Ecosystem Services 66 (2024) 101594

Contents lists available at ScienceDirect

Ecosystem Services

journal homepage: www.elsevier.com/locate/ecoser

Full Length Article

Unequal access to cultural ecosystem services of green spaces within the city of Rome – A spatial social media-based analysis

Giulia Benati [a,b], Fulvia Calcagni [c,d], Federico Matellozzo [e], Andrea Ghermandi [c], Johannes Langemeyer [b,d,*]

[a] Department of Methods and Models for Economics, Territory and Finance (MEMOTEF), University of Rome La Sapienza, Italy
[b] Institute of Environmental Science and Technology (ICTA), Universitat Autónoma de Barcelona, Spain
[c] School of Environmental Sciences, University of Haifa, Israel
[d] Institute of Geography, Humboldt Universität zu Berlin, Germany
[e] Department of Economics and Management (DISEI), University of Florence, Italy

ARTICLE INFO

Keywords:
Cultural ecosystem services
Urban green space
Social media data analysis
Spatial accessibility
Environmental equality
Landscape and urban planning

ABSTRACT

This groundbreaking study sheds new light on the unequal distribution of cultural ecosystem services (CES) within Rome's urban green spaces (UGS). Employing a novel methodology, we assess UGS quality through georeferenced social media data from Twitter, evaluate the green cover of UGS, and assess accessibility to these spaces using network analysis in a GIS environment. This unique methodology allows us to unveil marked disparities in both UGS accessibility and the provision of CES. Unlike traditional approaches, our analysis provides a more nuanced understanding of UGS quality and accessibility. Our findings reveal areas with high UGS accessibility, yet limited CES provision. These insights are crucial for targeted urban planning interventions, advocating for a more equitable distribution of UGS benefits. This research challenges traditional green space planning with a focus on green space availability. Importantly, our study goes further by identifying specific disadvantaged areas, offering valuable insights for promoting equity in urban areas, emphasizing the importance of UGS quality and accessibility. Thereby, this research provides a foundation for a more nuanced, equal, and quality-driven approach to UGS planning.

1. Introduction

In urban areas, where experiences of the natural environment are limited (Miller, 2005; Gaston & Soga, 2020), the presence of green spaces can have significant positive impacts on human well-being. These include benefits to physical and mental health (Bowler et al., 2010; Yeh et al., 2015; Li & Sullivan, 2016, Barton & Rogerson, 2017), cognitive development, stress reduction (Van den Berg et al., 2007; Maury-Mora et al., 2022), and social cohesion (Kaźmierczak, 2013; Dadvand et al., 2015; Jennings & Bamkole, 2019).

Urban Green Spaces (UGS) planning should ensure accessibility to such benefits for all urban citizens, promoting environmental justice and health (Anguelovski et al., 2020). Yet, disadvantaged groups often face reduced access to UGS, (Wolch et al., 2014) and to quality green spaces (Heynen et al., 2006; Rigolon, 2016), while proximity to UGS has been identified as a key factor in accessibility and use, influencing health outcomes (Grahn & Stigsdotter, 2003; Handley et al., 2003; Coombes et al., 2010; Irvine et al., 2013; Sugiyama et al., 2014; Ekkel & de Vries, 2017; Iraegui et al., 2020). Our research aligns with both the concepts of distributional equality and equity (Cook & Hegtvedt, 1983; Wu & Kim,2021; Zhang et al., 2022): on one hand, we assess accessibility and quality of different UGS across the city, on another, we check accessibility among different demographic groups, shedding light on spatial and social disparities in the urban environment. Beyond accessibility, UGS quality is crucial for urban dwellers' well-being (Biernacka & Kronenberg, 2019).

The concept of ecosystem services (ES) has gained increasing recognition as a framework for assessing the quality of natural areas, including urban green spaces, and their contribution to human well-being across different domains (Coutts & Hahn, 2015; Zabelskyte &

* Corresponding author at: Institute of Environmental Science and Technology (ICTA), Universitat Autónoma de Barcelona, Carrer de les Columnes s/n, Campus de la UAB, 08193 Bellaterra (Cerdanyola del Vallès), Barcelona, Spain

E-mail addresses: giulia.benati@uniroma1.it (G. Benati), fulvia.calcagni@hu-berlin.de (F. Calcagni), federico.martellozzo@unifi.it (F. Matellozzo), aghermand@univ.haifa.ac.il (A. Ghermandi), johannes.langemeyer@uab.cat (J. Langemeyer).

https://doi.org/10.1016/j.ecoser.2023.101594
Received 16 May 2023; Received in revised form 6 November 2023; Accepted 22 December 2023
Available online 23 January 2024

Matijosaitiene, 2020). The ES framework enables the modelling, representation, and mapping of "the benefits people obtain from ecosystems" (Millennium Ecosystem Assessment, 2005). Despite an increasing body of research focusing on inequalities in access to urban ES (Calderón-Argelich et al., 2021) and ES justice (Langemeyer & Connolly, 2020), inequalities in access to quality UGS and resulting unequal ES distributions are still widely overlooked in urban policies and planning.

Specifically, Cultural Ecosystem Services (CES) are pivotal in understanding UGS quality (Kosanic & Petzold, 2020), encapsulating a range of benefits which have direct implications for human well-being (Nowak-Olejnik, Schirpke, & Tappeiner, 2022). Indeed, CES are defined as the non-material benefits that people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences (Millennium Ecosystem Assessment, 2005) and they are therefore, characterized by intangibility (Havinga et al., 2020; Small et al., 2017), context- specificity and dependence on individual perception and specific relationships of people with their nature environment (Kabisch and Haase, 2014; Gai et al., 2022). In the effort of capturing the non-material benefits that people obtain from their interaction with nature, classifications of CES distinguish physical activity, aesthetics, social cohesion, education, heritage, and spiritual enrichment, among others (Haines-Young & Potschin-Young, 2018), which represent a useful framework to assess the (perceived) quality of UGS.

Utilizing social media data (SMD) offers a nuanced way to discern these diverse CES, capturing the perceived quality of UGS in contemporary research (Ghermandi et al., 2023; Langemeyer et al., 2023). Researchers assess and map the spatial distribution of CES by utilizing geolocated SMD from platforms such as Flickr, Instagram, Panoramio, Twitter (Zhang et al., 2022). However, existing studies lack of comprehensive approaches to detecting diverse CES, and most studies examine single CES (e.g. Van Zanten et al., 2016; Langemeyer et al., 2018; Dai et al., 2019; Teles da Mota & Pickering, 2020). For a comprehensive understanding of UGS's contributions to human well-being, it is essential to evaluate the full spectrum of CES rather than limiting the focus to individual services. While some studies may focus on specific aspects like recreation, a broader approach promises to capture the multi-dimensional benefits UGS provide, presenting a richer picture of their importance to urban residents. Geo-tagged posts from social media platforms, such as Instagram or Twitter, not only reveal public interactions with and valuations of environmental features, but also help in gauging aesthetic, recreational, and other values attributed to UGS through user-generated content, thereby serving as a proxy for the perception of UGS quality (Hamstead et al., 2018).

Even though research has advanced in understanding UGS, urban and environmental planning often still prioritize green space availability—expressed as land cover percentage or area—over critical factors like accessibility or quality. This narrow focus risks inadequate planning, potentially exacerbating spatial and social inequalities and inequities in the distribution of benefits. To improve resident's quality of life, the quality of UGS, particularly their CES, requires stronger attention, especially considering unequal accessibility to high-quality UGS.

The aim of this article is to examine the accessibility and quality of UGS, applying a semi-automatic methodology based on geotagged SMD to identify CES and to unveil environmental inequality and inequity. The specific objectives of this study are:

1. To assess UGS accessibility among different areas of the city (addressing the equality question) and among demographic classes (addressing the equity question), including gender, age groups, and foreign residents.
2. To assess the provision of CES in UGS and evaluate access to the most significant CES in the urban context.
3. To compare the accessibility and quality of UGS against the traditional approach, which uses availability as the sole parameter to represent UGS benefits to the population, and to analyze their spatial distribution among different municipalities.

The novelty of this research lies in its integrated approach, which merges geotagged SMD with geographical network analysis to meticulously assess both the accessibility and quality of UGS. Beyond mere availability, our study delves deep into the quality of UGS, focusing on the spectrum of CES to understand their multifaceted benefits to urban dwellers. By juxtaposing traditional availability-focused measures with our comprehensive indices of availability, accessibility, and quality, this research highlights the insufficiency of relying solely on availability metrics. Another significant strength of this approach is its replicability. The methodologies employed can be seamlessly applied to other cities, facilitating comparative studies across diverse urban contexts, and can also be repeated over time, allowing for dynamic assessments of changes in UGS accessibility and quality. Our findings provide a roadmap to identify areas with limited access to green spaces and the essential CES they provide, thereby offering insights for more equal urban planning and policy interventions.

2. Methodology

2.1. Materials and methods

2.1.1. Case study and data collection

Our selected case study is the territory of the City of Rome (Fig. 1), with a population of approximately 2.8 million people and an area of 1,287 km^2 (Comune di Roma Dipartimento Digitale U.O Statistica, 2022). Rome is the largest city in Italy and one of the most populated in Europe. Despite being the Italian city with the highest percentage of public green areas (35.3 % of its total surface area) (Comune di Roma Dipartimento Digitale U.O Statistica, 2016), a precise spatial dataset on green urban spaces in Rome is not available.

The Urban Atlas GIS layer and the CORINE land cover, which are publicly available spatial data sets from the European Copernicus project, are often used as primary sources of data for UGS. However, several studies have reported limitations in these datasets, including errors of commission and omission, which impact their accuracy (e.g., see Batista & Silva et al., 2013; Szatmári et al., 2019; Micek et al., 2020). These limitations are mainly attributed to the semi-automatic land cover interpretation methods used in generating the datasets and their minimum mapping units, which make them less precise for addressing the specific objectives of this study. We therefore relied on three different datasets that are originally manually developed: protected areas and historical villas (green public spaces surrounding ancient villas and palaces that once belonged to wealthy families or important historical figures) from the City of Rome Open Data (2011) and park data from OpenStreetMap (OSM) (2022). To ensure the assessment of accessibility for different residents, we also included parks whose entrances fall within a 1 km radius from the City limits, these being exclusively from OSM. To define UGS for this study, we used green public areas with a minimum extension of 0.5 ha. We chose this extension limitation as otherwise elements such as street-lined avenues and flowerbeds might also be included, while we want the object of our study to be areas whose extension allows human activities to take place (0.5 ha is considered adequate for this use, as it approximately corresponds to a 70mx70m area). This minimum extension choice is also recommended by the World Health Organization (2016) and by the European Common Indicators report (Berrini M. et al., 2003) and can be found in different UGS accessibility studies (Agay-Shay et al., 2014; Pinto et al., 2022).

We employed QGIS Desktop version 3.22.7 to import and process the spatial data. A summary of all the spatial layers utilized in this study is provided in Table 1.

For the population data we utilized the shapefile of the Italian official census from ISTAT (National Institute of Statistics), the most spatially detailed dataset available, which divides Rome's territory in 12,648

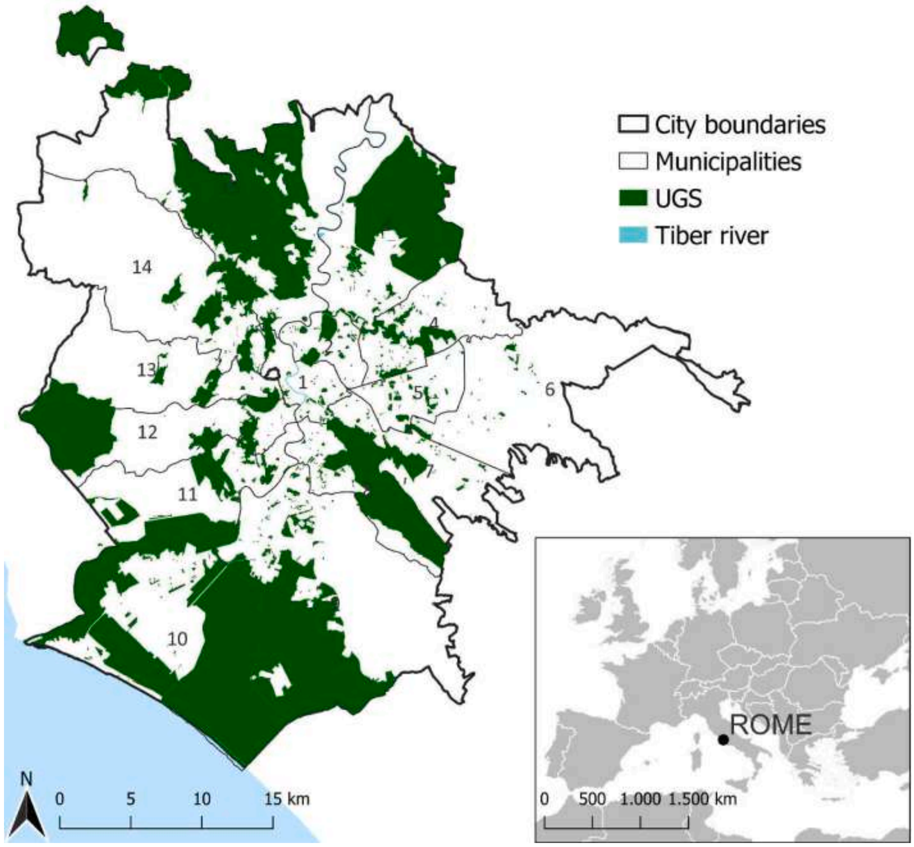

Fig. 1. Location of the City of Rome, Municipality division and Green Urban Spaces. Source: own elaboration based on Eurostat dataset; Historical Villas shapefile, Protected Areas shapefile, City of Rome dataset; OSM dataset. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Table 1
Spatially explicit layers utilized for the study.

Type of data	Layers	Feature Type	Format	Origin	Year
Green Urban Areas	Historical Villas	Polygon	Shapefile	City of Rome Open Data	2011
	Protected Areas	Polygon	Shapefile	City of Rome Open Data	2011
	Parks	Polygon	Shapefile	Open Street Map	2022
Population data	Population census	Polygon	Shapefile	ISTAT (National Institute of Statistics)	2011
Road network	Roads	Line	Shapefile	Open Street Map	2022
Geotagged Social Media Data	Twitter geotagged posts	Point	Csv, transformed into shapefile	Twitter	2016–2022

census tracts. Finally, we utilized Twitter geotagged posts from January 1, 2016, to December 31, 2022, as SMD for semantic analysis. We chose Twitter because it is text-centred, has a sufficiently large user base, and its data could, at the time the analysis was performed, be accessed by researchers rather freely through the Twitter API for academic research track. To extract relevant Twitter posts for analysis, we developed a Python script, which is available on Zenodo[1]. The script allowed us to download the metadata of each post and identify only geotagged posts within UGS, resulting in 57,611 tweets that were used for our analysis. In addition to the text and hashtags of the tweets, the script extracted the latitude and longitude, both when automatically detected and when a place id was specified by the user.

2.1.2. *Accessibility*

Many studies have used buffer distance as a measure of accessibility to green spaces (e.g., Kabisch and Haase (2014), Silva et al., (2018), Wysmułek et al., (2020)). However, this approach has been criticized for oversimplifying the representation of accessibility and neglecting the actual street network and parks' entrances, which can significantly affect individuals' ability to access green spaces (Chênes et al., 2021). To address these limitations, network distance analysis has been proposed as a more accurate methodology for estimating accessibility to green spaces by considering actual distances on existing walkable streets (WHO, 2016). This methodology has been utilized in various accessibility studies (Comber et al., 2008; Sotoudehnia and Comber, 2011; Iraegui et al., 2020; Ma, 2020). Our study also uses network distance analysis in GIS to assess inequalities in UGS access across different municipalities and inequity for the whole city among fragile population groups. We selected the demographic categories of: gender (men and women), children and teenagers under 19 years old, elderly individuals above 60 years old, and residents with different continents of origin (America, Europe, Africa and Oceania). We chose these categories, besides intrinsic limitation of available data, starting from the assumption that the need for and the effect of UGS is not the same for all demographic groups. Our choice to incorporate the gender-related variable was influenced by a broader understanding that men and women have varied needs and barriers when it comes to accessing and

[1] https://doi.org/10.5281/zenodo.7868061.

experiencing UGS and that therefore it is important to at least verify the same physical accessibility. This understanding is supported by several studies indicating that women are disadvantaged in the possibility to access green spaces compared to men. Even given the same physical accessibility, disparities arise due to UGS design and factors related to sense of safety or the presence or type of sport equipment (Ode Sang et al., 2020; Braçe et al., 2021). The categories children and elderlies have less ability to cover long walking distance, as well as a reduced or absent possibility to drive in autonomy to reach distant locations, resulting in a reduced mobility. Additionally, elderly individuals may rely more heavily on accessible services in their local area, such as UGS, to combat isolation and sedentary behaviour, which are correlated with negative health outcomes (WHO report, 2016). Children in particular benefit greatly from exposure to nature, as it is during their age that green spaces can positively impact their cognitive development (Strife & Downey, 2009; Schipperijn et al., 2010). Finally, we choose to study accessibility for foreign residents because often minority groups in cities often have fewer public resources at their disposal (Liu et al., 2021), and therefore the presence of a green space of proximity assumes particular importance. Moreover, this category is to be considering the recognized role of green spaces in dynamics of inclusion and place-making for immigrant residents (Edge et al., 2023; Gao et al., 2020; Gentin et al.,2019).

Through this assessment, the article aims to highlight deprived demographic categories in the access to UGS and among different municipalities. The metropolitan city of Rome and its 15 municipalities showcase notable socio-economic disparities, which inherently interplay with spatial and demographic factors, influencing UGS accessibility. For example, the 6th municipality is commonly identified as facing significant socio-economic challenges, featuring some of the highest levels of deprivation in the city, while in contrast, the 2nd municipality typically registers better socio-economic performance (Lelo, Monni, & Tomassi, 2019). These distinct socio-economic contexts across the municipalities naturally serve as a critical layer in our analysis, acknowledging that spatial inequalities in UGS access may be compounded by socio-economic factors, thereby impacting various demographic categories differently.

2.1.2.1. Metrics of accessibility. Accessibility that people have to UGS is inversely proportional to the distance they need to walk on road networks to reach UGS' entrance. Distance is indeed a key variable for assessing accessibility indicators (Ekkel & de Vries, 2017) and has been used in numerous studies (WHO, 2016). Therefore, identifying threshold metrics for representative distances is a necessary step. There is no universal agreement on a single distance binarily representing whether a green space is accessible or not (WHO, 2016), there is nonetheless a certain degree of agreement on some metrics. The most frequently used distance is 300 m, since it has been found that beyond this distance attendance begins to drastically drop (Ekkel & de Vries, 2017). English Nature (a UK government body) recommends that no citizens should live further than 300 m from a green area (Handley et al., 2003), emphasizing the importance of being able to reach UGS by walking and within a short time. It has been used to measure accessibility to UGS at different scales, including urban (Bovy, 1974; Pinto at al.,2022) and national/sub-national scales (Chênes et al., 2021). It was also found that above this distance from parks, health parameters of population significantly change, suggesting that this distance incentivizes the use of UGS and that living within 300 m provides great benefits both for physical and mental health. For instance, Reklaitiene et al. (2014) found that women living within 300 m from UGS have higher perceived general health and lower depressive symptoms that those living further away. Similarly, a study conducted in Spain (Triguero-Mas et al., 2015) demonstrated that the mental health of individuals living within 300 m of UGS is also higher. Some studies focussed on the effect of UGS proximity on pregnancy, showing that women living within 300 m have a lower probability of high-normal blood pressure during pregnancy (Grazulevičiene et al., 2014), and experience a beneficial effect on birth outcomes (Agay-Shay et al., 2014). The second distance we used for our analysis is 500 m, which aligns with the measurement utilized in the EnviroAtlas tool from the US Environmental Protection Agency[2]. This tool represents the 'residential population within 500 m walking distance along walkable roads of a park entrance' as an indicator (WHO, 2016). For the third and final distance, we chose 1000 m, as it serves as a threshold distance for attendance according to studies by Stigsdotter et al. (2010) and Chênes et al. (2021).

2.1.2.2. Gis-based network analysis for different demographic categories. We conducted a GIS-based network analysis (Comber et al., 2008) to identify walkable paths extending from park entrances on the road network for distances of 300 m, 500 m, and 1000 m (see Fig. 2). We used QGIS version 3.22.7 and loaded the OSM road shapefile. To locate park entrances, we applied the "intersect" tool, which intersected the road network (including the paths within the parks) with the perimeter of the green areas, resulting in a point shapefile representing the entrances of the parks. From the 471 UGS polygons we assessed, 4909 entrances were computed. From these points, we conducted the network analysis on roads and intersected it with the population census first on the whole city, which gave as a result the percentage population that lives within the three chosen distances on walkable streets. For each distance, we ran the "service area (from layer)" tool, producing a linear shapefile of streets within a specified distance radius from the park entrances. We then applied the "buffer" tool to each linear shapefile to generate a polygon within 30 m of the streets. Each polygonal layer, corresponding to a chosen distance, was intersected with the polygonal shapefile of the population census from ISTAT using the "clip" command. This layer contains information on a number of demographic characteristics for the resident population. We transformed the resulting attribute table (.dbf file) into an Excel file of the census of the population residing within 300 m, 500 m, and 1000 m from UGS entrances on walkable streets. From each distance, we calculated the percentage of the population with access to UGS out of the total population of Rome for the three chosen distances ($Accessibility_{dist}$). This percentage is an indicator that builds on the "Urban Green Space Indicator" proposed by the World Health Organization (2016), expressed as the percentage of the population living within a buffer area from UGS of a minimum size out of the total population of an area of interest. We overcame the limitation of this indicator by using park entrances instead of perimeters and service areas as road networks instead of buffers to improve the accuracy of the estimates. The indicator is therefore defined as:

$$Accessibility_{dist} = \frac{N_{networkdist}}{N_{tot}}\% \quad (1)$$

where: *dist* can assume the values of 300 m, 500 m or 1000 m; $N_{networkdist}$ is the number of people who live within one of the chosen distances on the walkable road network from park entrances; N_{tot} is the total number of people living in the considered area (which in our case is either the whole city or the single municipalities)

Analysing accessibility for residents living in peripheral areas we initially included the parks just outside the city limits. This did not add much to the analysis. Accessibility of residents to parks outside the city would increase our final results by 0.01 % for the distance of 300 m, 0.07 % for 500 m, and 0.3 % for 1000 m. We therefore decided to leave these green areas out of the analysis. Lastly, we selected specific categories including gender (men and women), children and teenagers under 19 years of age (divided into four age subgroups), elderly individuals above 60 years old (also divided into four age subgroups), and foreign residents compared to Italians and compared among continents

[2] https://www.epa.gov/enviroatlas

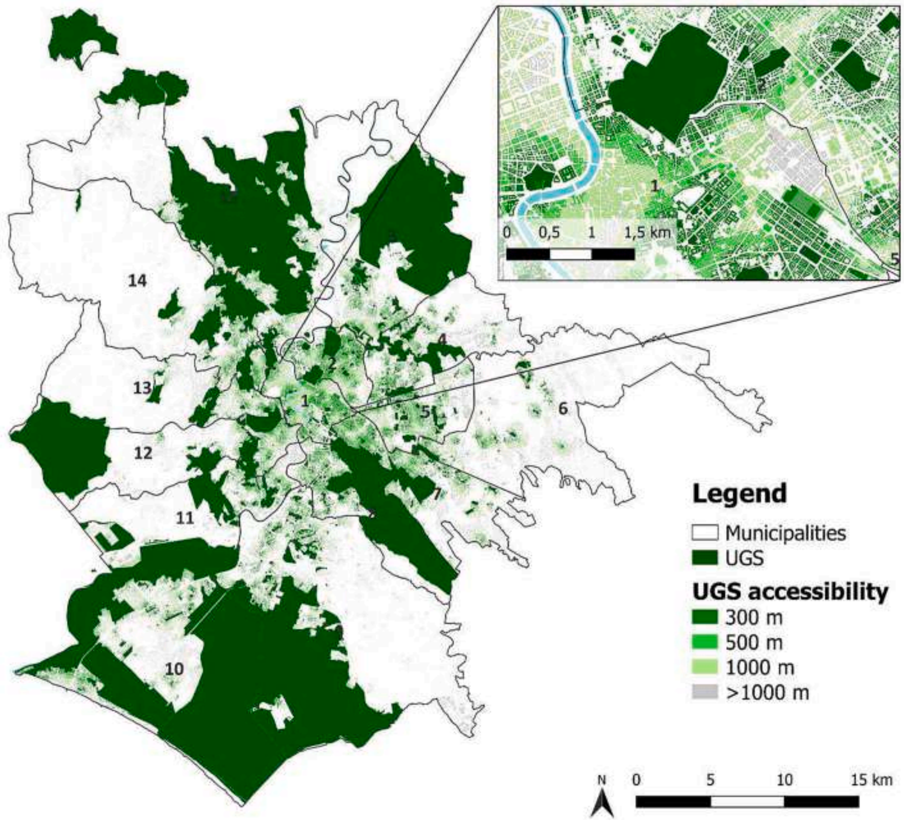

Fig. 2. Buildings with access to UGS entrances within 300 m, 500 m and 1000 m on the road network.

of origin (Africa, America, Europe, and Oceania) in the attribute table of the census tracts resulting from the operations, and computed the corresponding percentages. Given the substantial difference in UGS accessibility found across people from different countries, we verified the statistical significance of these findings by performing a Bartlett's test of homoscedasticity on R using the number of people from different countries living within the three analysed distances of 300, 500 and 1000 m per census tract. Prior to do so, we visually confirmed the required non-normal distribution of the sample through the function ggdensity.

2.1.2.3. Accessibility in different municipalities. We conducted our analysis on the 15 municipalities of Rome, focusing exclusively on the distance of 300 m, as it is the most recurring in literature and produced the most relevant results in our initial analysis for demographic groups across the entire city. Our primary aim was to identify disadvantaged municipalities in terms of access to UGS. To calculate accessibility in each municipality ($Accessibility_{300m}Mun_i$), we determined the percentage of the population living within 300 m of a UGS entrance on the road network, as a proportion of the total population of the municipality:

$$Accessibility_{300m}Mun_i = \frac{N_{network300m,Mun_i}}{N_{tot,Mun_i}}\% \quad (2)$$

where: $N_{network300m,Mun_i}$ is the number of people who live within 300 m from a park entrances on the road network in the municipality i; N_{tot,Mun_i} is the total number of people living in the municipality i

We then compared the accessibility across the different municipalities and with UGS cover. For the measurement of UGS cover, we used the definition provided by the UN Sustainable Development Solutions Network, which defines it as the "area of public and green space as a proportion of total city space." We calculated this measure using the field calculator command in the attribute table of the UGS polygonal layer and geometry tools. By comparing UGS cover with accessibility for the distance of 300 m across the entire city and within different municipalities, we were able to gain insights into the relationship between UGS cover and accessibility in these areas.

2.1.3. Quality

We utilized SMD from Twitter to conduct a semantic analysis of tweets geolocated within UGS, aiming to unravel the CES they offer and discern their distribution throughout Rome's cityscape. We strove to encapsulate the quality of UGS perceived by users by defining it through two proxies: the percentage of CES-related tweets against total tweets per park and for all the parks of municipalities, and the diversity of CES available in the parks of each municipality.

We acknowledge that these proxies could be perceived as more quantitative or prevalence-based; however, from a user-experience standpoint, these metrics offer insights into perceived quality and user engagement with varied CES. Traditional UGS quality assessments, which might encompass different material and non-material aspects of UGS, like biodiversity and maintenance, provide crucial insights yet might miss the human-centric and perception-based insights that SMD can unveil.

We recognized a spectrum of twelve CES categories as per the adaptation of the CICES V.5.1 definitions, including: physical recreation, experiential recreation, scientific value, educational value, heritage value, aesthetic value, social relation, symbolic value, sacred and religious value, entertainment value, existence value and bequest value (Calcagni et al., forthcoming).

The quality assessment of individual parks and the parks within each municipality was based on the quantity (percentage) and variety of identified CES, utilizing a semantic analysis of the text and hashtags from Twitter posts located within UGS, adhering to the procedure and protocol elucidated in the subsequent paragraph. A meticulously compiled keyword table for each of the CES enabled the classification of

57,611 posts automatically. For instance, keywords such as 'run', 'bike', and 'walk' were mapped to "physical recreation." To foster clarity and replicability, the correspondence between CES and keywords that resulted from this analysis is illustrated in the Appendix. Such tweets not only showcase user engagement with the UGS but also highlight the diverse, tangible, and intangible benefits derived, thereby enriching our understanding and classification of CES. Subsequent to the initial part of the analysis, we sharpened our focus on four pivotal CES—physical recreation, experiential recreation, social relations, and aesthetics—-which literature recognize for their significant effects on the physical and mental health of urban dwellers. Furthermore, we enhanced our examination by incorporating an analysis of spatial accessibility to these four vital CES.

2.1.3.1. Protocol for semantic analysis. To identify a robust set of keywords corresponding to each of the twelve CES, we utilized a novel iterative assessment protocol (Calcagni et al., forthcoming), which we contributed to improving with this article, which was also employed as a case study. During the study, we applied the beta-version 5 of the protocol, which consists of subsequent iterative phases. During the first phase, researcher A randomly selected a sub-group of data to analyse using a sample size calculator offered by the Creative Research System, imposing a confidence interval of 95 %, a confidence level of 5, and inserting the total number of posts from Twitter falling within parks for the population parameter. The selected data was then transformed into an Excel file, and twelve columns corresponding to the CES to assess were added, along with a column to fill with a "Y" in the case the text was translated into English and another column for any notes. In fact, we did not select a specific language for examination; instead, we analysed all the languages present, using a translation tool when necessary. We chose to exclude languages in which the number of posts was too low for the words to be representative. The CES columns were compiled, assigning a value of one when the text and hashtags of the post revealed the benefitting of a cultural ecosystem service, and then the words corresponding to each CES in the dictionary were filled. An example of tweets that reveal a CES benefit from users is reported in the Appendix. Researcher B performed the same analysis on the same sample. The two outputs from researcher A and B were compared, and the Matthew's coefficient was calculated to evaluate if there was enough agreement between the two assessments (Delgado & Tibau, 2019). If the coefficient is higher than 0.7, the agreement is considered sufficient to move ahead with the analysis. Otherwise, the loop has to be run again. The two researchers underwent an agreement phase, during which they completed an inter-coders' agreement document. This document highlighted the main differences in interpretation for each CES and provided guidelines for understanding the local-related meanings of certain words. In our case, the Matthew's coefficient was initially less than 0.7, requiring another loop of the cycle with researcher A coding another random sample and going through the same process with researcher C. After this second loop, the Matthew's coefficient was higher than 0.7, allowing us to proceed with the analysis. Once the corresponding words for each CES were defined, we developed and ran an automatic classification script in Python, available on Zenodo, that classified each post of the initial.csv file into the defined CES according to the classification criteria that resulted from the protocol application. Researcher A then manually checked the results for errors by excess or default and modified the words accordingly until no more errors were found. The output of this process was a new Excel file with the georeferenced posts classified into the twelve CES, allowing us to assess in the following analysis where CES were benefitted and which of the considered twelve CES was benefitted.

2.1.3.2. Distribution of CES benefits across the city. The first aim was to evaluate the quality of parks' CES across the city and to assess their distribution. We classified each UGS based on the percentage of posts classified as CES benefit ($N^{\circ} CESTweets_i$) as resulting from the previous step of the analysis, out of the total number of tweets falling within the considered UGS ($N^{\circ} CESTweets_i$), according to a Jenks natural breaks classification, in five classes.

$$CESperc, UGS_i = \frac{N^{\circ} CESTweets_i}{N^{\circ} totalTweets_i} * 100[\%] \tag{3}$$

Jenks natural breaks classification was chosen due to its ability to maximize the differences between classes while minimizing the variance within each class, making it ideal for representing the diverse and complex data of urban park quality (Slocum et al., 2008). The first class is the one of the UGS with the lowest quality, while the fifth correspond to the ones with the highest. Parks where the total number of tweets was less than five were excluded from the analysis for lack of representativeness and depicted in dark red in the map. This number was chosen empirically to avoid false high percentage values when the number of total posts is low. Next, we looked at whether certain municipalities are more likely to be classified as having high or low percentages of tweets related to CES and if there are patterns or trends that emerge when comparing the different municipalities, in order to provide a more comprehensive understanding of how CES are perceived across the city. To assess the distribution of the average quality of UGS across municipalities, we calculated the sum of CES-related tweets ($N^{\circ} CESTweets_{UGS_i}$) out of the total tweets posted within all UGS in each municipality ($N^{\circ} totalTweets_{UGS_i}$).

This allowed us to assess environmental inequality in the benefitting of CES across the different municipalities. Coherently to the previous point, we excluded from the total number of tweets those falling within parks with less than five tweets.

$$CESperc, Mun_x = \sum_{i=1}^{n} \frac{N^{\circ} CESTweets_{UGS_i}}{N^{\circ} totalTweets_{UGS_i}} * 100[\%] \tag{4}$$

where $x = 1,\ldots,15$; $n=$ total number of the UGS

We then classified the fifteen municipalities into different categories based on the quality of their parks. Our classification system ranged from those with a lower percentage of tweets classified as CES-benefit, indicating a lower quality of parks, to those with a higher quality of parks. This classification not only highlighted individual parks but also revealed environmental inequality patterns across entire municipalities.

2.1.3.3. CES variety. To further assess the quality of UGS, we calculated the variety of CES experienced in the parks of every municipality. To determine the extent of each CES category experienced by users, we counted the number of related Twitter posts in all parks within the municipality and expressed it as a percentage of the total number of CES posts. This allowed us to capture the range of CES experiences in each park and the proportion of each CES category relative to the overall number of CES posts in the municipality. The provision of multiple CES can cater to a broader range of people's needs and preferences (Daniel et al., 2012; Jennings et al., 2016). For instance, a park that can host social events, such as festivals or picnics, as well as opportunities for physical recreation, such as running trails and playgrounds, can attract visitors with diverse interests and with different demographic characteristics. This can create an inclusive public space and a positive perception of the UGS as a space that potentially can host a variety of activities. Furthermore, the provision of a variety of CES can create a sense of place attachment and pride in the local community. When people have positive experiences and memories associated with a park, they are more likely to feel a sense of ownership and attachment to it. This, in turn, can lead to a greater sense of responsibility to care for the park and protect it from harm (Andersson et al., 2015).

2.1.3.4. Access to CES. We identified four CES deemed most significant for improving both mental and physical health in urban settings based on existing literature: physical activity (Braubach et al., 2017; Nawrath et al., 2022), aesthetic value (X. Wang et al., 2016; R. Wang et al., 2019), social relations (A. Kazmierczak & James, 2007; Enssle & Kabisch, 2020) and experiential recreation (Van Den Berg & Custers, 2011; Carrus et al., 2015). To understand the spatial distribution of these CES, we conducted an accessibility analysis for each of them. For every UGS, we used the percentage of tweets related to each classified CES out of the total number of tweets as a parameter for our analysis. In (5), this parameter is considered, as an example, for the CES of physical activity.

$$PhysicalActivityperc, UGS_i = \frac{N^{\circ} PhysicalActivityTweets_i}{N^{\circ} totalTweets_i} * 100[\%] \quad (5)$$

Then, for each CES, we elaborated a binary classification of UGS, which classifies the parks in those in which there is an actual benefit of the considered CES and those where there is not.

To do so, we considered a minimum threshold above which the park is considered one where people actually benefit from that specific CES. We determined the threshold of benefitting as corresponding to the upper three classes of the Jenks distribution, considering the parks falling in the first two classes as where people do not benefit of that specific CES.

Next, we identified the UGS where each CES was beneficial and elaborated the services area layer for the distance of 300 m from the entrances of these UGS on the road network. We buffered the results to intersect them with the population census, and we identified areas where people have access to potential benefits related to physical activity, aesthetic value, social relation, and experiential recreation in UGS.

3. Results

3.1. Accessibility

We found that the population that have access to the entrance of UGS within the three chosen walking distances out of the total population of the city is: 55 % for 300 m, 72 % for 500 m and 87 % for 1000 m. Fig. 2 shows a close-up of the map representing the buildings where the people that have access to UGS entrances within 300 m walking distance live.

We did not find any great difference in accessibility between men and women. The most substantial difference in age is between children and elderly people: the older population lives, in average, closer to UGS than the younger generations. Elderly people present a slightly higher accessibility for every distance compared to children (see Table 2).

Differences can be noted instead in the access to UGS between Italians and foreigners, and among different countries of origin, as shown in Fig. 3. Specifically, for the distance of 300 m, the accessibility is considerably lower for African people: 37.9 % compared to 54.7 % of Americans (including both North and South Americans). It is important to highlight that the distance class of 300 m presents the most pronounced disparity among different continents, and that this differential abates with distance. The Bartlett's test performed to verify the heterogeneity of variance across the five countries of origin resulted in a p-value $< 2.2e-16$ for each of the road network distances analysed, validating the significance of our findings.

3.2. Quality

3.2.1. Inequality in the distribution of CES in UGS

Among the 57,611 Twitter posts originally collected within parks, our semantic analysis classified 2675 as related to the enjoyment of CES. Out of the 12 CES considered for our analysis, we were able to identify 8: physical recreation, experiential recreation, heritage value, aesthetics, social relations, sacred and religious value, and entertainment value.

Notably, the remaining four CES - symbolic value, scientific value, existence value, and bequest value - were not present in our sample. The classification of UGS quality based on the percentage of tweets related to CES out of the total number of tweets is depicted in Fig. 4. UGS are grouped into six classes, each representing a distinct level of quality.

The first class, depicted in dark red, consists of parks where fewer than five tweets in total, and they were not classified due to the lack of representativeness. A qualitative investigation, involving potential surveys or interviews, is considered necessary for these parks to ascertain the kinds of experiences and benefits they offer, considering the inadequacy of SMD in capturing the potential values of smaller parks.

The second class, depicted in red, consists of parks with no tweets related to the enjoyment of CES, indicating the lowest quality. The other classes present an increasing quality.

3.2.2. Variety of CES

Fig. 5 displays the variety of CES offered by the UGS of the 15 municipalities.

The map gives an overview of the variety of benefits that are enjoyed in the parks of each zone, providing a proxy for their quality.

The 6th municipality has the lowest variety of CES among all the areas, with UGSs offering the least number of benefits. In contrast, parks located in the central municipalities – such as the 1st and the 2nd, along with the 8th, 10th, and 12th - offer a more diverse range of CES benefits. The 8th and the 12th have two important extended parks, namely Parco degli Acquedotti and Villa Doria Pamphilj, that scored a high percentage of CES tweets percentage (see Fig. 4) and serve as significant public spaces for various activities and benefits for the population. The 10th municipality, located near the sea, hosts several extended protected areas that offer a high variety of CES, even if this municipality has a relatively low percentage of CES related tweets (see Figure 10). These findings emphasize the significance of analysing not just the volume of CES-related posts but also their diversity, which enhances the overall understanding of the distribution and quality of UGSs in a city.

3.3. Access to quality

These results identify both the UGS where the CES taken into consideration are perceived and the areas where these services are accessible to the population.

Fig. 6 presents four maps illustrating the census tracts where individuals with access to each CES within a 300 m radius from their residences are located. The yellow census tracts highlight areas where people have this access, while grey areas indicate the absence of this accessibility. The distribution of UGSs providing CES and their corresponding access areas varies across each considered CES. Examining the first CES, physical recreation, the distribution is generally uniform across the city, with the exception of the 6th and 14th municipalities, which show a higher level of disparity. In the 14th section, there are parks offering high-quality UGS for physical recreation, but they are primarily concentrated in the central areas of the municipality. Consequently, environmental inequality arises within the same municipality, as residents living in peripheral areas have limited access to high-quality UGS for physical recreation. When considering aesthetic value, it is worth noting that larger parks throughout the city are generally perceived to have a higher aesthetic value. Additionally, parks like Villa Borghese or Circo Massimo, although not the largest in size, are recognized for their elevated aesthetic appeal. Their central locations, along with other distinct features, might contribute to their perceived aesthetic value. In terms of social relations and experiential recreation, no clear pattern emerges. However, certain areas, particularly in the eastern part of the city, have a lower frequency of parks associated with these CES.

3.4. Availability, accessibility and quality compared

Our examination of public green spaces across Rome's 15 municipalities demonstrated that indicators of availability, accessibility, and quality of UGS offer different yet complementary information. Thus, it is

Table 2
Percentage of population that have access to UGS entrances within the three selected road network distances, among different demographic classes.

	Dist	Tot Pop	Men	Wom	< 5 years old	5–9 years old	10–14 years old	15–19 years old	60–64 years old	65–69 years old	70—74 years old	>74 years old
PopAcc [%]	< 300 m	54,6	54,1	55,0	53,5	53,8	54,3	54,6	55,6	56,1	56,3	56,6
	< 500 m	72,5	72,1	72,8	70,3	70,6	71,2	71,9	73,5	73,7	74,2	75,8
	< 1000 m	87,06	86,79	87,3	84,68	85,3	85,95	86,34	87,87	88,38	88,79	89,8

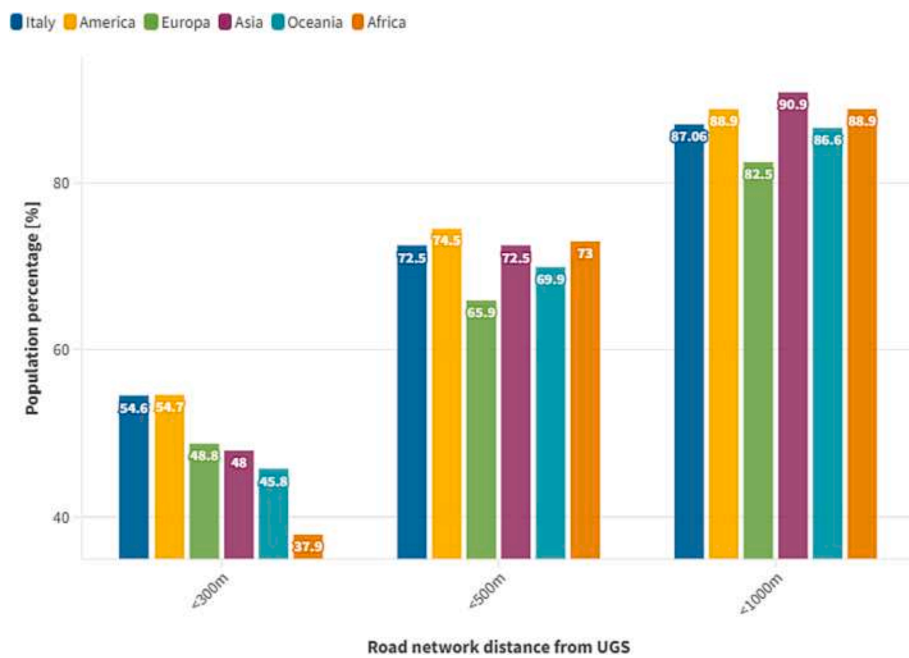

Fig. 3. Comparison of accessibility to UGS among residents of Italy and residents with different continents of origin at the three selected road network distances (Bartlett's test p-value < 2.2e-16).

imperative to consider all three indicators collectively when developing policies or interventions for UGS. The three maps, placed side by side, allow for easy comparison of the municipalities, which are ranked in 15 corresponding classes from worst to best provision of the indicators. Our analysis revealed both convergences and divergences in the three indicators. For example, the 6th municipality has the lowest green cover, accessibility, and quality, making it the most disadvantaged area in terms of receiving the benefits of UGS. In other cases, such as the 10th municipality, while having the highest green cover, it has low accessibility rates and medium–low quality, indicating that the mere presence of parks alone is not sufficient to deliver their benefits to the population. On the other hand, our analysis also revealed that some municipalities with low green cover, such as the 5th municipality, have good access to parks and a high quality of UGS, indicating that the existing parks are delivering benefits to the population despite the limited green cover. However, this finding also suggests that increasing the extension of these parks could further improve the provision of CES to the residents of these municipalities.

Overall, our examination highlighted a clear environmental inequality in the distribution of availability, accessibility and CES provided by UGS in the city.

4. Discussion

With an objective to curate and validate a methodology that navigates urban environmental justice across an entire city, this study illuminates and juxtaposes the disparate distribution of green cover, access, and quality across the expansive city of Rome. By pinpointing specific municipalities and individual UGS where particular interventions are imperative to ensure broader and more equal access to various CES, the methodology demonstrates its efficacy in proffering actionable insights for strategic intervention and adept urban and environmental planning. Specifically, the methodology employs three intersecting axes of analysis—green availability (or cover), accessibility, and quality—enabling a thorough and integrated approach to green accountability on an urban scale.

This approach not only identifies but also hones in on areas that exhibit deficiencies in availability, accessibility, or quality, both at the municipality level and, regarding quality, at the individual park level. Consequently, urban administrators can delve deeper into the analysis of these deprived areas, scrutinizing the reasons behind suboptimal quality and, when necessary, instigating initiatives to enhance it. Moreover, by isolating areas via these three parameters, the urban administration is equipped with the insight to discern which type of intervention is crucial: for example, certain municipalities may boast high availability yet grapple with low accessibility, hence the intervention would be aimed at augmenting the latter. Conversely, in locales where green space quantity is meagre but the quality is paramount, the intervention would naturally veer towards amplifying the number and extent of parks. This multi-faceted, analytical approach guides the prioritization of urban interventions, ensuring that they are not only relevant but also resonate with the specific needs and deficiencies of the identified areas, thereby fostering a more equal urban green framework.

4.1. Green availability

Being the greenest municipality among the biggest in Italy (Comune di Roma Dipartimento Digitale U.O Statistica, 2016), Rome potentially

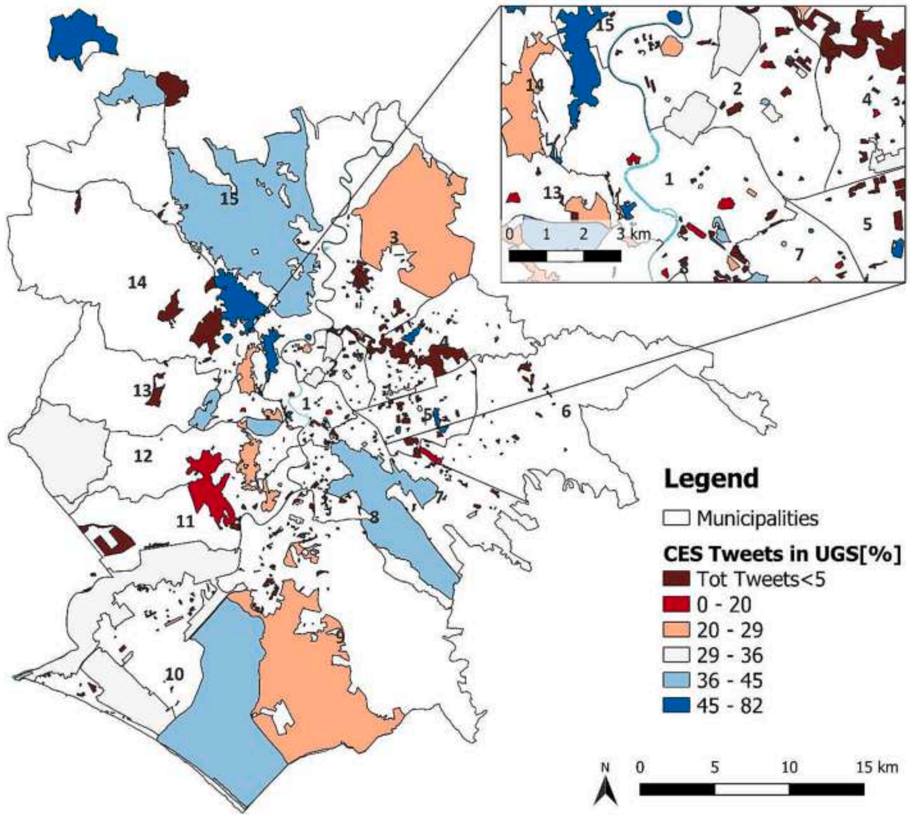

Fig. 4. Percentage of Tweets related to CES in the UGS out of the total number of Tweets, using a colour ramp ranging from red to blue to improve readability for individuals with colour blindness. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

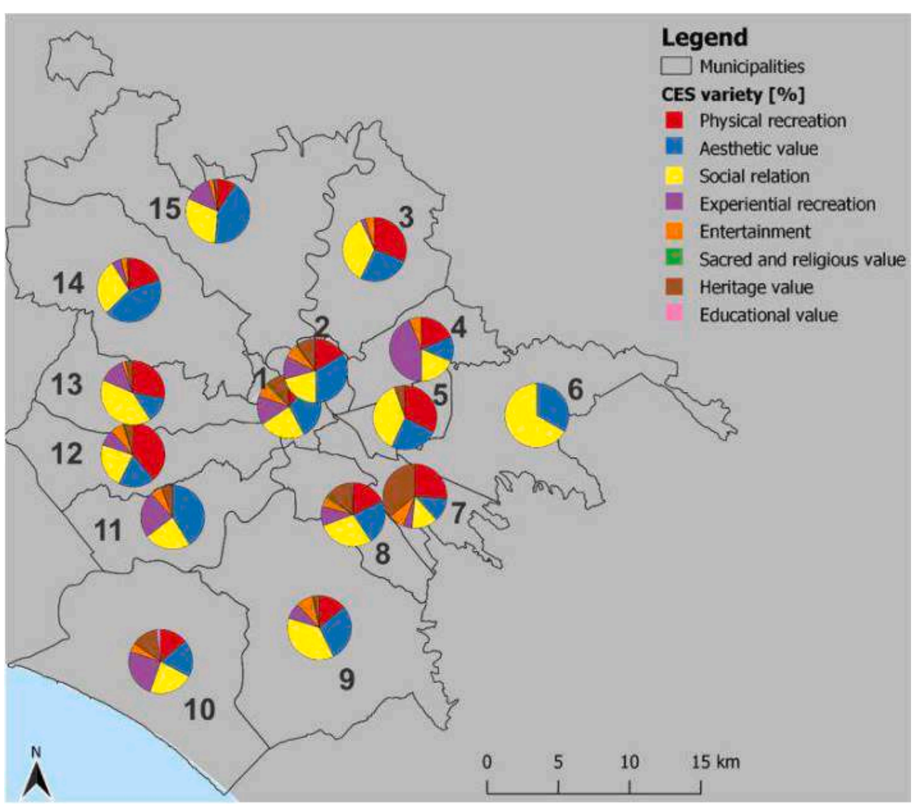

Fig. 5. variety of CES in each municipality.

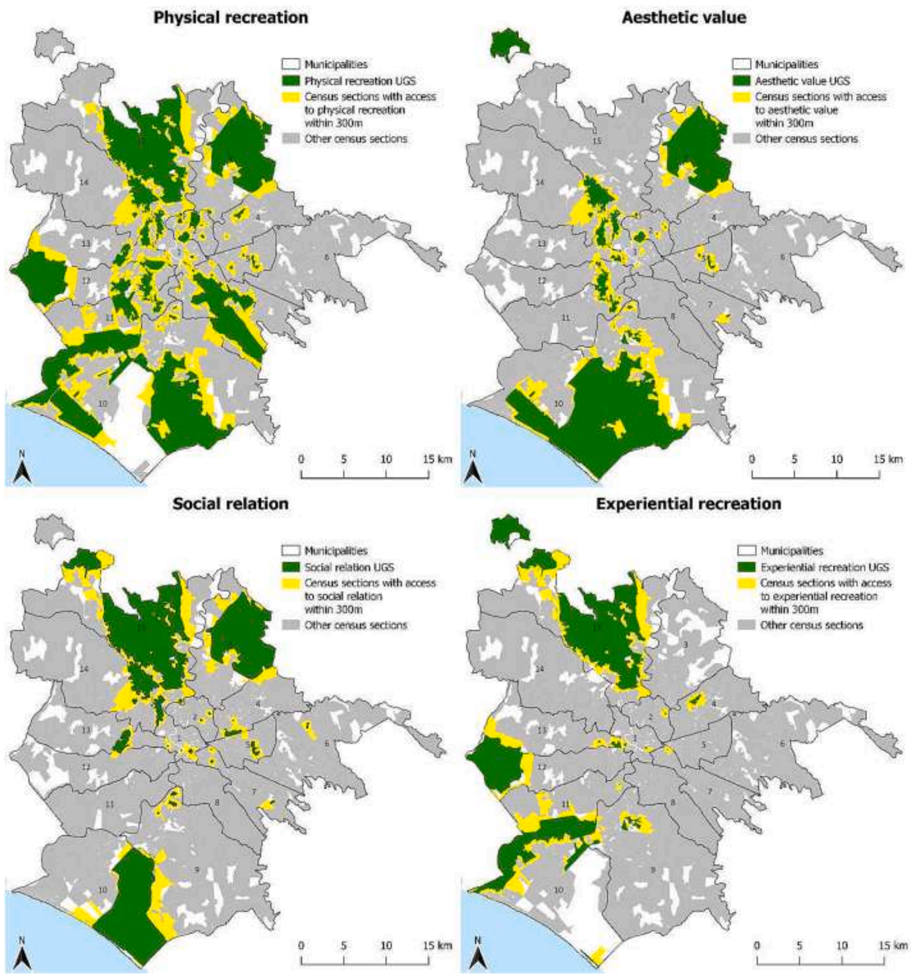

Fig. 6. distribution of the UGS where the four considered CES are detected and census tracts where people have access to them.

provides access to an average of 14.4 sqm per inhabitant, which is consistently higher than the standard of 9.5 sqm/in as set by law (Rome Municipality 2008). However, as evident from our results (see Fig. 7), the availability of green is unevenly distributed across the city. City-scale metrics neglect the relevance of multiple subjective, situated and temporary everyday tactics of experiences within the city, as called by feminist and queer scholarship (Beebeejaun 2017). Similarly, these metrics underestimate the importance of actual social-ecological interactions in the uptake of ecosystem benefits, especially for cultural services, which cannot be supplied by distant ecosystems as in the case of provisioning or regulating services (Calderón-Argelich et al., 2021). Therefore, by overlooking questions of accessibility along social dimensions and the different factors for UGS attractiveness, and the presence of the possible physical and psychological barriers activating therein (Biernacka and Kronenberg, 2019), wide-scale metrics provide a broad but insufficient picture to inform decision-making over UGS distributional justice.

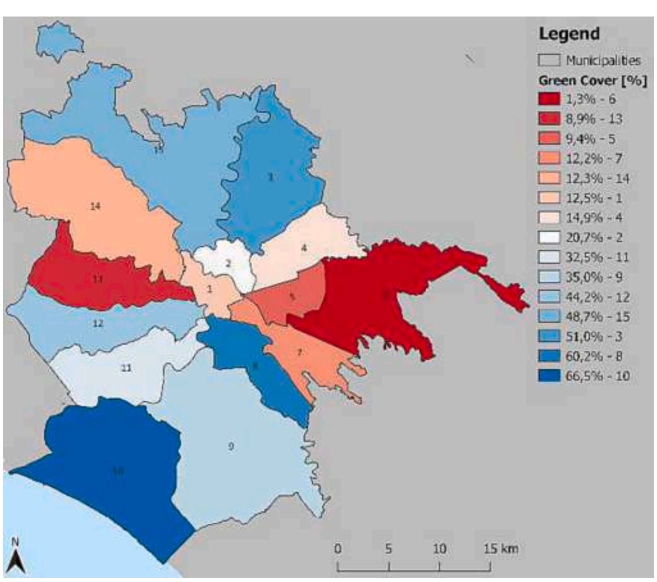

Fig. 7. Availability: land cover percentage of UGS in each municipality.

4.2. Green accessibility

When comparing maps on UGS availability and access (Figs. 7 and 8 respectively), we can see that while some municipalities rank comparably for both indicators, others display very different information. The results highlight significant disparities in the accessibility of UGS in different areas of Rome, with the 6th municipality emerging as a priority intervention area due to its significantly lower access to UGS compared to other municipalities, worsened by being the most economically fragile one[3]. This correlation is not coincidental, as distributional environmental injustices have been found to perpetuate existing

[3] https://www.comune.roma.it/web-resources/cms/documents/Ben_econ_2018_Municipi_rev.pdf.

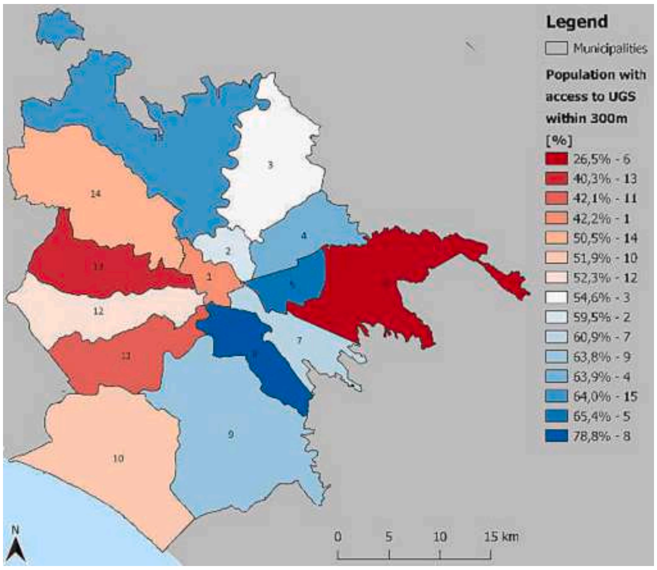

Fig. 8. Accessibility: percentage of people living within 300 m from UGS in each municipality.

inequalities and exacerbate health disparities.

As a result, individuals living in economically vulnerable conditions in underserved areas of the city (e.g., in terms of ecosystem services), may lack the resources to access other outdoor recreation or leisure opportunities, thereby missing out on the corresponding benefits.

Differently from the 6th municipality, where low availability is exacerbated by low accessibility, the 5th municipality (and, to a lower extent, the 4th, the 7th, and the 2nd) is characterised by a relatively high accessibility despite being covered by a relatively low percentage of green areas over the total municipal area. This might be due to a higher population density in inner city areas, as seen in other studies (Kabisch and Haase, 2014). With regards to the 10th municipality (and the 11th and 12th to a lower extent), instead, we can see the opposite relationship between the two indicators, with high availability contrasted by low accessibility. This might be due to the lower population density of the peripheries, but could also be explained by a sparser road network in the surrounding of the UGS.

When analysing socio-demographics determinants of accessibility, we found age and origin to play a significant role. The older population having more close access to UGS than the youth may be explained by the fact that houses close to parks have higher – and, over years, likely increasing – prices and that we might assist to a phenomenon of green gentrification (Anguelovski et al., 2022) with an additional component of age, displacing the youngest away from the areas close to the parks. This assumption would be in general in line with the findings from Lelo at al.[4] for Rome, who found that the youngest population groups live in peripheries while oldest people live in the city centre, where house prices are higher. Results related to place of origin, with Africans being the smaller community with access to UGS within 300 m, confirm previous findings and the need for a continued endeavour towards urban environmental justice (Kabisch and Haase, 2014). Given the categorization based on continents of origin used in our analyses, it's pivotal to recognize that, while providing an initial glance into disparities among various demographic segments, there are substantial limitations due to data aggregation. Our data availability was bound to continent-level demographic details, thereby potentially masking insightful variations that may exist between specific nationalities or more intricate population sub-groups within a continent. Thus, our findings, while offering a broad overview and acting as a starting point for assessing spatial disparities in UGS access, ought to be interpreted with caution due to this limitation. Future research, granted it is enabled by more granular demographic data, should strive to dissect these disparities at a more intricate level, consequently uncovering more nuanced insights into UGS accessibility among different population groups within the city.

In conclusion, using green cover as the sole indicator for UGS representation is highly limiting, and insufficient in informing urban public administrations about the state of parks and any necessary interventions. Urban planning should prioritize improving access to existing green spaces or creating new accessible ones in order to promote equal and equitable access and improve overall community health and well-being.

4.3. *Green quality*

The map in Fig. 9 is instrumental to identifying areas with lower CES provision, enabling targeted interventions to further improve environmental equality in the city. Additionally, accounting for CES diversity (Fig. 5) means acknowledging the variety of individuals' preferences and interests. Therefore, we assume that parks with a higher variety of CES are likely to attract a more diverse range of visitors, thereby enhancing their overall contribution to environmental justice in the city. By representing these data graphically, we could not only observe the percentage of CES benefitting UGS in each municipality, but also the variety of CES. This proxy for the quality of UGS provided a more holistic understanding of the distribution of environmental equality. High quality scores in the parks within the 1st, 2nd and 8th municipalities can be attributed to the higher level of attention from urban administrations towards managing and maintaining central and more touristic parks. Likewise, low quality in the 6th municipality aligns with the actual state of UGS therein, which are known to be neglected and poorly maintained. The situation has been a cause for concern for the very active civic associations present in the area for several years, whose struggle has even deserved coverage in local news[5]. In addition, physical access to UGS is not always equal to access to ES (Biernacka & Kronenberg, 2019). This is evident from the maps showing accessibility to the different CES (see Fig. 6), which highlight how, within the same municipality, some residents have access to higher quality parks compared to others. By combining CES assessment with the accessibility analysis, we were able to identify the areas in the city where people have access to the CES that are considered most important for human health and where they do not. This information is crucial in understanding the distribution of physical and health benefits from UGS in the city. Our findings reveal patterns of environmental inequality, which can inform policies aimed at improving access to CES and promoting health equality in urban areas. The employed methodology, indeed, highlights environmental inequalities both between single parks and entire municipalities areas. Moreover, it shows the accessibility to the four most significant CES for improving both mental and physical health, identifying where people have access to those benefits and where they do not, and providing insight for urban planning intervention.

It is, thus, important to consider both the municipality map and the map of individual parks to gain a complete understanding of the distribution of CES within the city. This comprehensive approach is vital for effective urban planning that aims to promote environmental equality.

[4] https://www.mapparoma.info/mappe/mapparoma5-anziani-in-centro-i-giovani-fuori-raccordo/.

[5] https://www.romatoday.it/zone/torri/torre-maura/parchi-giungla-municipio-vi.html; https://roma.repubblica.it/cronaca/2022/06/14/news/torbellamonaca_rifiuti_degrado_aree_verdi-353902728/.

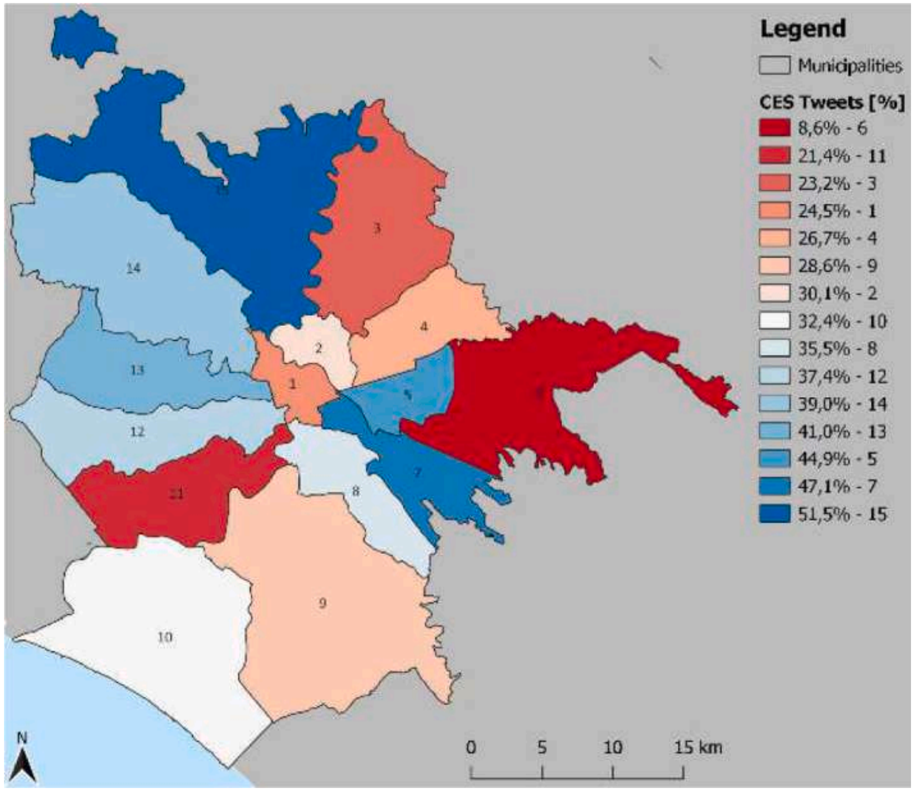

Fig. 9. Quality: average percentage of tweets related to CES out of total tweets in the UGS of each municipality, indicating the mean quality of UGS in each area.

4.4. Potential and limitations

The results of this study demonstrate the potential of using SMD, specifically Twitter, to assess the perception of CES of UGS and to represent them spatially. The use of semantic analysis of tweet text allowed for the identification of specific CES and the evaluation of the distribution of their benefit within different areas of the city, allowing to identify distributional inequality patterns and critical areas for urban intervention. One of the key potentials of using SMD to assess the perception of CES of public parks is the cost and resource efficiency it provides compared to traditional methods such as surveys and questionnaires. These traditional methods can be time-consuming and expensive to administer, often requiring significant resources and personnel to carry out. In contrast, SMD analysis offers a more efficient and cost-effective approach to gathering extensive amounts of data on public perceptions of green urban spaces. In particular, the approach used in this study provides a semi-automatic tool for urban administration, allowing decision-makers to quickly and easily assess the perception of CES of public parks. By using semantic analysis of tweets, this approach is able to provide insights into public perceptions without the need for manual data entry or analysis. Furthermore, the use of SMD provides a real-time and up-to-date view of public perceptions of CES, allowing decision-makers to respond quickly to changes in public sentiment. This is especially important in rapidly changing urban environments where the perception of public spaces can shift quickly in response to environmental, social, and economic factors. Overall, the use of SMD offers significant potential benefits for the assessment of CES in green spaces, providing a cost-effective and efficient means of collecting and analysing large amounts of data on public perceptions.

However, there are several limitations to using SMD that must be considered. One of the main limitations is the potential for bias in the data, as social media users may not be representative of the population, and may not reflect the opinions of those who do not use social media, such as children and elderly people. Additionally, the demographic characteristics of social media users may differ from those of the general population, leading to potential biases in the results. It is also important to note that we do not know who the people who are tweeting are, and they could be mostly tourists, which could bias our results in ways we cannot predict. It is also noteworthy that the use of SMD might lack essential contextual information about the green spaces and their history, which is often crucial in environmental justice research. Understanding a green space's historical, social, and political context is pivotal to identify past injustices, discriminatory practices, or an unequal distribution of environmental resources. Therefore, future research endeavours might be more robust and insightful if the analyses of perceptions and qualities of UGS gained through SMD are complemented by an understanding of the historical and socio-political context of the green spaces being analysed.

As a next step, future research could provide a more nuanced analysis by differentiating the CES identified in the tweets based on whether the user is a local or a tourist. Previous studies have done this by looking at the information provided by the users in their profile description or by applying some techniques to infer the home location of the visitors (Sinclair et al., 2020). Another limitation is that some CES are more easily detectable than others. For instance, symbolic value, scientific value, existence value, and bequest value were not detected through our analysis. Compared to other CES, such as physical recreation or aesthetic value, these are characterized by a much more intangible nature, and are very difficult to express and consequently detect through a post on social media. However, recent progress in AI suggests that future research could improve the identification of CES beyond the current lexicographic approach (i.e., searching for specific keywords) that was implemented in this study (Mouttaki et al., 2022). While usually the automatic classifications largely rely on and reproduces the biases produced with the subjective interpretation of the manual assessment phase, in this study we implemented a procedure intended to increase the consistency and replicability of the analysis (Calcagni et al. forthcoming). CES analysis using SMD can be used to identify the most critical parks for CES based on the quality of the parks by the public on the scale of the urban context. This information can then be used to prioritize the allocation of resources and planning interventions for parks that are most in need of improvement. However, it is important to note that this method should not be solely relied on: indeed, in-depth analyses might well combine this perspective with orthodox quality assessments to present a more comprehensive view of UGS quality and its varied facets, ensuring a well-rounded approach to understanding and improving UGS. Future studies could incorporate multiple data sources, such as traditional surveys or in-person observations, to gain a more in-depth understanding of the perceptions of the CES services, particularly on the most critical and despaired areas, to both assess the reasons of the low perceived quality and deepen the understanding of the perception of citizens of the considered green areas. Additionally, the development of more advanced natural language processing techniques could improve the accuracy and efficiency of semantic analysis of SMD. In conclusion, this study demonstrates the potential of using SMD to assess the perception of CES in public parks. While there are limitations to using SMD, the accessibility, speed, and diverse perspectives it provides make it a valuable tool for understanding public perception and informing urban planning and management decisions.

5. Conclusion

This study introduces an innovative approach to estimate the quality of UGS, namely the perceived CES, by leveraging semantic analysis of SMD across an entire city. Twitter's abundant text-based data was the ideal candidate for semantic analysis due to its vast amount of information. In addition, the geotagged nature of the data enabled us to perform assessments of environmental equality and identify instances of environmental inequality in accessibility to quality UGS across the city, underscoring significant implications for urban planning. This highlights the need for policies that address disparities in access to green spaces and their associated CES. However, it is important to note that social media-based assessments of CES are biased by the representativeness of users' profiles and interpretation of the data, and tend to underestimate some CES which are less detectable through SMD, such as symbolic or bequest value. While we minimized these biases through a standardized approach, these limitations grow as the study area's size increase, such as with single UGS: wherever possible, this method should be complemented by qualitative approaches for the detection of people's perceptions of CES, such as interviews or questionnaires. The paper highlights the importance of considering both the quality and accessibility of UGS in urban planning, promoting a holistic approach that acknowledges the CES they provide to the urban community. Our study responds to the call for representation of the benefits that people derive from UGS through a time- and resource-convenient method, uncovering environmental inequality. Through a spatially and demographic explicit analysis we provide a replicable tool for equal and equitable urban planning.

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

I have shared the link to my data and codes within the article

Acknowledgments

F.C., A.G., and J.L. acknowledge funding by the German-Israeli Foundation for Scientific Research and Development (#I- 1533-500.15/2021). G.B. would like to extend her heartfelt gratitude to ICTA-UAB for their generous support and hospitality during her research project, special thanks go to Isabelle Anguelovski for facilitating her visiting period. We would also like to express our sincere appreciation to the BCNUEJ research group for their enriching discussions throughout the course of this research. This work contributes to ICTA-UAB "María de Maeztu" Programme for Units of Excellence of the Spanish Ministry of Science and Innovation (CEX2019-000940-M); it has been supported by the Laboratory for the Analysis of Social-Ecological Systems in a Globalized World (LASEG, 2021-SGR-00182).

Appendix

Dictionary resulted from the semantic analysis

The dictionary that resulted from the application of the protocol to the text of the posts from twitter is here presented. Since the classification was run in python, some keywords are cut in order to capture a broader number of terms. For instance, the keyword 'cycl', used for the CES of physical recreation, capture all the words with other possible suffixes, such as 'cycling', 'cycle', 'cycled', etc. This operation was applied especially for verbs, in order to not miss all possible conjugation of the same word. The dictionary is presented in a way that can be copied and pasted in a python environment, in order to allow for easy replicability. The definition of the criteria for choosing each word, through the iterative inter-coders agreement protocol, depends on the definition of each CES given within the protocol (Calcagni et al., forthcoming). It also depends on the specific words that were found in the text of the posts, as explained in the section dedicated to the sematic analysis.

CulturalEcosystemServices = {.

'PhysicalRecreation': ['run','race','corsa','fit', 'bike', 'cycl', 'bycicle','bici', 'hike', 'hiking', 'walk','cammin', 'passegg', 'tennis', 'basket', 'yoga', 'trofeo', 'gare', 'dance', 'endomondo', 'bodybuilding', 'cardio', 'train', 'workout', 'allena', 'samba', 'esercizio', 'canoa'],

'Experientialrecreation': ['pace', 'peace', 'magia', 'magic', 'spettacol', 'tranquil', 'enjoy', 'vacanze', 'adventure', 'roam', 'riscopr', 'atmosphere', 'umore', 'explor', 'dream', 'emozion', 'relax', 'sundayvibe', 'goingaround', 'visit', 'ortiurbani', 'orto'],

'Scientific': ['research', 'science'],

'Heritage': ['nostalgi', 'roman', 'memorial', 'remember', 'tradizion', 'history', 'cultur'],

'Aesthetic': ['stunning', 'bell', 'hermoso', 'art', 'beaut', 'magnific', 'panoram', 'maravill', 'landscape', 'pretty', 'beleza', 'meravigl', 'scorci', 'paesagg', 'view'],

'Socialrelation': ['party', 'festa', 'famiglia', 'people', 'wedding', 'matrimonio', 'mamma', 'papà', 'togther', 'insieme', 'gente', 'birthday', 'family', 'mom', 'mother', 'friend', 'love', 'partner', 'tiamo', 'amic', 'boyfriend', 'children', 'bambin', 'daddy', 'couple'],

'Sacred': ['sacr', 'meditazione', 'meditation'],

'Entertainment': ['photography', 'portrait', 'micro', 'macro', 'photoshop', 'gopro', 'nikon', 'canon', 'fotograf', 'blackandwhite', 'photojournalism', 'scattare', 'nikon', 'canon', '14 mm', 'closeup', 'instadaily', 'fotografia', 'fujifilm', 'blackandwhite', 'lumia', 'illustration', 'drawing'],}.

Examples of Tweets that were classified as revealing the benefit of specific CES.

Here is reported, for exemplification, the text of some tweets that have been classified like one or more CES. Note that the special character is just a by-product of the download process and should not be considered.

Text	CES
So upset that I'm leaving this beautiful city tomorrow Ã°Å¸ËœÂ¬ Italia IÃ¢â‚¬Â¦ https://t.co/Lc3yrhJ2eW	Aesthetic
Pausa pranzo con 'sta pace qua. #rome #roma #eur #lago #laghetto #lunch #break #job #office @Ã¢â‚¬Â¦ https://t.co/kFD6FeD6cd	ExperientialRecreation
Happy birthday Mamy Ã¢ÂÂ ¤ #birthday #selfie #family #mamy #mom #happy #party #love @ Caio funkyÃ¢â‚¬Â¦ https://t.co/NJyQuDMwfZ	SocialRelation
Passeggiata invernale nella Valle della Caffarella nel bellissimo scatto di maurozanecchiaÃ¢â‚¬Â¦ https://t.co/5LJ7BiY7io	PhysicalRecreation
Ti devo un ritorno. #tb #nostalgia #quantoseibellaroma #bigcity @ Terrazza del Pincio https://t.co/UlANZIwrct	Heritage, Aesthetic
#trentundicembre #WeRunRome #werunrome2016 #10 km #termedicaracalla #circomassimo #piazzaveneziaÃ¢â‚¬Â¦ https://t.co/tgxqaDdBZk	PhysicalRecreation
Would you even believe this is in Rome? So peaceful and beautiful. I went with my mother, sisterÃ¢â‚¬Â¦ https://t.co/rQ2iy1689m	ExperientialRecreation, Aesthetic, Socialrelation
Troppa bellezza a #villaborghese #Roma #igersroma #tree #colors #1gennaio #welcome2017 #2017 @Ã¢â‚¬Â¦ https://t.co/9PvjfvbLPR	Aesthetic
Chi si allena a capodanno… #training #workout #keepstrong #Capodanno #buonanno bye2016Ã¢â‚¬Â¦ https://t.co/dUcvhgzVU1	RhysicalRecreation
// r h o m e // #rhome #beautiful #magicplace #endoftheyear #city #terrazzadelpincio #sunsetÃ¢â‚¬Â¦ https://t.co/ZJ4AfJPZRi	ExperientialRecreation, Aesthetic
Running with sheeps. #caffarella #rome @ Parco della Caffarella https://t.co/Yagi1ySaTc	PhysicalRecreation
A Villa with a #view #Roma #igersroma #noidiroma #Rome @ Villa Sciarra https://t.co/CNIy8jfFJl	Aesthetic
Preparing a long run #streetphotography #sportphotography #running #arewerunningtodayÃ¢â‚¬Â¦ https://t.co/Q4IcAHk2N6	PhysicalRecreation
Buongiorno (spero) #namaste #asana #yogainspiration #instayoga #meditationÃ¢â‚¬Â¦ https://t.co/vrgajrNHjA	PhysicalRecreation, Sacred
Oggi visita guidata alla tomba di Cecilia Metella. Se volete visitare il parco dell'Appia miÃ¢â‚¬Â¦ https://t.co/McqJ3Geabz	ExperientialRecreation, Educational
In diretta #visitaguidata con attivitÃƒÂ #didattica per #bambini alla #casinadellecivette @ casinaÃ¢â‚¬Â¦ https://t.co/0H8rExGZDb	ExperientialRecreation, Educational, SocialRelation
Il piccolo #gladiatore pronto per la battaglia #visitaguidata #roma #bambini #ciceroinrome @ ViaÃ¢â‚¬Â¦ https://t.co/s0aQgoGCFc	ExperientialRecreation, Educational, SocialRelation
In diretta #visitaguidata per #bambini a #ostiaantica #roma #cultura @ Ostia Antica (district) https://t.co/KRUbI7R9bE	ExperientialRecreation, Educational, Heritage, Socialrelation
Rome by night Ã°Å¸â€™â€°Ã¢ÂÂ¤Ã¯Â¸ÂÃ¢Å“Â¨ #roma #igersroma #night #photography #rome #landscape #city #eternalcityÃ¢â‚¬Â¦ https://t.co/SxrHbR77zz	Aesthetic, Entertainment
#nofilter #picoftheday #fujinonxc1650mm #xc1650 #fujifilmxm1 #xm1 #fujifilm #fujinonÃ¢â‚¬Â¦ https://t.co/K4UmVPgAYo	Entertainment
Great walk after the storm this morning at #acquedottiromani Park I'm amazed about thisÃ¢â‚¬Â¦ https://t.co/0lH1ACZtOn	PhysicalRecreation, Heritage
#fujifilmxm1 #longexposure #fujinon #xc1650 #xm1 #fujifilm #parcodegliacquedotti #igersromaÃ¢â‚¬Â¦ https://t.co/GCMckXtYUb	Entertainment
Da un altro punto di vista di villa Pamphili #corsa #roma #villapamphili #scorci #nofilter @Ã¢â‚¬Â¦ https://t.co/Jn0blrWe5x	PhysicalRecreation, Aesthetic
I just finished running 12.04 km in 1 h:02 m:29 s with #Endomondo #endorphins https://t.co/wKSTUwJry3	PhysicalRecreation
Enjoying the dolce vita in Roma with amazing women Ã°Å¸ËœÅ½ I'm grateful to have so many great friendsÃ¢â‚¬Â¦ https://t.co/ueEvJnkpeD	ExperientialRecreation, SocialRelation

References

Agay-Shay, K., Peled, A., Crespo, A.V., Peretz, C., Amitai, Y., Linn, S., Friger, M., Nieuwenhuijsen, M.J., 2014. Green spaces and adverse pregnancy outcomes. Occup. Environ. Med. 71 (8), 562–569. https://doi.org/10.1136/oemed-2013-101961.

Andersson, E., Tengö, M., McPhearson, T., Kremer, P., 2015. Cultural ecosystem services as a gateway for improving urban sustainability. Ecosyst. Serv. 12, 165–168. https://doi.org/10.1016/j.ecoser.2014.08.002.

Anguelovski, I., Brand, A.L., Connolly, J.J.T., Corbera, E., Kotsila, P., Steil, J., Garcia-Lamarca, M., Triguero-Mas, M., Cole, H., Baró, F., Langemeyer, J., del Pulgar, C.P., Shokry, G., Sekulova, F., Argüelles Ramos, L., 2020. Expanding the Boundaries of Justice in Urban Greening Scholarship: Toward an Emancipatory, Antisubordination, Intersectional, and Relational Approach. Ann. Am. Assoc. Geogr. 110 (6), 1743–1769. https://doi.org/10.1080/24694452.2020.1740579.

Anguelovski, I., Connolly, J.J.T., Cole, H., Garcia-Lamarca, M., Triguero-Mas, M., Baró, F., Martin, N., Conesa, D., Shokry, G., del Pulgar, C.P., Ramos, L.A., Matheney, A., Gallez, E., Oscilowicz, E., Máñez, J.L., Sarzo, B., Beltrán, M.A., Minaya, J.M., 2022. Green gentrification in European and North American cities. *Nature*. Communications 13 (1). https://doi.org/10.1038/s41467-022-31572-1.

Barton, J., Rogerson, M., 2017. The importance of greenspace for mental health. BJPsych. International 14 (4). https://doi.org/10.1192/s2056474000002051.

Batista e Silva, F., Lavalle, C., & Koomen, E. (2013). A procedure to obtain a refined European land use/cover map. Journal of Land Use Science, 8(3). https://doi.org/10.1080/1747423X.2012.667450.

Berrini M., Bono L., Ferrari G., Tarzia V., & Merola M. (2003). European Common Indicators - Towards a local sustainability profile (Final Project Report) Ambiente Italia, Milano, Italy (2003).

Biernacka, M., Kronenberg, J., 2019. Urban Green Space Availability, Accessibility and Attractiveness, and the Delivery of Ecosystem Services. Cities and the Environment (CATE) 12 (1). https://digitalcommons.lmu.edu/cate/vol12/iss1/5.

Bovy, P.H., 1974. Le rôle du piéton dans les transports urbains. Bulletin Technique De La Suisse Romande 100 (6), 116–126. http://retro.seals.ch/digbib/view?pid=bts-002:1974:100::638.

Bowler, D.E., Buyung-Ali, L.M., Knight, T.M., Pullin, A.S., 2010. A systematic review of evidence for the added benefits to health of exposure to natural environments. BMC Public Health 10 (1), 1–10. https://doi.org/10.1186/1471-2458-10-456/TABLES/1.

Braçe, O., Garrido-Cumbrera, M., Correa-Fernández, J., 2021. Gender differences in the perceptions of green spaces characteristics. Soc. Sci. Q. 102 (6) https://doi.org/10.1111/ssqu.1307.

Braubach, M., Egorov, A., Mudu, P., Wolf, T., Ward Thompson, C., & Martuzzi, M. (2017). Effects of Urban Green Space on Environmental Health, Equity and Resilience (pp. 187–205). https://doi.org/10.1007/978-3-319-56091-5_11.

Calderón-Argelich, A., Benetti, S., Anguelovski, I., Connolly, J.J.T., Langemeyer, J., Baró, F., 2021. Tracing and building up environmental justice considerations in the urban ecosystem service literature: A systematic review. Landsc. Urban Plan. 214 https://doi.org/10.1016/J.LANDURBPLAN.2021.104130.

Carrus, G., Scopelliti, M., Lafortezza, R., Colangelo, G., Ferrini, F., Salbitano, F., Agrimi, M., Portoghesi, L., Semenzato, P., Sanesi, G., 2015. Go greener, feel better? The positive effects of biodiversity on the well-being of individuals visiting urban and peri-urban green areas. Landsc. Urban Plan. 134, 221–228. https://doi.org/10.1016/j.landurbplan.2014.10.022.

Chênes, C., Giuliani, G., Ray, N., 2021. Modelling Physical Accessibility to Public Green Spaces in Switzerland to Support the SDG11. Geomatics 1 (4), 383–398. https://doi.org/10.3390/geomatics1040022.

Comber, A., Brunsdon, C., Green, E., 2008. Using a GIS-based network analysis to determine urban greenspace accessibility for different ethnic and religious groups. Landsc. Urban Plan. 86 (1), 103–114. https://doi.org/10.1016/j.landurbplan.2008.01.002.

Cook, K.S., Hegtvedt, K.A., 1983. Distributive Justice, Equity, and Equality. Annu. Rev. Sociol. 9 (1) https://doi.org/10.1146/annurev.so.09.080183.001245.

Coombes, E., Jones, A.P., Hillsdon, M., 2010. The relationship of physical activity and overweight to objectively measured green space accessibility and use. Soc Sci Med 70 (6), 816–822. https://doi.org/10.1016/j.socscimed.2009.11.020.

Copenhagen: World Health Organization Regional Office for Europe. (2016). Urban green spaces and health.

Coutts, C., Hahn, M., 2015. Green infrastructure, ecosystem services, and human health. In. Int. J. Environ. Res. Public Health Vol. 12, Issue 8. https://doi.org/10.3390/ijerph120809768.

Dadvand, P., Nieuwenhuijsen, M.J., Esnaola, M., Forns, J., Basagaña, X., Alvarez-Pedrerol, M., Rivas, I., López-Vicente, M., De Pascual, M.C., Su, J., Jerrett, M., Querol, X., Sunyer, J., 2015. Green spaces and cognitive development in primary schoolchildren. PNAS 112 (26), 7937–7942. https://doi.org/10.1073/pnas.1503402112.

Dai, P., Zhang, S., Hou, H., Yang, Y., Liu, R., 2019. Valuing sports services in urban parks: A new model based on social network data. Ecosyst. Serv. 36 https://doi.org/10.1016/j.ecoser.2019.01.003.

Daniel, T. C., Muhar, A., Arnberger, A., Aznar, O., Boyd, J. W., Chan, K. M. A., Costanza, R., Elmqvist, T., Flint, C. G., Gobster, P. H., Grêt-Regamey, A., Lave, R., Muhar, S., Penker, M., Ribe, R. G., Schauppenlehner, T., Sikor, T., Soloviy, I., Spierenburg, M., Von Der Dunk, A. (2012). Contributions of cultural services to the ecosystem services agenda. In Proceedings of the National Academy of Sciences of the United States of America (Vol. 109, Issue 23, pp. 8812–8819). https://doi.org/10.1073/pnas.1114773109.

Delgado, R., Tibau, X.A., 2019. Why Cohen's Kappa should be avoided as performance measure in classification. PLoS One 14 (9). https://doi.org/10.1371/journal.pone.0222916.

Comune di Roma Dipartimento Digitale U.O Statistica. (2016). Il Verde Pubblico Di Roma Capitale.

Comune di Roma Dipartimento Digitale U.O Statistica. (2022). La popolazione di Roma, anno 2021.

Edge, S., Davis, C., Dean, J., Onilude, Y., Rishworth, A., Wilson, K., 2023. The role of urban and rural greenspaces in shaping immigrant wellbeing and settlement in place. Wellbeing, Space and Society 4. https://doi.org/10.1016/j.wss.2023.100127.

Ekkel, E.D., de Vries, S., 2017. Nearby green space and human health: Evaluating accessibility metrics. Landsc. Urban Plan. 157, 214–220. https://doi.org/10.1016/j.landurbplan.2016.06.008.

Enssle, F., Kabisch, N., 2020. Urban green spaces for the social interaction, health and well-being of older people— An integrated view of urban ecosystem services and socio-environmental justice. Environ Sci Policy 109, 36–44. https://doi.org/10.1016/j.envsci.2020.04.008.

Gai, S., Fu, J., Rong, X., Dai, L., 2022. Users' views on cultural ecosystem services of urban parks: An importance-performance analysis of a case in Beijing. China. Anthropocene 37. https://doi.org/10.1016/j.ancene.2022.100323.

Gao, S., Bosman, C., Dupre, K., 2020. Understanding the Well-Being of Older Chinese Immigrants in Relation to Green Spaces: A Gold Coast Study (Australia). Front. Psychol. 11 https://doi.org/10.3389/fpsyg.2020.551213.

Gaston, K.J., Soga, M., 2020. Extinction of experience: The need to be more specific. People and Nature 2 (3), 575–581. https://doi.org/10.1002/pan3.10118.

Gentin, S., Pitkänen, K., Chondromatidou, A. M., Præstholm, S., Dolling, A., & Palsdottir, A. M. (2019). Nature-based integration of immigrants in Europe: A review. In *Urban Forestry and Urban Greening* (Vol. 43). https://doi.org/10.1016/j.ufug.2019.126379.

Ghermandi, A., Langemeyer, J., Van Berkel, D., Calcagni, F., Depietri, Y., Sinclair, M., Venohr, M., Wood, S.A., 2023. Social media data for environmental sustainability: A critical review of opportunities, threats, and ethical use. One Earth 6, 236–250. https://doi.org/10.1016/j.oneear.2023.02.008.

Grahn, P., & Stigsdotter, U. A. (2003). Landscape planning and stress. Urban Forestry & Urban Greening, 2(1), 1–18. https://doi.org /10.1078/1618-8667-00019.

Grazuleviciene, R., Dedele, A., Danileviciute, A., Vencloviene, J., Grazulevicius, T., Andrusaityte, S., Uzdanaviciute, I., Nieuwenhuijsen, M.J., 2014. The influence of proximity to city parks on blood pressure in early pregnancy. Int. J. Environ. Res. Public Health 11 (3), 2958–2972. https://doi.org/10.3390/ijerph110302958.

Haines-Young, R., Potschin-Young, M.B., 2018. Revision of the common international classification for ecosystem services (CICES V5.1): A policy brief. One Ecosystem 3. https://doi.org/10.3897/oneeco.3.e27108.

Hamstead, Z.A., Fisher, D., Ilieva, R.T., Wood, S.A., McPhearson, T., Kremer, P., 2018. Geolocated social media as a rapid indicator of park visitation and equitable park access. Comput. Environ. Urban Syst. 72 https://doi.org/10.1016/j.compenvurbsys.2018.01.007.

Handley, J., Pauleit, S., Slinn, P., Lindley, S., a, M. B., Barber, L., & Jones, C. (2003). Providing accessible natural greenspace in towns and cities: a practical guide to assessing the resource and implementing local standards for provision. Report to Natural England, 1–36. http://publications.naturalengland.org.uk/file/78003.

Havinga, I., Bogaart, P.W., Hein, L., Tuia, D., 2020. Defining and spatially modelling cultural ecosystem services using crowdsourced data. Ecosyst. Serv. 43 https://doi.org/10.1016/j.ecoser.2020.101091.

Heynen, N., Perkins, H.A., Roy, P., 2006. The political ecology of uneven urban green space: The impact of political economy on race and ethnicity in producing environmental inequality in Milwaukee. Urban Aff. Rev. 42 (1), 3–25. https://doi.org/10.1177/1078087406290729.

Iraegui, E., Augusto, G., Cabral, P., 2020. Assessing equity in the accessibility to urban green spaces according to different functional levels. ISPRS Int. J. Geo Inf. 9 (5) https://doi.org/10.3390/ijgi9050308.

Irvine, K.N., Warber, S.L., Devine-Wright, P., Gaston, K.J., 2013. Understanding urban green space as a health resource: A qualitative comparison of visit motivation and derived effects among park users in sheffield, UK. Int. J. Environ. Res. Public Health 10 (1), 417–442. https://doi.org/10.3390/ijerph10010417.

Jennings, V., Bamkole, O., 2019. The relationship between social cohesion and urban green space: An avenue for health promotion. Int. J. Environ. Res. Public Health 16 (3). https://doi.org/10.3390/ijerph16030452.

Jennings, V., Larson, L., Yun, J., 2016. Advancing sustainability through urban green space: Cultural ecosystem services, equity, and social determinants of health. Int. J. Environ. Res. Public Health 13 (2). https://doi.org/10.3390/ijerph13020196.

Kabisch, N., Haase, D., 2014. Green justice or just green? Provision of urban green spaces in Berlin, Germany. Landsc. Urban Plan. 122, 129–139. https://doi.org/10.1016/j.landurbplan.2013.11.016.

Kaźmierczak, A., 2013. The contribution of local parks to neighbourhood social ties. Landsc. Urban Plan. 109 (1), 31–44. https://doi.org/10.1016/j.landurbplan.2012.05.007.

Kazmierczak, A., James, P., 2007. The role of urban green spaces in improving social inclusion. In Landscape and Urban Planning. https://usir.salford.ac.uk/id/eprint/11339.

Kosanic, A., & Petzold, J. (2020). A systematic review of cultural ecosystem services and human wellbeing. In Ecosystem Services (Vol. 45). Elsevier B.V. https://doi.org/10.1016/j.ecoser.2020.101168.

Langemeyer, J., & Connolly, J. J. T. (2020). Weaving notions of justice into urban ecosystem services research and practice. In Environmental Science and Policy (Vol. 109). https://doi.org/10.1016/j.envsci.2020.03.021.

Langemeyer, J., Calcagni, F., Baró, F., 2018. Mapping the intangible: Using geolocated social media data to examine landscape aesthetics. Land Use Policy 77, 542–552. https://doi.org/10.1016/j.landusepol.2018.05.049.

Langemeyer, J., Ghermandi, A., Keeler, B., & van Berkel, D. (2023). The future of crowd-sourced cultural ecosystem services assessments. In Ecosystem Services (Vol. 60). Elsevier B.V. https://doi.org/10.1016/j.ecoser.2023.101518.

Lelo, K., Monni, S., Tomassi, F., 2019. Le mappe della disuguaglianza: Una geografia sociale metropolitana. Postfazione di Walter Tocci. Saggine (Vol. 323). ISBN: 9788868439880.

Li, D., Sullivan, W.C., 2016. Impact of views to school landscapes on recovery from stress and mental fatigue. Landsc. Urban Plan. 148, 149–158. https://doi.org/10.1016/J.LANDURBPLAN.2015.12.015.

Liu, D., Kwan, M.P., Kan, Z., 2021. Analysis of urban green space accessibility and distribution inequity in the City of Chicago. Urban For. Urban Green. 59 https://doi.org/10.1016/J.UFUG.2021.127029.

Ma, F., 2020. Spatial equity analysis of urban green space based on spatial design network analysis (sDNA): A case study of central Jinan. China. Sustainable Cities and Society 60. https://doi.org/10.1016/j.scs.2020.102256.

Maury-Mora, M., Gómez-Villarino, M.T., Varela-Martínez, C., 2022. Urban green spaces and stress during COVID-19 lockdown: A case study for the city of Madrid. Urban For. Urban Green. 69 https://doi.org/10.1016/j.ufug.2022.127492.

Micek, O., Feranec, J., Stych, P., 2020. Land use/land cover data of the urban atlas and the cadastre of real estate: An evaluation study in the Prague metropolitan region. Land 9 (5). https://doi.org/10.3390/LAND9050153.

Millennium Ecosystem Assessment (Program), 2005. Ecosystems and human well-being : synthesis. Island Press.

Miller, J.R., 2005. Biodiversity conservation and the extinction of experience. Trends Ecol. Evol. 20 (8), 430–434. https://doi.org/10.1016/j.tree.2005.05.013.

Mouttaki, I., Bagdanavičiūtė, I., Maanan, M., Erraiss, M., Rhinane, H., Maanan, M., 2022. Classifying and Mapping Cultural Ecosystem Services Using Artificial Intelligence and Social Media Data. Wetlands 42 (7). https://doi.org/10.1007/S13157-022-01616-9.

Nawrath, M., Elsey, H., Rijal, M.L., Dallimer, M., 2022. Greenspaces and Human Well-Being: Perspectives from a Rapidly Urbanising Low-Income Country. Environments - MDPI 9 (12). https://doi.org/10.3390/environments9120148.

Nowak-Olejnik, A., Schirpke, U., Tappeiner, U., 2022. A systematic review on subjective well-being benefits associated with cultural ecosystem services. Ecosyst. Serv. 57 https://doi.org/10.1016/J.ECOSER.2022.101467.

Ode Sang, Å., Sang, N., Hedblom, M., Sevelin, G., Knez, I., Gunnarsson, B., 2020. Are path choices of people moving through urban green spaces explained by gender and age ? Implications for planning and management. Urban For. Urban Green. 49, 126628 https://doi.org/10.1016/j.ufug.2020.126628.

Pinto, L.V., Ferreira, C.S.S., Inácio, M., Pereira, P., 2022. Urban green spaces accessibility in two European cities: Vilnius (Lithuania) and Coimbra (Portugal). Geography and Sustainability 3 (1), 74–84. https://doi.org/10.1016/j.geosus.2022.03.001.

Reklaitiene, R., Virviciute, D., Tamosiunas, A., Baceviciene, M., Luksiene, D., Sapranaviciute Zabazlajeva, L., Radisauskas, R., Bernotiene, G., Grazuleviciene, R., Dedele, A., Vensloviene, J., Bobak, M., Nieuwenhuijsen, M.J., 2014. The relationship of green space, depressive symptoms and perceived general health in urban population. Scand. J. Public Health 42 (7), 669–676. https://doi.org/10.1177/1403494814544494.

Rigolon, A., 2016. A Complex Landscape of Inequity in Access to Urban Parks: A Literature Review Vol. 153, 160–169. https://doi.org/10.1016/j.landurbplan.2016.05.017.

Schipperijn, J., Ekholm, O., Stigsdotter, U.K., Toftager, M., Bentsen, P., Kamper-Jørgensen, F., Randrup, T.B., 2010. Factors influencing the use of green space: Results from a Danish national representative survey. Landsc. Urban Plan. 95 (3), 130–137. https://doi.org/10.1016/j.landurbplan.2009.12.010.

Silva, C. de S., Viegas, I., Panagopoulos, T., & Bell, S. (2018). Environmental justice in accessibility to green infrastructure in two European Cities. Land, 7(4). https://doi.org/10.3390/land7040134.

Sinclair, M., Mayer, M., Woltering, M., Ghermandi, A., 2020. Using social media to estimate visitor provenance and patterns of recreation in Germany's national parks. J. Environ. Manage. 263 https://doi.org/10.1016/J.JENVMAN.2020.110418.

Slocum, T.A., McMaster, R.B., Kessler, F.C., Howard, H.H., 2008. Thematic cartography and geovisualization : Librairie Lavoisier. In: Prentice Hall Series in Geographic Information Science, p. 576.

Small, N., Munday, M., Durance, I., 2017. The challenge of valuing ecosystem services that have no material benefits. Glob. Environ. Chang. 44 https://doi.org/10.1016/j.gloenvcha.2017.03.005.

Sotoudehnia, F., Comber, L., 2011. Measuring Perceived Accessibility to Urban Green Space: An Integration of GIS and Participatory Map. The 14th AGILE International Conference on Geographic Information Science.

Stigsdotter, U.K., Randrup, T.B., Ekholm, O., Schipperijn, J., Toftager, M., Kamper-Jørgensen, F., 2010. Health promoting outdoor environments - Associations between green space, and health, health-related quality of life and stress based on a Danish national representative survey. Scand. J. Public Health 38 (4), 411–417. https://doi.org/10.1177/1403494810367468.

Strife, S., Downey, L., 2009. Childhood development and access to nature: A new direction for environmental inequality research. Organ. Environ. 22 (1), 99–122. https://doi.org/10.1177/1086026609333340.

Sugiyama, T., Cerin, E., Owen, N., Oyeyemi, A.L., Conway, T.L., van Dyck, D., Schipperijn, J., Macfarlane, D.J., Salvo, D., Reis, R.S., Mitáš, J., Sarmiento, O.L., Davey, R., Schofield, G., Orzanco-Garralda, R., Sallis, J.F., 2014. Perceived neighbourhood environmental attributes associated with adults[U+05F3] recreational walking: IPEN Adult study in 12 countries. Health Place 28, 22–30. https://doi.org/10.1016/j.healthplace.2014.03.003.

Szatmári, D., Kopecká, M., Feranec, J., 2019. Verification and qualitative evaluation of the Urban Atlas layers in Slovakia. Kartograficke Listy 27 (1).

Teles da Mota, V., Pickering, C., 2020. Using social media to assess nature-based tourism: Current research and future trends. J. Outdoor Recreat. Tour. 30 https://doi.org/10.1016/j.jort.2020.100295.

Triguero-Mas, M., Dadvand, P., Cirach, M., Martínez, D., Medina, A., Mompart, A., Basagaña, X., Gražulevičiene, R., Nieuwenhuijsen, M.J., 2015. Natural outdoor environments and mental and physical health: Relationships and mechanisms. Environ. Int. 77, 35–41. https://doi.org/10.1016/j.envint.2015.01.012.

Van Den Berg, A.E., Custers, M.H.G., 2011. Gardening promotes neuroendocrine and affective restoration from stress. J. Health Psychol. 16 (1), 3–11. https://doi.org/10.1177/1359105310365577.

Van den Berg, A.E., Hartig, T., Staats, H., 2007. Preference for nature in urbanized societies: Stress, restoration, and the pursuit of sustainability. J. Soc. Issues 63 (1), 79–96. https://doi.org/10.1111/J.1540-4560.2007.00497.X.

Van Zanten, B.T., Van Berkel, D.B., Meentemeyer, R.K., Smith, J.W., Tieskens, K.F., Verburg, P.H., 2016. Continental-scale quantification of landscape values using social media data. PNAS 113 (46), 12974–12979. https://doi.org/10.1073/pnas.1614158113.

Wang, X., Rodiek, S., Wu, C., Chen, Y., Li, Y., 2016. Stress recovery and restorative effects of viewing different urban park scenes in Shanghai, China. Urban For. Urban Green. 15, 112–122. https://doi.org/10.1016/j.ufug.2015.12.003.

Wang, R., Zhao, J., Meitner, M.J., Hu, Y., Xu, X., 2019. Characteristics of urban green spaces in relation to aesthetic preference and stress recovery. Urban For. Urban Green. 41, 6–13. https://doi.org/10.1016/j.ufug.2019.03.005.

Wolch, J.R., Byrne, J., Newell, J.P., 2014. Urban green space, public health, and environmental justice: The challenge of making cities "just green enough". Landsc. Urban Plan. 125, 234–244. https://doi.org/10.1016/j.landurbplan.2014.01.017.

Wu, L., Kim, S.K., 2021. Exploring the equality of accessing urban green spaces: A comparative study of 341 Chinese cities. Ecol. Ind. 121 https://doi.org/10.1016/j.ecolind.2020.107080.

Wysmułek, J., Hełdak, M., Kucher, A., 2020. The analysis of green areas' accessibility in comparison with statistical data in poland. Int. J. Environ. Res. Public Health 17 (12), 1–17. https://doi.org/10.3390/IJERPH17124492.

Yeh, H.-P., Stone, J. A., Churchill, S. M., Wheat, J. S., Brymer, E., & Davids, K. (2015). Physical, Psychological and Emotional Benefits of Green Physical Activity: An Ecological Dynamics Perspective. https://doi.org/10.1007/s40279-015-0374-z.

Zabelskyte, G., Matijosaitiene, I., 2020. Relationship between urban ecosystem services and human health risks: Systematic review. WIT Trans. Ecol. Environ. 249 https://doi.org/10.2495/SC200231.

Zhang, H., Huang, R., Zhang, Y., Buhalis, D., 2022. Cultural ecosystem services evaluation using geolocated social media data: a review. Tour. Geogr. 24 (4–5), 646–668. https://doi.org/10.1080/14616688.2020.1801828.