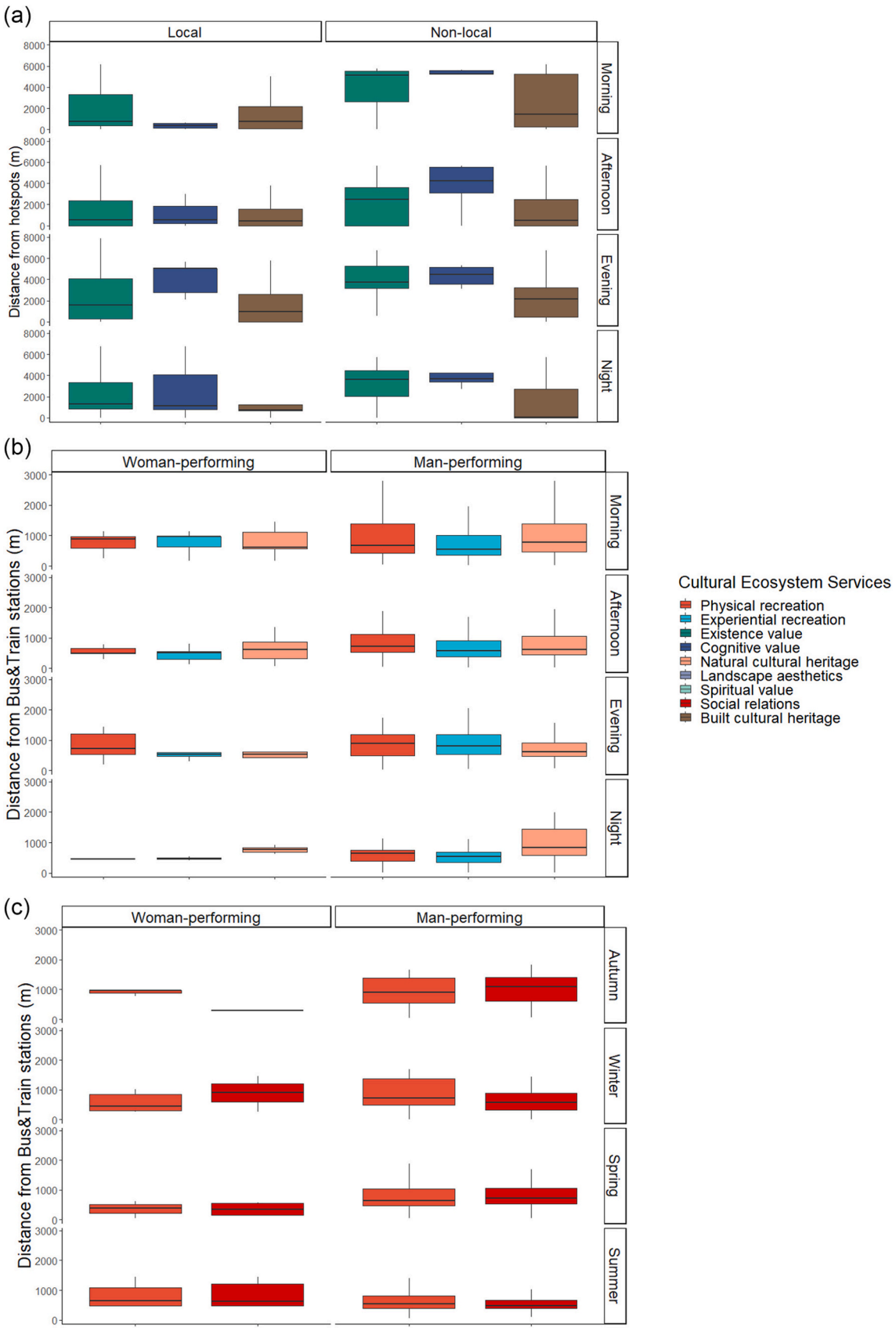

Fig. 11. a) Daily distribution of residency-based distances from hotspots for the uptake of the different statistically correlated relational CES benefits. b) Daily distribution of performed gender-based distance from bus and train stations for the uptake of the different statistically correlated relational CES benefits. c) Seasonal distribution of performed gender-based distance from bus and train stations for the uptake of the different statistically correlated relational CES benefits.

attempt to engage with data skewedness in terms of gender and place of residence, as called for in recent literature (Ghermandi et al., 2023). As future research prospects, we encourage stated gender data collections to further analyse how gender identity is performed online and weights on individual behaviours, both in digital and public green spaces. Finally, we did not perform intersectional analysis (namely combining the two demographic variables) because not statistically correlated, but we encourage other studies to engage in investigating all the possible statistically relevant combinations of the different dimensions, also including other demographic factors, such as age, class, race, disability, education level, etc.

5. Conclusions

With the aim to inform value-based justice and sustainability transformations, this study provides several insights by complementing SM data content analysis with metadata analysis. Firstly, it shows the differential access to CES benefits across space, time, and demographics. In particular, we show that the qualitative information provided by SM metadata is crucial to advancing the understanding of relational CES values that tie people to natural environments, e.g., by analysing the relative distribution of relational CES values held by different social actors across space and time. Overall, the revealed patterns correspond to those resulting from an extensive survey conducted in the same case-study area, confirming that social media platforms are useful and valid data sources to assess relational CES values distribution at fine-grained and wide scales.

Secondly, with the intention to account for the embodied positionality of SM users in relational CES values distribution over space and time, we performed a descriptive cross-analysis and demonstrated how embodied experiences of CES benefits are dynamically negotiated across the demographic categories that was possible to retrieve or assume. We, thus, provide novel information about the multiple and situated spatial and temporal ordinary practices and tactics of CES benefits uptake, and the respective relational values distribution, producing on-the-ground evidence for informing transformations rooted in CES and ES provision that are sensitive to diversity (Beebeejaun, 2017; Connolly, 2019). At the same time, this study proves the importance of considering SM platforms as objects of study as well, revealing neglected relationships between digital and offline reality. In particular, it highlights an important aspect to always consider when performing social media-based CES assessments: the representativeness of the SM sample for the specific case-study area and its different social groups. By revealing demographic information of SM users, we addressed a crucial gap in most SM-based CES studies and demonstrated the uneven proportion of performing men and women in this study, partially confirmed by the survey as well. Although we cannot assume it is fully representative of the offline reality, geolocated SM data (in this case Flickr) reveal imbalances in gender representation, and representation at the intersection with other demographic factors, that are critical for justice transformations to account for. However, SM-based assessment approaches might lead to highly inaccurate representations of the actual access to and uptake of relational CES values in place if the limitations of the data highlighted here are not accounted for, and would thus not serve to properly guide decision-making. In addition, in line with other studies (Ghermandi & Sinclair, 2019; Vaz et al., 2020), the outcomes of this study seriously question the wider application of SM-based assessments without complementing and validating them with ground-level data. Notwithstanding, statistically relevant performing gender- and residency-based differences in the accessibility to Collserola, evident from our results, also indicate that demographic-specific approaches to urban and peri-urban landscape planning are overdue.

Ethics statement

Flickr data were collected through the Flickr API complying with Flickr's terms of service. To account for users' privacy, in the retrieval process only performed gender (woman/man) and translated places of residence (local/non-local) were noted down for each ID. The most sensitive of these data, such as names and places of residence, were not recorded. To reinforce the anonymity guaranty to Flickr users, we encrypted the folders storing the data. Individual data and spatial data have been represented in aggregated form and disjunct from each other, to avoid the possible reconstruction of links between them through data processing. It should be noted that the retrieval and use of SM data requires strong ethical considerations (Boyd & Crawford, 2012; Ghermandi et al., 2023; Ghermandi & Sinclair, 2019). Especially with reference to personal data, retrieved either manually or using advanced methods such as 'inferring demographics' (see, i.e., Lampos, Aletras, Geyti, Zou, & Cox, 2016), the anonymity of users needs to be guaranteed by applying privacy precautions in observation of the respective legislative body (*General Data Protection* Regulation, 2016). Concerns on whether SM data should be considered useful to research in the public interest underlies an ongoing ethical debate that, to date, restricts data access and hinders data sharing by users. The scientific relevance that information extracted from SM increasingly demonstrates, call for urgently establishing a common and clear ethical framework.

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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Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.diggeo.2023.100065.

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