Environmental and Sustainability Indicators 11 (2021) 100131

Contents lists available at ScienceDirect

Environmental and Sustainability Indicators

journal homepage: www.sciencedirect.com/journal/environmental-and-sustainability-indicators

Biocultural diversity in an urban context: An indicator-based decision support tool to guide the planning and management of green infrastructure

Paula Gonçalves [a,*], Kati Vierikko [b], Birgit Elands [c], Dagmar Haase [d], Ana Catarina Luz [a], Margarida Santos-Reis [a]

[a] Centre for Ecology, Evolution and Environmental Changes (cE3c), Faculdade de Ciências, Universidade de Lisboa, Campo Grande, 1749-016, Lisboa, Portugal
[b] Environmental Policy Centre, Finnish Environment Institute (SYKE), Latokartanonkaari 11, Helsinki, FI-00790, Finland
[c] Forest and Nature Conservation Policy Group, Wageningen University & Research, P.O. Box 47, 6700, AA, Wageningen, the Netherlands
[d] Humboldt Universität zu Berlin, Department of Geography, And Helmholtz Centre for Environmental Research – UFZ, Department for Computational Landscape Ecology, Germany

ARTICLE INFO

Keywords:
Socio-ecological systems
Greenspaces
Multi-layered indicators
Natural and cultural realms
Decision support tool

ABSTRACT

Cities face growing challenges and urban greenspaces (UGS) play a key role in improving cities liveability. UGS are complex socio-ecological systems and evidence-based and context-sensitive tools are needed to assist planning and manage environmentally sound and socially inclusive UGS. In this paper, we propose an innovative indicator-based tool to operationalize the biocultural diversity (BCD) framework in urban contexts, deriving from its three conceptual layers – materialized, lived and stewardship. Indicators proposed are bundled in themes representing essential components when assessing and analyzing urban BCD from a contextual and sensitizing perspective. The set of indicators highlight key features of socio-cultural and ecological systems, theirs links and interactions, both material and non-material, to capture the essence of biocultural diversity at site-level. By offering a uniform scoring system with the possibility to set site-specific benchmarks, these can be used in any type of greenspace of any city, while allowing different communities/neighborhoods/city councils to embrace different approaches to meet their objectives towards larger scale goals. Twelve urban parks in Lisbon were used as a test-bed for the indicator-based tool and proved its feasibility to gather an overall snapshot of all parks and to demonstrate the possibility to deepen the study to only two parks uncovering self-exclusion processes that otherwise would have remained hidden. The BCD tool brings together essential information scattered over several quality and good practices assessment tools and protocols and, by including indicators specifically addressing governance and stewardship, offers a policy-driven instrument able to capture trade-offs and/or synergies between ecological, social and political domains.

1. Introduction

The pace of urbanization has increased in recent decades and is expected to continue to increase in the future, with more than 70% of the human population predicted to be living in cities by 2050 (Elmqvist et al., 2018). The growth of cities is placing major pressure on ecosystems and societies (Cortinovis et al., 2019; Yin et al., 2016). Balancing the increasing pressure of growing cities with long-term protection of the environment, while being inclusive, culturally diverse, and economically equitable is a major societal challenge, as recognized by the United Nations (UN) Sustainable Development Goal (SDG) 11 for 2030.

In the context of urban expansion and natural habitat loss, the availability and quality of urban green space (UGS) has become an increasingly important aspect of urban planning and research. The role of UGS in improving the quality of life of urban residents, through its contribution to ecosystem services (ES) and human well-being, has been widely reported (Elmqvist et al., 2013). UGS improves environmental quality through the attenuation of air and noise pollution and regulation of the microclimate (Grilo et al., 2020). It also provides free and

* Corresponding author. Centre for Ecology, Evolution and Environmental Changes (cE3c), Faculdade de Ciências da Universidade de Lisboa, Campo Grande, 1749 - 016, Lisboa, Portugal.

E-mail addresses: pigoncalves@fc.ul.pt (P. Gonçalves), kati.vierikko@ymparisto.fi (K. Vierikko), birgit.elands@wur.nl (B. Elands), dagmar.haase@geo.hu-berlin.de (D. Haase), acluz@fc.ul.pt (A. Catarina Luz), mmreis@fc.ul.pt (M. Santos-Reis).

https://doi.org/10.1016/j.indic.2021.100131
Received 8 September 2020; Received in revised form 17 May 2021; Accepted 22 June 2021
Available online 24 June 2021

universal access to recreation and relaxation opportunities, further contributing to physical and mental health (Chiesura, 2004; Kabisch et al., 2015; Lovell et al., 2014). UGS also provides locations where different groups can meet together, fostering tolerance and social cohesion (Cattell et al., 2008; Peters et al., 2010).

There are many different types of UGSs in cities, including urban forests, schoolyards, urban parks, derelict land, street trees, allotment gardens, and green roofs or bioswales; each performing specific ecological functions. Each type of UGS is embedded in a diverse and dynamic social context, and in addition to maximizing ecosystem functioning, must provide inclusive, fit for purpose, quality spaces that address both local needs and the individual city vision. To consider and incorporate the complex interactions between the natural and cultural realms, and to cope with ecological and social demands, adequate tools are needed to guide UGS planning and management, and assist decision making (Groffman et al., 2017; Pickett et al., 2016). As part of a mosaic governance approach, the challenge is to "*combine the planning-based, long-term vision for spatial green space networks with local people's enthusiasm and dedication manifested in locally embedded, but usually not spatially interconnected, initiatives from active citizens*" (Buijs et al., 2018). As quoted by Arslan et al. (2016) (Arslan et al., 2016), to monitor progress regarding the UN SDG 11, "*there is a need for globally-identified and comparable indicators that can translate information obtained through evaluation into information relevant to policy-making and planning at the neighborhood level*".

This study focused on the social and ecological role of UGS and developed a new indicator-based methodology for promoting and measuring its performance building on a 3-dimensional conceptual framework presented in a previous study (Elands et al., 2019).

1.1. Review of UGS audit and valuation tools

Several green space quality audit tools are available, but their focus is mostly on assessing accessibility, the adequate provision of amenities, space maintenance, and safety issues (Joseph, 2016; Knobel et al., 2019; Chen et al., 2020). Examples of these audit tools include the Community Park Audit Tool (CPAT) (Kaczynski et al., 2012), the Quality of Public Open Space Audit Tool (POST) (Broomhall et al., 2004), and the Natural Environment Scoring Tool (NEST) (Gidlow et al., 2018). Very few tools incorporate an ecological assessment, and this has therefore been mostly addressed by ES dedicated tools, which are applicable but not specific to the urban context, e.g., i-Tree (I-Tree eco user's manual), Toolkit for Ecosystem Service Site-Based Assessment (TESSA) (Peh et al. et al.), and Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) (In (Integrated Valuat). A recent review of valuation toolkits from the urban perspective (Van Oijstaeijen et al., 2020) highlighted the heterogeneity of the criteria used and their mismatch with specific requirements in the planning and management context, namely a limited use of social and governance parameters. The importance of the social benefits derived from UGS and the need to engage stakeholders in toolkit development was not considered.

New approaches and tools, incorporating both biological and social assessments, and including the benefits derived from visiting green spaces and governance aspects, are, therefore, necessary to address the complex relationships between people and ecosystems. Such approaches will effectively advance our capacity to assist and inform decision making, negotiate trade-offs, implement management plans, and assess their outcomes (McPhearson et al., 2016a, 2016b).

1.2. Purpose of the study

This study developed a framework and methodology for using context-sensitive indicators that address both ecological and social requirements. The method could be used as a research and a decision-support tool, fulfilling the need for an integrated and unified methodological approach to advance our understanding of complex urban socio-ecological systems (McPhearson et al., 2016a, 2016b).

The biocultural diversity (BCD) indicator framework is briefly presented as the basis for the current work, with the main focus of the study being the step-by-step development of a methodology for implementing the BCD indicators. Guidelines are provided as the context for using the methodology and the results of a pilot test of the methodology are presented.

2. The indicator framework

Developing a context-sensitive tool that addresses the complexity of UGS functions requires an adequate underlying conceptual framework (Brown, 2009), with a deep integration of ecological and social concepts (Groffman et al., 2017; Pickett et al., 2016). The BCD concept, with its emphasis on the diversity of human-nature interrelations (Persic and Martin, 2008; Pretty et al., 2009), provides the necessary integrative and unifying perspective to assist the research, planning, and management of UGS. Drawing on this concept, Elands et al. (2018) (Elands et al., 2019) developed a conceptual framework addressing human-nature interrelations in an urban context. This framework proposed that BCD manifests in three mutually influencing dimensions. (1) *Lived BCD*, which embraces the ways people perceive, experience, and value UGS, as well as their culturally-embedded biological assemblages. (2) *Materialized BCD*, which concerns the experiences and practices of lived BCD, through which green spaces come to exist in tangible biophysical expressions, meaning discrete objects that exist regardless of the perceptions about them. (3) *Stewardship of BCD*, which represents an active and conscious engagement of people with urban space and its shaping.

Biocultural diversity is more a sensitizing concept than a definitive concept, with a clear definition of attributes or fixed benchmarks (Buizer et al., 2016). Sensitizing concepts, e.g., quality of life or sustainable development, lack such specific attributes and precise reference values. Definitive concepts provide prescriptions of what to observe, while sensitizing concepts only provide a starting point and a general sense of guidance that can be used to inform fieldwork. Sensitizing concepts merely suggest directions along which to observe, capture, and understand what is happening. These directions, herein designated as themes, enable complex concepts to be broken into distinguishable, manageable, and observable elements (Blumer, 1954; Patton, 2015).

The three BCD dimensions offer city planners and UGS managers a rich source of information and are departure points to study UGS from the BCD perspective. However, as M.C. Patton stated, "*Operationalization involves translating an abstract construct into concrete measures for the purpose of gathering data on the construct*" (Patton, 2015). This means that to be truly useful to inform strategic planning and decision making, this framework needs to be operationalized, with each dimension translated into indicators providing concrete, measurable, and comparable information.

The objective of this study was therefore to operationalize the urban BCD framework through the development of an indicator-based tool, which would serve both as a research and a decision-support tool to inform BCD analysis in the urban context. The aim was to meet the need for indicators to study biocultural diversity (Harmon et al., 2010) and for an integrated and unifying methodological approach to advance our understanding of complex urban socio-ecological systems (McPhearson et al., 2016a, 2016b). The proposed tool acknowledges and incorporates the diversity of meanings and contexts, and informs multiple modes and scales of decision making.

3. Methodology to operationalize the BCD indicator-based decision support tool

3.1. Themes and selection of indicators

The operationalization of the BCD based decision support tool involved the breaking down of each of the three BCD dimensions into themes, within which we proposed a set of indicators that we considered essential to address when studying UGS through a BCD lens.

The choice of themes was largely based on a description of the BCD layers themselves, which was achieved with reference to previous work on the areas of intersection and interdependence between biological and cultural diversity (Persic and Martin, 2008; Pretty et al., 2009). These studies encompassed many aspects of BCD, including systems of values, beliefs, and meanings; livelihoods and practices; knowledge and knowledge transfer; and social relations with others, places, and institutions (e.g., place attachment and governance systems).

Within the BCD perspective, the preservation and active co-creation of quality UGS implies an equal access to environmentally sound and inclusive green spaces that are planned and managed to fulfil their intended purpose for that specific location and community (Scotland, 2008). A quality green space is one that meets the needs of people, place, and environment, while engaging stakeholders in its planning and management. The choice of themes had to consider the role of biophysical and socio-cultural features in promoting ecological quality and well-being, and in ascribing meaning and identity to places (Andersson and Barthel, 2016). The themes also had to integrate the need to consider different values, levels of knowledge, and practices in the governance and decision processes (Buizer et al., 2016). Thus, the selected themes aimed to assess if the space was ecologically sound, inclusive, and fit for purpose; what the motivations, practices, and experiences associated with the space were, and what governance systems were in place.

The selected indicators were chosen to provide place-based information, i.e., they were i) biologically, socially, and politically relevant; ii) clear and readily understandable, and interpretable by the public and policy makers; and iii) integrative and sensitive to management practices (Brown, 2009). Selected indicators encompassed instrumental and contextual indicators (Rapport and Hildén, 2013) through the use of both quantitative and qualitative data, obtained either by site-based sampling and assessments, or by consulting existing documentation made available by municipalities and other stakeholders. For each indicator, one or more metrics were suggested, which were designed to be as easily measurable and interpretable as possible under objective criteria. They provided basic but meaningful information that could be used in municipalities' monitoring schemes and decision processes. The consideration of a wide-range of indicators, with diverse metrics, data sources, and scales of analysis, provides multiple options to study UGS according to site socio-ecological specificities, evaluation requirements, and the extent and availability of resources, through the selection of an adequate set of indicators, covering as much as possible the three BCD layers and several themes.

On the basis of a literature review we proposed a total of 14 themes, with a variable number of indicators per theme (Table 1). For *Materialized BCD* we proposed four themes, including standard measurements of biological, functional, and landscape diversity to assess ecological function; the assessment of biophysical features that may promote or hinder the welcomeness of space; and biocultural features that create place identity. Six themes were suggested for *Lived BCD*, with indicators addressing the diversity of socio-cultural identities, how people relate and interact with physical space and other people, and how these interactions are perpetuated over time. *Stewardship of BCD* had four themes, with indicators related to participation in governance processes and how people actively engage with space and take responsibility for it through civic ecological practices.

Below we provide the rationale underlying each indicator. Detailed information on candidate metrics, units of measurement, and links to the BCD concept are provided in the Supplementary Material.

Table 1
Proposed themes and indicators to operationalize the BCD framework.

Layer	Themes	Indicators	References
Materialized	**UGS biophysical attributes**	Spatial heterogeneity; Vegetation structure; Biological diversity; Functional diversity; Tree health and regeneration	(Lovett et al., 2005; Oliver et al., 2015; Díaz et al., 2007; Goodness et al., 2016)
	Welcomeness	Physical accessibility; Infrastructure and amenities; Cleanliness/neglect; Security	(Dunnett et al., 2002; Holland et al., 2007; Mehta, 2014; Ellicott, 2016)
	Signs of social memory carriers and socio-cultural symbols	Biological salient features; Cultural artefacts; Biocultural artefacts; Signs of prior use; Relicts and remnants	(Andersson and Barthel, 2016; Byrne and Wolch, 2009; Tweed and Sutherland, 2007; Florgård et al., 2009)
	Neighborhood biophysical attributes	Permeability; Complementarity; Park provision	(Ersoy, 2016; Mehta, 2008; Colding, 2007; Lovell and Johnston, 2009)
Lived	**User group diversity (social identities)**	Socio-demographic and other differentiation; Ethnicity/urban subcultures; Residence	
	Neighborhood socio-cultural attributes	Socio-demographic characterization; Local economy; Crime rate; Health status	(Loukaitou-Sideris, 1995; Seaman et al., 2010)
	Space usage	Visitation rate; Frequency and duration; Uses and motivations to use; Social activities	(Cattell et al., 2008; Lovell and Johnston, 2009)
	Interactions	Human-human interactions; Human-nature interactions	(Tuan, 1975; Peters, 2010)
	Meanings, perceptions, and values of users	Safety; Inclusiveness; Perceived UGS qualities; Biodiversity and ecosystem services; Sense of place; Wellbeing; Conflict	(Mehta, 2014; Tuan, 1975; Sterling et al., 2017a; Voigt and Wurster, 2014; Manzo and Perkins, 2006)
	Memory carriers of place	Place memory; Reputation; Digital external memory; Local Ecological Knowledge (LEK); LEK transfer and exchange	(Andersson and Barthel, 2016; Cilliers et al., 2015a; Yli-Pelkonen and Kohl, 2005)
Stewardship	**Property rights regime**	Conditions to access; Specific rules and norms	Sikor et al. (2017)
	Governance	Stakeholders; Opportunities and barriers;	(Buijs et al., 2018; Gavin et al., 2018)
	Civic practices	Stakeholders' activities; Citizen science; Civic ecologic/environmental practices; Engagement	(Krasny and Tidball, 2012; Cosquer et al., 2012)
	Management	Ecological practices	(Aronson et al., 2017; Zhang, 2017; Space, 2004)

3.2. Rationale for selected indicators

3.2.1. Materialized BCD indicators

The ***UGS biophysical attributes*** theme refers to an ecosystem's components and functions, the foundation of ecological quality, adaptation capacity, and ecological resilience, as well as people-nature interactions (Luck et al., 2009). It includes the indicators of **Spatial heterogeneity**, **Vegetation structure**, **Biological diversity**, **Functional diversity**, **Tree health**, and **Regeneration status. Spatial heterogeneity**, or the existence of spatial units with different characteristics or functions (Shugart, 1998), is crucial for ecological functioning and resilience because it promotes the coexistence of a large diversity of taxa (Lovett et al., 2005). The diversity of landscape elements also supports multifunctionality and affords people the opportunity for multiple uses, while being associated with aesthetic and landscape preferences (Dronova, 2017). The same type of relationships are found with **Vegetation structure**, which is directly related to biodiversity (Beninde et al., 2015), attractiveness, preferences, and psychological restoration (Bjerke et al., 2006; Jiang et al., 2015; Chiang et al., 2017). **Biological diversity** in UGS provides direct and indirect benefits to urban dwellers (Oliver et al., 2015), namely physical health, cognitive performance, and psychological well-being (Keniger et al., 2013). Biodiversity can be assessed in various ways, such as species richness and diversity (Colwell et al., 2009), the presence of keystone species that are essential for community structure and integrity (Mills et al., 1993), or the presence of species with conservation status, which represent important elements for biodiversity conservation. The large number of vascular plants in cities encompasses both native and non-native species. In many cases, the decline of native species caused by urban sprawl is compensated for by the introduction of non-native species. Exotic species contribute to ES provision (Schlaepfer, 2018), with ornamental species being particularly important for human appreciation (Wilson et al., 2016). However, they may also present negative impacts, the analysis of which is beyond the scope of this work, but which must be considered when planning and managing UGSs (Gaertner et al., 2017). More than simply the number and diversity of species, **Functional diversity** determines the functioning and resilience of an ecosystem (Peterson et al., 1998; Díaz and Cabido, 2001). Functional diversity also plays an important role in human appreciation and engagement with nature, with a higher diversity of visual traits affording multiple ways to explore and appreciate biodiversity (Goodness et al., 2016; Andersson and McPhearson, 2018). **Tree health and regeneration status** is important to ensure system continuity (Fuller and Quine, 2015; Greenberg et al., 2011). This is particularly important in urban forests and horticultural green spaces, where the existence of young specimens is critical to the maintenance of habitat structure and quality (Le Roux et al., 2014). On the other hand, dead and fallen trees, when security issues have been considered, can contribute to a high biological diversity (Stokland et al., 2012).

Welcomeness as a theme of materialized BCD focuses on tangible and visible features providing an accessible, inclusive, and comfortable environment, and an adequate layout for the purpose of visiting the space (Dunnett et al., 2002; Holland et al., 2007; Mehta, 2014). This theme includes indicators of **Physical accessibility**, **Infrastructure and amenities**, **Cleanliness/neglect**, and **Security**. An inclusive green space welcomes people of all ages, socio-economic status, and walks of life, without any barriers: physical, cultural, or emotional (Elands et al., 2018). Equity in **Physical accessibility** to green spaces involves providing access without natural or artificial physical barriers or transportation difficulties (Van Herzele and Wiedemann, 2003). Access to green spaces considers not only the ability to reach the space but also to use it in a meaningful way. Adequate and well-kept **Facilities and amenities** are key for a meaningful visit and will encourage regular visits (Mehta, 2014). The quality of the space is also determined by **Cleanliness and maintenance**, with cleanliness offering a sense of comfort and relaxation, and the presence of damaged property or incivilities often being associated with a perception that areas are unsafe (Mehta, 2014; McCormack et al., 2010). **Safety** is often cited as the first concern in public spaces. Although its perception is strongly influenced by a few factors, the presence of adequate lighting and/or staff in urban parks is associated with an immediate sense of safety (Holland et al., 2007; McCormack et al., 2010).

The ***Signs of social memory carriers and cultural symbols*** theme refers to manifestations of close and consistent human-nature interactions, embodied in the UGS. These signs can range from complex architecture, park design, and the composition of ornamental species in a park, to a desired path through derelict land or a tree carving in a forest. They reflect different periods, socio-cultural contexts, and ideologies of natural creations, bringing past meanings and experiences into the present. These elements contribute to the building of a place's character and unique identity to which people relate (Andersson and Barthel, 2016; Byrne and Wolch, 2009; Green, 2009). The indicators informing this layer are **Biological salient features**, **Cultural artefacts**, **Biocultural artefacts**, **Signs of prior use**, and **Relicts and remnants. Biological salient features** represent elements with historical, cultural, aesthetic, and educational value that perpetuate cultural value for keystone species, umbrella species, and long-living organisms (Andersson and Barthel, 2016). **Cultural artefacts**, such as architectonic elements or urban art, provide information about a societies' history, and how people used to live and express themselves. In a green space, artefacts can offer meaning and identity, create a sense of belonging, and help preserve cultural heritage (Andersson and Barthel, 2016; Tweed and Sutherland, 2007). **Biocultural artefacts**, created from and/or representing nature represent and perpetuate the dynamic relationships between people and nature (Salick et al., 2014). Consistent patterns of user engagement with a space create novel uses and functions and leave spatially explicit traces of their interaction with the space that are designated as **Signs of prior use** (Campbell et al., 2016). These signs of space appropriation, e.g., informal sports pitches or desired paths, inscribe the memory of repeated human action in the landscape and stimulate the perpetuation of these novel uses and functions. **Relicts and remnants** of natural ecosystems in the city preserve a species composition closer to the original natural landscape, hosting many native and endangered species (Kowarik and von der Lippe, 2018). They also retain the original ecosystem functioning that cannot be fully replaced by novel man-made habitats (Kowarik, 2011) and have a high conservation and educational value (O'Farrell et al., 2012). Remnants of natural vegetation also contribute to visual diversity in the urban landscape, which is often designed to be homogenous, and also provide a sense of identity and belonging by bringing historical land-uses into contact with people (Florgård et al., 2009).

Each UGS is embedded in a given socio-ecological context and biological and cultural diversities in a green space cannot be dissociated from its surrounding matrix (Ersoy, 2016; Werner, 2011). A theme of ***Neighborhood biophysical attributes***, with indicators of **Permeability** and **Complementarity** was included. **Permeability** indicates the degree to which the matrix facilitates or impedes the movement of organisms. This includes not only animal and plant species, for which movement and dispersal is essential for ecosystem functioning and resilience, but also the movement of people (Ersoy, 2016; Lu et al., 2018; Zuniga-Teran et al., 2016; Southworth, 2005). **Complementarity** recognizes the need for a variety of land-uses that perform complementary socio-ecological functions in the spatial green space network. Urban human-made habitats are not likely to perform the entire range of ecological functions of natural ecosystems, but each can contribute to overall ecosystem functioning (Kowarik, 2011) by means of land-use or habitat complementation (Colding, 2007; Lovell and Johnston, 2009). The same principle applies to the social functions of green spaces because no single space is likely to meet all of the desired facilities or layouts. The existence of different types of green spaces in a neighborhood may offer alternative and/or more interesting functions for some users in a multifunctional network of green spaces (Lovell and Taylor, 2013; Hansen and Pauleit, 2014).

3.2.2. Lived BCD indicators

The ***User group diversity*** theme directly assesses users' cultural diversity in terms of their origin, socio-demographic and economic status, and visible patterns of allegiance to any kind of subculture. The indicators for this theme are **Socio-demographic and other differentiation**, **Ethnicity/urban subcultures**, and **Residence**. Actual access to a UGS can be determined by experiential barriers and the level of perceived integration, more than by UGS resources or physical qualities (Seaman et al., 2010; Paloniemi et al., 2018). Because people tend to use the spaces that are closest to their place of residence (McCormack et al., 2010), green spaces should reflect the neighborhood characteristics. The underrepresentation of some groups may reveal the existence of self-exclusion processes (Seaman et al., 2010). The theme ***Neighborhood cultural characteristics*** captures the existence of such processes by determining if the cultural diversity of the neighborhood is fully represented in the green space. Culture and economy are mutually influential and the development of the **Local economy** is intertwined with social processes that shape place meaning as good or bad (McCann, 2002). In addition to being representative of a neighborhood's economic status, a diverse range of businesses and services provides a sense of usefulness and promotes walking behavior (Mehta, 2008). In contrast, the perception of a lack of safety, of which the **Crime rate** provides a real picture, restricts this willingness to walk in the streets (Mehta, 2008). UGSs offer opportunities for physical activity and relaxation in clean, cool, and quiet environments, with significant positive effects on a resident's mental and physical **Health status** (Braubach et al., 2017).

The ***Space usage*** theme that includes **Visitation rate, Frequency and duration**, **Uses and motivations**, and **Social activities**, indicates if the UGS supports regular visitation and different uses. Regularly visiting a green space for prolonged periods allows a consistent interaction with nature, while fostering feelings of connectedness and an emotional bond to the space (Smaldone et al., 2007). A diversity of activities and their actors may reveal the extent of the usefulness and inclusiveness of the space, with the presence of other people also increasing the perception of UGS safety and attractiveness (Mehta, 2014). Interactions with someone or something provide a foundation to develop an emotional connection towards the object of interaction (Tuan, 1975). The theme ***Interactions***, with indicators of **Human-human interactions** and **Human-nature interactions**, accounts for the ways people interact in and with nature, and its importance for social cohesion and place attachment. Social interactions promote the creation of bonds and the sense of community, providing the base for social cohesiveness (Cattell et al., 2008; Peters, 2010). The same is true for interactions with nature, with emotional experiences with the natural world inducing empathy for the environment and the desire to protect and conserve nature (Soga and Gaston, 2016).

People perceive and enjoy nature in many ways, and are conditioned by the meaning and value they ascribe to a green space and what it has to offer. A theme dealing with ***Meanings, perceptions, and values of users*** is of uttermost importance when dealing with BCD (Sterling et al., 2017a). Perceptions of **Safety**, **Inclusiveness**, **UGS qualities**, **Biodiversity and ecosystem services**, **Sense of place**, **Wellbeing**, and **Conflict** are the indicators proposed for this theme. Perceived safety, inclusiveness, and integration are some of the most important factors making people feel welcome and comfortable in the space and its perceived qualities, the convenience of visiting and satisfaction with the place, are often more important than its physical availability (Mehta, 2014; McCormack et al., 2010). Biodiversity perception plays an important role in the perception of benefits derived from visiting the green space (Dallimer et al., 2012; Schebella et al., 2019; Gonçalves et al., in press). Some people may appreciate the space solely for its aesthetic properties, or the useful amenities and infrastructures it provides, while others can develop a more emotional or affective relationship that translates to a sense of belonging and attachment to place. The perception of **Wellbeing** and **Sense of place** indicates how well the green space is performing in providing such benefits.

Users have different needs and experience a place in various manners that can clash with the interests and well-being of others, causing **Conflicts,** self-exclusion, or space-time segregation. Conflict can also arise with nature itself or with management institutions, through the constraining of certain behaviors or activities or by managing land-uses that are not welcomed (Dinnie et al., 2013; von Döhren and Haase, 2015; McMillen et al., 2018).

The history of a place is engraved in people's memories and represents an informal repository of information, perpetuated in time through knowledge transfer (Andersson and Barthel, 2016). The theme ***Memory carriers of place***, with indicators of **Place memory**, **Reputation**, **Digital external memory**, **Local ecological knowledge (LEK)**, and **LEK transfer and exchange** accounts for such dynamics. Experiences and stories create a **place memory**, which is important in assigning value to a place and for keeping a record of past events and changes to the biophysical or social structure of the place (Cilliers et al., 2015b). These memories and their dissemination are major contributors to a space's **Reputation**. Spaces acquire reputations that are built upon real facts or based on rumors. They persist over time and affect the way people use or avoid the UGS (Holland et al., 2007). **Digital records** are useful tools to disseminate knowledge and share experiences, while keeping a memory of place that lasts over time for future generations. One of the key areas of interdependence between biological and cultural diversity is **LEK** and its **Transfer and exchange**. In addition to providing a memory repository for future use, **LEK** provides additional information about ecological processes and meaningful places, representing a very useful tool for planners and managers (Yli-Pelkonen and Kohl, 2005).

3.2.3. Stewardship of BCD indicators

Land tenure and ***Property rights regime*** (Bac, 1998) are the first conditioning factors in determining how people may access and use green spaces. The existence of **Conditions to access** represent control rights that may impose restraints on the rights of some groups by restricting free access to a space (Sikor et al., 2017). **Specific rules and norms**, either formal or informal, may promote or deter certain uses and activities and shape the way people interact with the space.

Governance is a system of decision making processes, in which actors other than legal institutions can take part. The way actors, formally or informally, can have an active voice in the decision process, depends on their position and role among the actors' involved and the way they relate to each other and with legal institutions. **Stakeholders** represent the official and non-official entities that are actively involved in planning, managing, and maintaining the green space, while **Opportunities and barriers** indicates the capacity of stakeholders to have a real voice in decision making (Buijs et al., 2018; Sterling et al., 2017a; Gavin et al., 2018).

The ***Civic practices*** theme represents an active engagement with the space through environmental stewardship (Krasny and Tidball, 2012) and includes the indicators of **Stakeholders' activities**, **Citizen science**, **Civic ecologic/environmental practices**, and **Engagement**. The type, **Stakeholders' activities**, indicates people's involvement and relationships with the events occurring in UGS. Engagement in **Citizen science** or in **Civic ecologic practices** denotes a direct interaction with nature that translates into pro-conservation attitudes and behavior (Cosquer et al., 2012).

Although the major purpose of some green spaces is to provide clean, welcoming places with many choices of activities and relaxation opportunities, UGS managers must incorporate best ***Management*** practices to conserve, protect, and promote biodiversity and ES provisioning (Aronson et al. et al.).

3.3. Guidelines for using the indicator-based support tool

The number of suggested indicators is rather large because it relies on disaggregated information. Although it is potentially more difficult to obtain, interpret, and share, disaggregated information has the advantage of providing clear, place-based information on what is influencing the system, as well as how or why. Aggregated information, as in indexes, offers a generalized perspective that can only indicate that something is happening, but not the causes behind it (Wong, 2015). Indexes may obscure important information in the underlying data or may fail to recognize the complexity of the dimension of interest. In such cases, data in their raw, disaggregated form are often more useful than when compiled in a composite measure. The use of disaggregated indicators allows this information to be selected and referred to the specific issue under analysis, as will be demonstrated in the next section.

An underlying principle common to all diversity measurements is that they are teleological, i.e., they are conducted for a specific purpose. A biocultural approach assumes a place-based definition of locally relevant goals, grounded on the local cultural context and its values, perceptions, and needs (Sterling et al., 2017a). As such, the proposed indicators are not meant to provide precise measurements of BCD with benchmarks to achieve, but rather a way of organizing and understanding information in a contextual way, providing a methodology to analyze the interaction between people, places, and biodiversity and a foundation on which to base policy decisions. The contextual indicators describe the wider contexts of UGS, e.g., social or environmental, and can be used to understand how a phenomenon operates in each context (Mayoux, 2001), while the BCD indicators are used for a specific purpose and context determined by "what, for what, and for whom".

3.3.1. Defining the scope of analysis

The analysis process should begin with a clear statement of the purpose and precise objectives of the study and desired outcomes. However, different planning and management policies have different goals. Different stakeholders seek different outcomes, qualities, functions, and experiences, and they use and value UGS in different ways. These variabilites regarding UGS' management can be overcome by fully engaging stakeholders, from the objectives to all stages of implementation, including the selection of indicators. This allows for alternative understandings of the problem, and the identification of competing interests, priorities, and constraints. In this way, various parties are more likely to actively engage in the process and agree on common solutions, and these solutions are more likely to be implemented and widely-accepted (Buijs et al., 2018; Sterling et al., 2017a; Gavin et al., 2018). The first step in the process starts by agreeing on the discussion and decision models, which could be either workshops, focus groups, or other commonly used participatory methodologies (Mayoux, 2001; Mayoux et al., 2006). This step is by itself informative with regard to the ***Governance*** and ***Civic practices*** themes because it will identify existing actors and their ability to both participate and have a meaningful voice in the decision process. The participants can then define the purpose and objectives of the study, discuss the goals and desired outcomes, and define indicators and the scale and time frame of the analysis. Indicators are not only useful to measure progress, but also to identify problems and set management goals. Goals and outcomes may be articulated as baselines or targets to achieve, or simply a direction in which to move, with indicators selected accordingly. Depending on the purpose, context, and what the indicator is measuring, its relevance, robustness, and sensitivity to change may vary.

3.3.2. Selecting indicators

The indicators selected should be aligned with the city's strategic vision, while being able to address the specific context and its people, place, and environmental values. The indicators also must be sensitive to the changes induced by municipal policies and actions taken to address problems. To ensure that they are reconciled with a cities' vision, indicators are usually aligned with broader regional, national, and international goals and guidelines, with local needs and visions of optimal futures requiring negotiations between all concerned parties. Because no single solution will maximize the benefits for all groups, decision making should be based on well-established and transparent decision methodologies, e.g., multi-criteria analysis, analytical hierarchy process, Delphi methods, and Q-methodology (Castro Pardo and Urios, 2017; Saaty, 1987). This decision process is also useful to assess the importance and relevance of the indicators to the different parties, negotiate priorities, and give weights to the indicators if wanted.

The selection of indicators must be carefully balanced. Fewer indicators are generally better, mostly for time and resource consumption reasons, with too many indicators becoming complex to manage and difficult to implement. Although it is common to agree to a minimum set of indicators, for a complete understanding it is advisable to consider the use of indicators from all themes. The assessment of indicators that are apparently not relevant may provide complementary information that is important to contextualize the problem. Restraining the number of indicators due to resource availability can lead to weaknesses in the analysis of the situation prior to any intervention, failure to uncover hidden aspects, and biased interpretations (Kaye-Blake et al., 2017). For each indicator, we suggest one or more metrics of different levels of detail and resource investment, which should be selected to be as easily measurable and interpretable as possible under objective criteria. With several possibilities available it is likely that a suitable indicator will be found, but even a lack of information may be informative by itself, expressing that some problem or deficiency needs to be addressed.

3.3.3. Scoring the selected indicators

To make sense of the analysis and convey a meaningful message, each indicator must be scored through a rating system that translates the indicator value to an interpretation of its meaning regarding the question under consideration, and it is then compared to the desired outcomes. This scoring system involves two steps. The first transforms all variables into a quantitative variable, for which we propose a five-point scale or a five-class grouping depending on the data type and structure. Quantitative variables may be rescaled to a five-point scale using an indicator's highest and lowest values or using any other appropriate method, such as linear interpolation (Lu et al., 2015). Others can be grouped into five categories, classes, or generally accepted strata, e.g., age or education. Qualitative variables can be inductively classified into five groups, while those based on Likert or scoring scales, can be directly used in the second step. This step involves rating each indicator on a five-point scoring scale that translates the indicator value to an interpretation of its performance regarding the question under consideration. Scoring criteria are based on the purpose of the analysis, UGS typology, and their intended ecological and social functions, both local and in the city context. Criteria must be as objective and accurate as possible to maximize comparability and minimize the subjectivities of personal interpretations (Wong, 2003), while also being adjustable. As an example, depending on whether the function is to maximize the number of species that are representative of a city's biodiversity, to serve as a repository of native species for educational purposes, or to maximize aesthetical appreciation, a naturalness metric would score higher in the first and second cases and, probably, lower in the third case. UGSs are highly dynamic systems. Changes in their biophysical structure and/or surroundings influence the way people use, perceive, and experience such spaces and indicators should be able to reflect this. People and cities needs change over time, and therefore the desired outcomes and criteria need to be revised and adjusted accordingly. The proposed two-step five-point scoring system allows all indicators to be converted, independently of their nature, into a single, quantitative, uniform, and thus comparable value. This can be easily understood and used by lay people, allowing them to assess temporal trends by reviewing past scores and considering predicted future scores.

The scoring criteria define the meaning assigned to the indicator, while the actual score measures how well it performs in regard to that meaning. This involves a comparison with some standard of measurement, or expected or reference value. Biocultural indicators have no *a priori* defined reference values or general standards for comparison (Sterling et al., 2017b). A general standard would imply an assumption of how a UGS should be structured or should be experienced. Reference values refer to the objectives and desired outcomes negotiated during the decision process. The indicator score measures how the indicator is performing in relation to that specific outcome. This allows *benchmarks* to be established (Ammons, 2014), representing a target to achieve in a vision of the future desired by communities and local government.

The scoring criteria and reference values need to acknowledge the city's strategic vision and major planning options, existing norms, and quality standards for recreational green spaces. They also need to consider the current knowledge regarding social and ecological sciences, as well as climate change adaptation, landscape preferences, ecological functioning, affordances, and place making theories. These sources of information can be used to establish ratified values, i.e., a "*value attributed by institutions acting in the name of the community and public interest*" (Cassatella, 2011), which are then used as references. This reference system allows *performance benchmarks* (Ammons, 2014) to be established, against which green spaces are compared. This will develop a knowledge baseline and aide in the assessment to where the UGSs stand regarding the city's strategic vision. It should be noted that institutional criteria may fail to address a user's needs and result in solutions that are disconnected from the local reality.

An alternative is to use a reference site or a narrative of an ideal space as an example of best practice to achieve the desired outcomes. The scores assess how distant the UGS under analysis is from the reference site, which is conducted with reference to the outcomes and not the solutions adopted to reach those outcomes. To assume the solution as the reference would risk the standardization of what and how a green space should be, and the transposition of successful solutions would be decontextualized from the local reality. This kind of reference system allows the establishment of "best practice" benchmarks, where a site is compared to an outstanding performer. This allows the circumstances that account for better results to be assessed and seeks ways to adapt practices and make them suitable for their own use.

Either way, scores assess how the indicator behaves regarding the chosen reference. The indicators can be compared between sites and even cities; not in terms of their absolute value but in how they behave regarding the locally established benchmarks. Benchmarks are framed by the problem addressed and the scenario envisaged by planners and the community. The indicators will determine where the green space stands in relation to that locally defined goal. Provided that the same question is assessed with the same set of indicators and metrics, and scored under the same agreed rating criteria, this tool can be used across scales because the indicators are scored under a common system.

In summary, for each metric it is necessary to define scales and/or classes for measurement, as well as scoring criteria that are defined and agreed among partners or stakeholders, and operate according to the context, questions raised, and desired outcomes. Once rating scales are defined, each metric can be scored accordingly. If desired, scores can be weighted according to schemes reflecting locally defined goals, and then graphed for visualization or analyzed with appropriate methods. Score weightings must be agreed during the negotiation process based on their relevance and importance. Weighting an indicator, when not done through sound governance processes, involves a pre-assumption of its importance and may be subject to arbitrary and subjective judgement or a lack of transparency (Wong, 2003). With all indicators translated to a score of 1–5, it is then easy to visualize the results either with spider graphs or in a geographic information system (GIS), as shown in the next section. Although several indicators do not have a spatial basis, they always refer to a specific place and can be represented in a qualitative GIS. These visualizations ensure that the indicators and their interplay are easily understandable and are adequate for further analysis, interpretation, and sharing.

The overall process and its various stages are depicted in Fig. 1.

4. From theory to practice: results of a pilot-test

Twelve urban parks in Lisbon (Portugal) were used as the test-bed of a BCD indicator-based tool through the framework of the GREENSURGE project (https://greensurge.eu/). The study involved multi-taxa biodiversity sampling and face-to-face questionnaires addressing the motivations of people for visiting parks and their perceived benefits from those visits. The details of the park selection and sampling

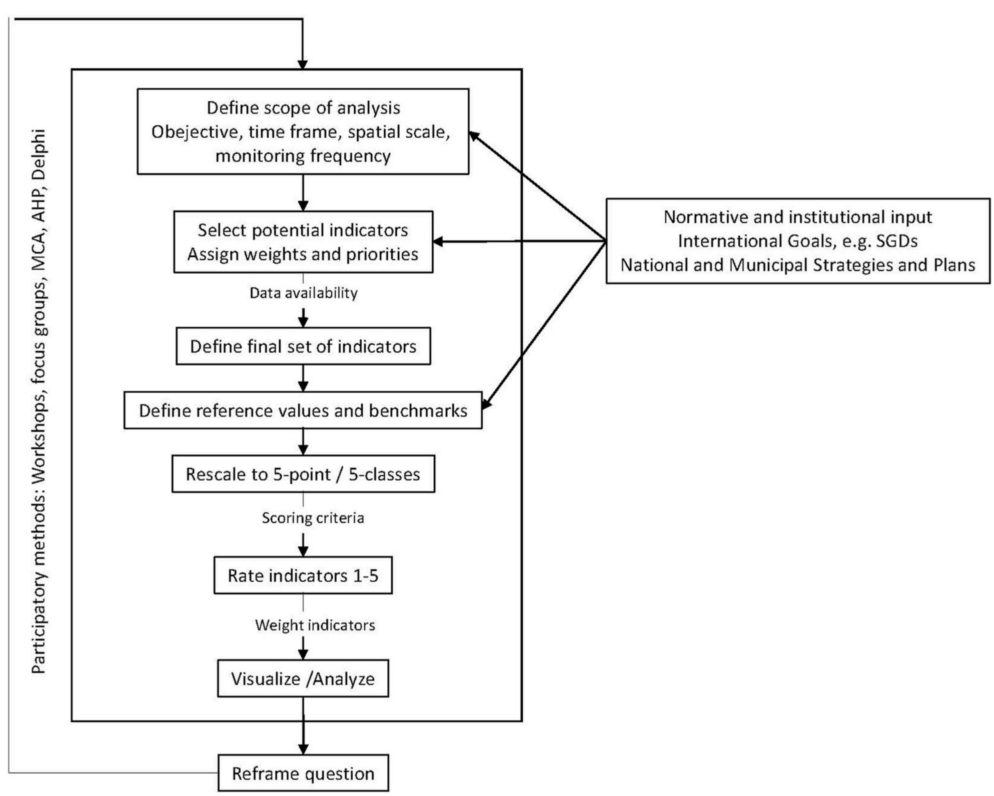


Fig. 1. Flowchart of the indicator-based process.

methodologies are available in (Vierikko et al., 2020) and (Gonçalves et al., in press). To demonstrate the tool's usage we considered the question, "*are the studied parks addressing the needs of their users and neighborhoods?*". We also assumed a social function of recreation and mental restoration, and an environmental function of mitigating the urban heat island effect. These were the assumptions supporting the choice of indicators and scoring criteria used to rate parks. The best performer for each indicator was used as the reference for other indicators. The metrics, scaling systems, and scoring criteria are shown in Table 2, with data sources, raw data, and scores for all parks being provided in the Supplementary Material (Appendix B).

Because we considered the environmental function of cooling the temperature and reducing the urban heat island effect, a higher canopy cover corresponded to a higher score. If only the park's recreational and mental restoration function were under consideration, the scoring criteria would have been based on landscape preferences or affordances theories. Such theories state the preference for a mixture of open and closed areas (Jiang et al., 2015). Thus, the extremes of completely open and closed cover would score as low and a proportionate mixture of open and closed cover would score as high.

Table 2
Indicators used to test the tool, with the metrics, scaling, and classifications used to re-scale each indicator on a 5-point scale, and the scoring criteria used to rate the indicator.

Theme Indicator Metric	Scale/classes	Scoring criteria
UGS biophysical attributes **Vegetation structure** Canopy cover *(COV)*	Mean canopy cover rescaled to 1–5	1 – Low cover - low mitigation to 5 - High cover- high mitigation
Welcomeness **Cleanliness and maintenance** Cleanliness *(CLN)*	1- No signs of litter/dog feces to 5 - Visible litter/dog feces; overloaded trash bins	1 - Visible litter - Very unclean, inviting and unwelcoming; 5 - No signs of litter - very clean, inviting, and welcoming
Neighborhood biophysical attributes **Complementarity** Complementary in 300 mt *(CPL)*	1 - Absence of complementary GS to 5 - High provision of complementary GS	1-Poor provision of complementary features; 5 - Very good provision of complementary features
User group diversity vs Neighborhood socio-cultural attributes **Socio-demographic and other differentiation** Age and education *(AGE, EDU)* strata	Absolute difference between strata percentages rescaled to 1–5 1 – No difference between users' and neighborhood age/education strata to 5 – Very large difference between users' and neighborhood age/education strata	1 – Neighborhood not reflected in users - potential high self-exclusion processes to 5 - Neighborhood reflected in users - no self-exclusion processes
Meanings, perceptions, and values of users **Satisfaction with space** Complaints about UGS *(SAT)*	Number of referred annoyances per visitor interviewed rescaled to 1–5 1 - Low percentage of complaints to 5 - High percentage of complaints	1 – Low satisfaction with the space to 5 - High satisfaction with the space
Sense of place Is this place special? *(SPE)*	Percentage of users referring connection with place rescaled to 1–5 1 - Low percentage of users to 5 - High percentage of users referring to connection with place	1 - Little emotional bond to the place 5 - Strong emotional bond to the place
Wellbeing Perceived Restorativeness *(PR)*	Weighted average score (1–5) of the Perceived Restorativeness Scale 1 - Low PR score to 5 - High PR score	1 - Low perception of psychological restoration to 5 - High perception of psychological restoration

To be easily understood by decision-makers the final scores may be visualized using a colored results matrix (e.g., Table 3) or a GIS map (e.g., Fig. 2).

The coloring system enabled a rapid visualization of how parks performed for the various indicators assessed and which aspects are in need of intervention.

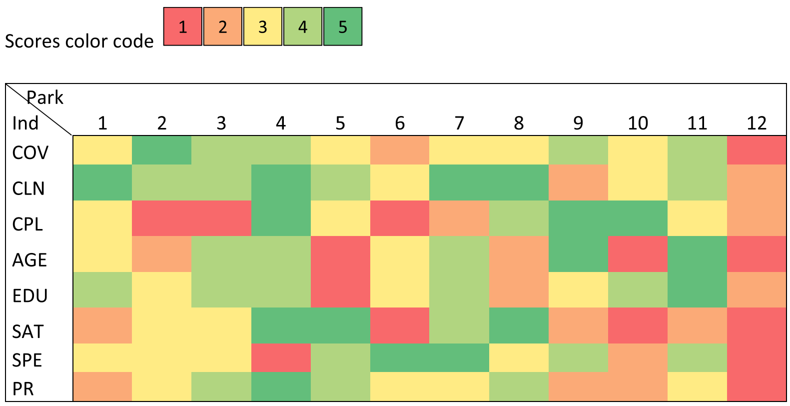
Although a more profound analysis of the observed differences was beyond the scope of this study, one park (VFundão) stood out due to its low scores for all indicators. The lowest scores were attained when comparing the demographic strata of users and the neighborhood, which suggested the existence of self-exclusion phenomena. Another park (Gulbenkian) also displayed low scores for the same indicators, despite it being a very well-known, high quality park in Lisbon (Luz et al., 2019). As such, we re-initiated the process to understand why these parks were not fulfilling the needs of their neighborhoods. For this analysis, we added indicators related to spatial heterogeneity, biological diversity, infrastructure and amenities, security, biological salient features and cultural artefacts, frequency and duration of visits, human-human interactions, and reputation. Site quality was assumed to be high as it was a site offering a clean and safe welcoming environment, with an adequate number of well-maintained amenities and facilities. These were the assumptions underlying the scoring criteria for these indicators. Data, scaling, and scoring criteria for these indicators are available in the Supplementary Material (Appendix B).

Gulbenkian, located in a wealthy neighborhood, is one of the most well-known and frequently visited parks in Lisbon (Luz et al., 2019). It offers a very well-kept, highly diverse environment, with numerous amenities of excellent quality, providing high levels of well-being and place attachment (Fig. 3). In contrast, VFundão, located in a low socio-economic stratus neighborhood, scored much lower in all indicators related to spatial layout and quality. The same pattern was observed for indicators of well-being, connection, and satisfaction with the space. This park is clearly not addressing the needs of its users nor is it accomplishing its role of a place for mental restoration. However, it plays a very important social role as a meeting place, enabling local people to be together, as shown by the frequent visits and high rates of user interaction (Fig. 3).

Despite the major differences in most indicators, both parks scored poorly with regard to the representation of the neighborhood's demographic classes among park visitors. VFundão is mainly used by elderly and less educated people, and lacks representation among the younger educated adults within the neighborhood. Gulbenkian is mainly visited by young, highly educated adults, with the older and less educated people within the neighborhood not well-represented. We used the "Distance to home/work" indicator to discard the possibility of this result being due to a preponderance of visitors from outside the neighborhood. This indicator showed that 70% of the interviewees lived less than 1 km away and the distribution of educational level was reasonably similar (data in the Supplementary Table). These results suggest the presence of self-exclusion processes in both parks. In VFundão, this is likely due to the lack of facilities and attractive features, raising issues related to space welcomeness, which should be addressed by the city council. In Gulbenkian the self-exclusion is probably due to a feeling of non-belonging. The use of the complementarity indicator is important to assess the existence of other areas of UGS in the neighborhood that fulfil the needs of the self-excluded population.

The two analyses conducted here demonstrated the usefulness of BCD indicators to evaluate the performance of established urban recreational parks. This indicator-based tool can be applied to any type of UGS, to address site-specific questions, such as if the space is ecologically sound and fit for purpose, or how users perceive and value the space and its biodiversity, or even if the stakeholders have an active voice in decision making.

Table 3
Results matrix (columns – Parks; rows – Indicators) for the 12 parks in Lisbon: 1 – Mata de Benfica; 2 – Mata de São Domingos de Benfica; 3 – Parque Recreativo do Calhau; 4 – Miradouro de Montes Claros; 5 – Alameda Keil do Amaral; 6 - Tapada das Necessidades; 7 – Jardim da Estrela; 8 – Jardins Gulbenkian; 9 – Mata da Quinta das Conchas; 10 – Mata de Alvalade; 11 – Parque Urbano de Vale do Silêncio; 12 – Parque Urbano do Vale Fundão: COV – Canopy cover; CLN – Cleanliness; CPL – Complementarity; AGE/EDU – Representation of a neighborhood's age and education; SAT – satisfaction with space; SPE – Connection with place; PR – Perceived restorativeness.



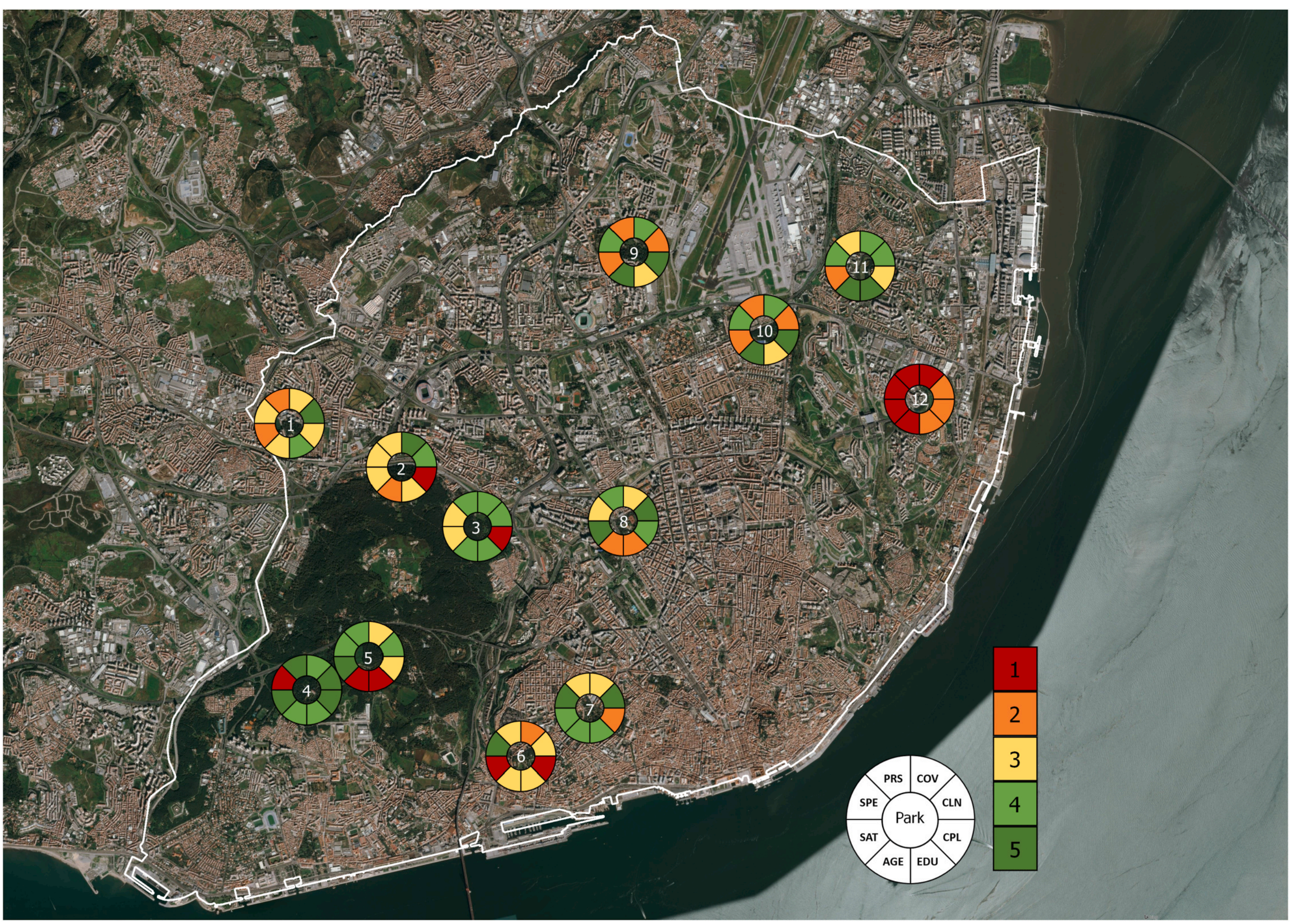


Fig. 2. Map showing the location of the 12 parks with scores represented by color. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

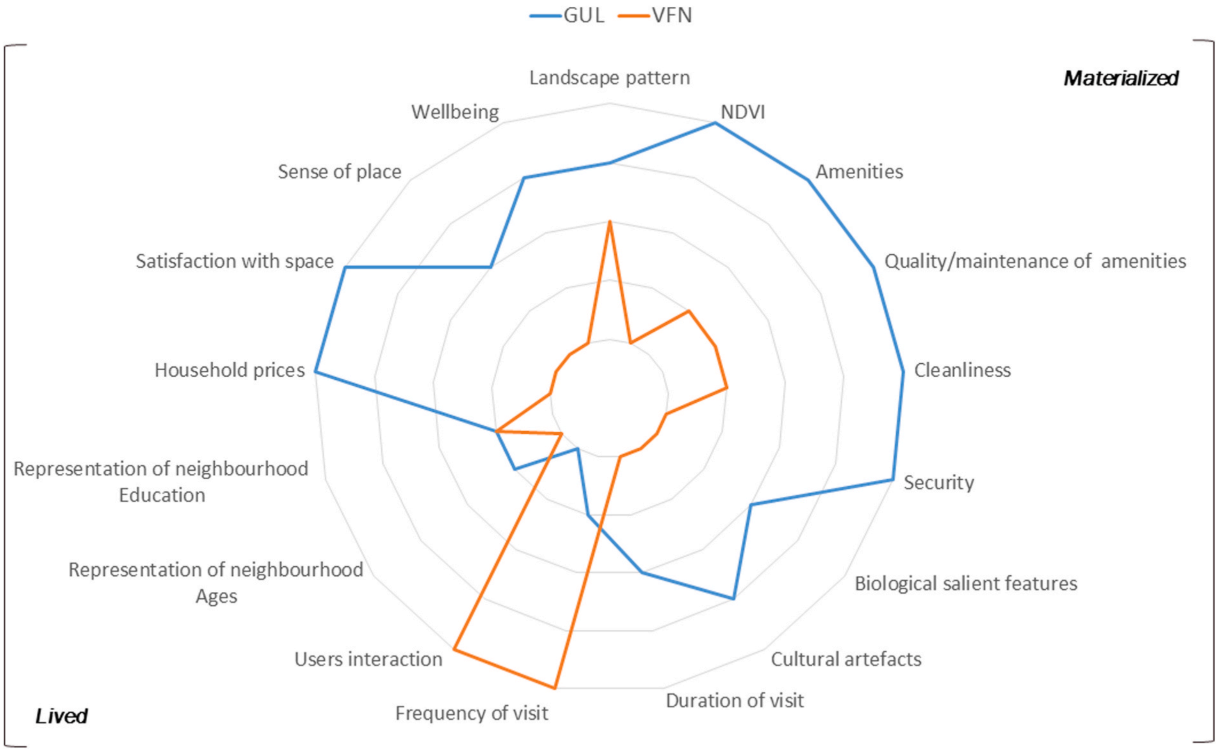


Fig. 3. Application of BCD indicators to two urban parks in Lisbon (GUL – Gulbenkian; VFN – Vale Fundão).

5. Discussion

This study developed a new indicator-based tool intended to facilitate the strategic planning of UGS and improve decision-making in compliance with the UN's SDG 11 - Make cities and human settlements inclusive, safe, resilient and sustainable. Making cities sustainable involves, among other actions, investment in creating high-quality green public spaces and improvements in urban planning and management in participatory and inclusive ways. These challenges align well with the BCD conceptual framework proposed by Elands et al. (2019) and were the underlying motivation for this study. By achieving our initial goal and being able to test it in practice, we have attained a scientifically justified development and have demonstrated its application.

This indicator-based tool has a few key characteristics. It is teleological. It presupposes the existence of an underlying research question "of what, for what, and for whom", upon which the choice and selection of indicators, metrics, scales, and scoring criteria are based. Although informative on their own, indicators are not supposed to be used individually but rather in conjunction with others to provide a complete and integrative view of the UGS. This applies not only at the local scale, but also when taking into account their location and function in the urban green infrastructure. The fundamental purpose is to integrate information from all relevant indicators to identify synergies and/or conflicts and then weigh and negotiate trade-offs. This is not prescriptive or intended to provide solutions, but instead offers conceptual guidance and communicates priorities, while recognizing that processes will develop differently for different cities, neighborhoods, and types of UGS. Benchmarks are framed by the question itself and the scenario envisaged by planners and the community. The indicators will inform where green spaces are in relation to the locally defined goals and desired outcomes. This tool therefore moves from the pure technical and normative approach of "*generating the right indicators and then tailoring the solution in order to get the indicators 'back on track*" (Scerri and James, 2010) to a more reflexive constructivist approach. This approach considers that nature is socially constructed and co-created, and its planning and management needs to be adjusted to the local realities (Buizer et al., 2016).

Although an index is more easily comprehended and interpreted than disaggregated information, the proposed scoring and visualization system offers an easy understanding of how a UGS is performing. Not only does it provide this information as an overall perspective, but also for each indicator. Such a visualization may be particularly important for non-technical stakeholders and the general public. They might find it easier to understand an overall index, but this would risk missing the real reasons underlying such an index score. Disaggregated information provides real power and arguments to non-technical stakeholders to discuss and implement solutions that meet their needs and desires.

6. Conclusion

The proposed indicator-based tool brings together essential information that is currently scattered over several tools and offers a policy-driven instrument able to capture trade-offs and/or synergies between ecological, social, and political domains. It includes both top-down and bottom-up indicators that are mostly part of either cities' monitoring systems or are outputs of modern city governance. By suggesting detailed indicators for each dimension and the possibility to establish its own benchmarks, the tool can be used to compare multiple green spaces in a city or even to compare green spaces in different cities. Although proposing informational criteria at the neighborhood or city level, it can also be used at the regional or even global scale. As long as goals and scoring systems are commonly defined, and are agreed and uniform among cities, it can be made clear what means what to whom. The next step to prove the tool's feasibility is to analyze UGS in several cities, and to evaluate how it performs in different contexts. This new tool represents a powerful and holistic instrument that fulfils the demand for tools to assist the decision making processes towards more livable, equitable, sustainable, and resilient cities.

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.

Acknowledgements

This research was supported by the European Commission, 7th Framework Programme Grant GREEN SURGE collaborative project, FP7-ENV.2013.6.2-5-603567 and by Fundação para a Ciência e Tecnologia (FCT) through the doctoral scholarship to P. Gonçalves (PD/BD/106042/2015) and funds to Centre for Ecology, Evolution and Environmental Changes - cE3c (UID/BIA/00329/2013, UID/BIA/00329/2015–2018, UID/BIA/00329/2019 and UIDB/00329/2020). Funding sources were not involved in any decision during this study.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.indic.2021.100131.

References

Ammons, D., 2014. Municipal Benchmarks: Assessing Local Perfomance and Establishing Community Standards: Assessing Local Perfomance and Establishing Community Standards. Routledge.
Andersson, E., Barthel, S., 2016. Memory carriers and stewardship of metropolitan landscapes. Ecol. Indicat. 70, 606–614.
Andersson, E., McPhearson, T., 2018. Making sense of biodiversity: the affordances of systems ecology. Front. Psychol. 9.
Aronson, M.F.J., Lepczyk, C.A., Evans, K.L., Goddard, M.A., Lerman, S.B., MacIvor, J.S., et al., 2017. Biodiversity in the city: key challenges for urban green space management. Front. Ecol. Environ. 15, 189–196.
Arslan, T.V., Durak, S., Aytac, D.O., 2016. Attaining SDG11: can sustainability assessment tools be used for improved transformation of neighbourhoods in historic city centers? Nat. Resour. Forum 180–202.
Bac, M., 1998. Property rights regimes and the management of resources. In: Natural Resources Forum, pp. 263–269.
Beninde, J., Veith, M., Hochkirch, A., 2015 Jun. Biodiversity in cities needs space: a meta-analysis of factors determining intra-urban biodiversity variation. Ecol. Lett. 18 (6), 581–592.
Bjerke, T., Østdahl, T., Thrane, C., Strumse, E., 2006. Vegetation density of urban parks and perceived appropriateness for recreation. Urban For. Urban Green. 5 (1), 35–44.
Blumer, H., 1954. What is wrong with social theory? Am. Socio. Rev. 19 (1), 3–10.
Braubach, M., Egorov, A., Mudu, P., Wolf, T., Thompson, C.W., Martuzzi, M., 2017. Effects of urban green space on environmental health, equity and resilience. In: Kabisch, N., Korn, H., StadlerJ, Bonn, A. (Eds.), Nature-Based Solutions to Climate Change Adaptation in Urban Areas. Springer, pp. 187–205.
Broomhall, M., Giles-Corti, B., Lange, A., 2004. Quality of Public Open Space Tool (POST). School of Population Health, The University of Western Australia.
Brown, D., 2009. Good practice guidelines for indicator development and reporting. In: Third World Forum on 'Statistics, Knowledge and Policy' Charting Progress, Building Visions, Improving Life Busan, Korea.
Buijs, A., Hansen, R., der Jagt, S., Ambrose-Oji, B., Elands, B., Rall, E.L., et al., 2018. Mosaic Governance for Urban Green Infrastructure: Upscaling Active Citizenship from a Local Government Perspective. Urban For Urban Green.
Buizer, M., Elands, B., Vierikko, K., 2016. Governing cities reflexively—the biocultural diversity concept as an alternative to ecosystem services. Environ. Sci. Pol. 62, 7–13.
Byrne, J., Wolch, J., 2009. Nature, race, and parks: past research and future directions for geographic research. Prog. Hum. Geogr. 13, 743–765.
Campbell, L.K., Svendsen, E.S., Sonti, N.F., Johnson, M.L., 2016. A social assessment of urban parkland: analyzing park use and meaning to inform management and resilience planning. Environ. Sci. Pol. 62, 34–44.
Cassatella, C., 2011. Assessing visual and social perceptions of landscape. In: Landscape Indicators: Assessing and Monitoring Landscape Quality. Dordrecht. Springer, pp. 105–140.
Castro Pardo, M de, Urios, V., 2017. A critical review of multi-criteria decision making in protected areas. Econ Agrar y Recur Nat Resour Econ 16 (2), 89–109.
Cattell, V., Dines, N., Gesler, W., Curtis, S., 2008. Mingling, observing, and lingering: everyday public spaces and their implications for well-being and social relations. Health Place 14 (3), 544–561.
Chen, S., Sleipness, O., Yu, Y., Park, K., Christensen, K., 2020. A Systematic Review of Alternative Protocols for Evaluating Non-spatial Dimensions of Urban Parks. Urban For Urban Green, 126718.
Chiang, Y.-C., Li, D., Jane, H.-A., 2017. Wild or tended nature? The effects of landscape location and vegetation density on physiological and psychological responses. Landsc. Urban Plann. 167, 72–83.
Chiesura, A., 2004. The role of urban parks for the sustainable city. Landsc. Urban Plann. 68 (1), 129–138.
Cilliers, E.J., Timmermans, W., den Goorbergh, F., Slijkhuis, J., 2015a. Green place-making in practice: from temporary spaces to permanent places. J. Urban Des. 20 (3), 349–366.
Cilliers, E.J., Timmermans, W., den Goorbergh, F., Slijkhuis, J.S.A., 2015b. The story behind the place: creating urban spaces that enhance quality of life. Appl Res Qual Life 4 (10), 589–598.
Colding, J., 2007. 'Ecological land-use complementation'for building resilience in urban ecosystems. Landsc. Urban Plann. 81 (1), 46–55.
Colwell, R.K., 2009. Biodiversity: concepts, patterns, and measurement. In: Levin, S., Carpenter, S., Godfray, C., Kinzig, A., Loreau, M., Losos, J., et al. (Eds.), The Princeton Guide to Ecology. Princeton University Press Princeton, NJ, USA, pp. 257–263.
Cortinovis, C., Haase, D., Zanon, B., Geneletti, D., 2019. Is urban spatial development on the right track? Comparing strategies and trends in the European Union. Landsc. Urban Plann. 181, 22–37.
Cosquer, A., Raymond, R., Prevot-Julliard, A.-C., 2012. Observations of everyday biodiversity: a new perspective for conservation? Ecol. Soc. 17 (4), 2.
Dallimer, M., Irvine, K.N., Skinner, A.M.J., Davies, Z.G., Rouquette, J.R., Maltby, L.L., et al., 2012. Biodiversity and the feel-good factor: understanding associations between self-reported human well-being and species richness. Bioscience 62 (1), 47–55.
Díaz, S., Cabido, M., 2001. Vive la difference: plant functional diversity matters to ecosystem processes. Trends Ecol. Evol. 16 (11), 646–655.
Díaz, S., Lavorel, S., Chapin, F.S., Tecco, P.A., Gurvich, D.E., Grigulis, K., 2007. Functional diversity—at the crossroads between ecosystem functioning and environmental filters. In: Terrestrial Ecosystems in a Changing World. Springer, pp. 81–91.
Dinnie, E., Brown, K.M., Morris, S., 2013. Community, cooperation and conflict: negotiating the social well-being benefits of urban greenspace experiences. Landsc. Urban Plann. 112, 1–9.
Dronova, I., 2017. Environmental heterogeneity as a bridge between ecosystem service and visual quality objectives in management, planning and design. Landsc. Urban Plann. 163, 90–106.
Dunnett, N., Swanwick, C., Woolley, H., 2002. Improving Urban Parks, Play Areas and Green Spaces. Urban Research Report. Department of Landscape, University of Sheffield Department for Transport, Local Government and the Regions, London, p. 217.
Elands, B.H.M., Peters, K.B.M., de Vries, S., 2018. Promoting social cohesion – increasing wellbeing. In: van den Bosch, M., Bird, M. (Eds.), Oxford Textbook of Nature and Public Health. Oxford University Press, pp. 116–121.
Elands, B.H.M., Vierikko, K., Andersson, E., Fischer, L.K., Gonçalves, P., Haase, D., et al., 2019. Biocultural diversity: a novel concept to assess human-nature interrelations, nature conservation and stewardship in cities. Urban For \& Urban Green. 40, 29–34.
Ellicott, K., 2016. Raising the Standard: the Green Flag Award Guidance Manual. CABE, London.
Elmqvist, T., Fragkias, M., Goodness, J., Güneralp, B., Marcotullio, P.J., McDonald, R.I., et al., 2013. Urbanization, Biodiversity and Ecosystem Services: Challenges and Opportunities: a Global Assessment. Springer.
Elmqvist, T., Bai, X., Frantzeskaki, N., Griffith, C., Maddox, D., McPhearson, T., et al., 2018. The Urban Planet: Knowledge towards Sustainable Cities. Cambridge University Press.
Ersoy, E., 2016. Landscape Ecology Practices in Planning: Landscape Connectivity and Urban Networks.
Florgård, C., 2009. Preservation of original natural vegetation in urban areas: an overview. In: McDonnell, M.J., Hahs, A.K., Breuste, J.H. (Eds.), Ecology of Cities and Towns: a Comparative Approach. Cambridge University Press, New York, pp. 380–398.
Fuller, L., Quine, C.P., 2015. Resilience and tree health: a basis for implementation in sustainable forest management. For An Int J For Res 89 (1), 7–19.
Gaertner, M., Wilson, J.R.U., Cadotte, M.W., MacIvor, J.S., Zenni, R.D., Richardson, D. M., 2017. Non-native Species in Urban Environments: Patterns, Processes, Impacts and Challenges. Springer.
Gavin, M.C., McCarter, J., Berkes, F., Mead, A.T.P., Sterling, E.J., Tang, R., et al., 2018. Effective biodiversity conservation requires dynamic, pluralistic, partnership-based approaches. Sustainability 10 (6), 1–11.
Gidlow, C., van Kempen, E., Smith, G., Triguero-Mas, M., Kruize, H., Gražulevičienė, R., et al., 2018. Development of the Natural Environment Scoring Tool (NEST), vol. 29. Urban For Urban Green, pp. 322–333.
Gonçalves P, Grilo F, Mendes R, Vierikko K, Elands B, Marques T, et al. What's Biodiversity Got to Do with it? Perceptions of Biodiversity and Restorativeness in Urban Parks. Ecol Soc. :(in press)..
Goodness, J., Andersson, E., Anderson, P.M.L., Elmqvist, T., 2016. Exploring the links between functional traits and cultural ecosystem services to enhance urban ecosystem management. Ecol Indic 70, 597–605.
Green, R.J., 2009. Coastal Towns in Transition: Local Perceptions of Landscape Change. Springer Science & Business Media.
Greenberg, C.H., Collins, B., Thompson III, F.R., McNab, W.H., 2011. Introduction: what are early successional habitats, why are they important, and how can they Be sustained?. In: Sustaining Young Forest Communities. Springer, pp. 1–10.
Grilo, F., Pinho, P., Aleixo, C., Catita, C., Silva, P., Lopes, N., et al., 2020. Using green to cool the grey: modelling the cooling effect of green spaces with a high spatial resolution. Sci Total Environ 724, 138182.
Groffman, P.M., Cadenasso, M.L., Cavender-Bares, J., Childers, D.L., Grimm, N.B., Grove, J.M., et al., 2017. Moving towards a new urban systems science. Ecosystems 20 (1), 38–43.
Hansen, R., Pauleit, S., 2014. From multifunctionality to multiple ecosystem services? A conceptual framework for multifunctionality in green infrastructure planning for urban areas. Ambio 43 (4), 516–529.

Harmon, D., Woodley, E., Loh, J., 2010. Measuring status and trends in biological and cultural diversity. Nat Cult Rebuilding a lost Connect eds S Pilgirm JN Pretty, Earthscan. 41–64.
Holland, C., Clark, A., Katz, J., Peace, S., 2007. Social Interactions in Urban Public Places. Policy Press.
I-Tree eco user's manual v.5.0. https://www.itreetools.org/resources/manuals/Eco_Manual_v5.pdf.
InVEST (Integrated Valuation of Ecosystem Services and Tradeoffs) ([Internet])..
Jiang, B., Larsen, L., Deal, B., Sullivan, W.C., 2015. A dose–response curve describing the relationship between tree cover density and landscape preference. Landsc Urban Plan 139, 16–25.
Joseph, R.P., 2016. Comparative analysis of five observational audit tools to assess the physical environment of parks for physical activity. Prev Chronic Dis 13, 2016.
Kabisch, N., Qureshi, S., Haase, D., 2015. Human–environment interactions in urban green spaces—a systematic review of contemporary issues and prospects for future research. Environ Impact Assess Rev 50, 25–34.
Kaczynski, A.T., Stanis, S.A.W., Besenyi, G.M., 2012. Development and testing of a community stakeholder park audit tool. Am J Prev Med 42 (3), 242–249.
Kaye-Blake, W., Smith, M., Stirrat, K., 2017. Signs to Look for: Criteria for Developing and Selecting Fit for Purpose Indicators.
Keniger, L.E., Gaston, K.J., Irvine, K.N., Fuller, R.A., 2013 Mar. What are the benefits of interacting with nature? Int J Environ Res Public Health 10 (3), 913–935.
Knobel, P., Dadvand, P., Maneja-Zaragoza, R., 2019. A systematic review of multi-dimensional quality assessment tools for urban green spaces. Health Place 59, 102198.
Kowarik, I., 2011. Novel urban ecosystems, biodiversity, and conservation. Environ Pollut 159 (8), 1974–1983.
Kowarik, I., von der Lippe, M., 2018. Plant population success across urban ecosystems: a framework to inform biodiversity conservation in cities. J Appl Ecol 55 (5), 2354–2361.
Krasny, M.E., Tidball, K.G., 2012. Civic ecology: a pathway for Earth Stewardship in cities. Front Ecol Environ 10 (5), 267–273.
Le Roux, D.S., Ikin, K., Lindenmayer, D.B., Manning, A.D., Gibbons, P., 2014. The future of large old trees in urban landscapes. PLoS One 9 (6) e99403.
Loukaitou-Sideris, A., 1995. Urban form and social context: cultural differentiation in the uses of urban parks. J Plan Educ Res 14 (2), 89–102.
Lovell, S.T., Johnston, D.M., 2009. Designing landscapes for performance based on emerging principles in landscape ecology. Ecol Soc 14 (1), 44.
Lovell, S.T., Taylor, J.R., 2013. Supplying urban ecosystem services through multifunctional green infrastructure in the United States. Landsc Ecol 28 (8), 1447–1463.
Lovell, R., Wheeler, B.W., Higgins, S.L., Irvine, K.N., Depledge, M.H., 2014. A systematic review of the health and well-being benefits of biodiverse environments. J Toxicol Environ Health B Crit Rev 17 (1), 1–20.
Lovett, G.M., Turner, M.G., Jones, C.G., Weathers, K.C. (Eds.), 2005. Ecosystem Function in Heterogeneous Landscapes. Springer, New York.
Lu, Y., Wang, R., Zhang, Y., Su, H., Wang, P., Jenkins, A., et al., 2015. Ecosystem health towards sustainability. Ecosyst Heal Sustain 1 (1), 1–15.
Lu, Y., Sarkar, C., Xiao, Y., 2018. The effect of street-level greenery on walking behavior: evidence from Hong Kong. Soc Sci Med 208, 41–49.
Luck, G.W., Smallbone, L.T., O'Brien, R., 2009. Socio-economics and vegetation change in urban ecosystems: patterns in space and time. Ecosystems 12 (4), 604–620.
Luz, A.C., Buijs, M., Aleixo, C., Metelo, I., Grilo, F., Branquinho, C., et al., 2019. Should I Stay or Should I Go? Modelling the Fluxes of Urban Residents to Visit Green Spaces. Urban For Urban Green.
Manzo, L.C., Perkins, D.D., 2006. Finding common ground: the importance of place attachment to community participation and planning. J Plan Lit 20 (4), 335.
Mayoux, L., 2001. Participatory methods. EDIAIS Appl. Guid. Note. https://watsanmissionassistant.org/wp-content/uploads/2018/08/participatory-methods-_linda-mayoux.pdf.
Mayoux, L., 2006. Quantitative, qualitative or participatory? Which method, for what and when? In: Desai, V., Potter, R.B. (Eds.), Doing Development Research. SAGE Publications, Ltd, London, pp. 115–129.
McCann, E.J., 2002. The cultural politics of local economic development: meaning-making, place-making, and the urban policy process. Geoforum 33 (3), 385–398.
McCormack, G.R., Rock, M., Toohey, A.M., Hignell, D., 2010 Jul. Characteristics of urban parks associated with park use and physical activity: a review of qualitative research. Health Place 16 (4), 712–726.
McMillen, H., Campbell, L.K., Svendsen, E.S., 2018. Weighing Values and Risks of Beloved Invasive Species: the Case of the Survivor Tree and Conflict Management in Urban Green Infrastructure. Urban For Urban Green.
McPhearson, T., Haase, D., Kabisch, N., Gren, Å., 2016a. Advancing Understanding of the Complex Nature of Urban Systems. Elsevier.
McPhearson, T., Pickett, S.T.A., Grimm, N.B., Niemelä, J., Alberti, M., Elmqvist, T., et al., 2016b. Advancing urban ecology toward a science of cities. Bioscience 66 (3), 198–212.
Mehta, V., 2008. Walkable streets: pedestrian behavior, perceptions and attitudes. J Urban 1 (3), 217–245.
Mehta, V., 2014. Evaluating public space. J Urban Des 19 (1), 53–88.
Mills, L.S., Soulé, M.E., Doak, D.F., 1993. The keystone-species concept in ecology and conservation. Bioscience 43 (4), 219–224.
Oliver, T.H., Heard, M.S., Isaac, N.J.B., Roy, D.B., Procter, D., Eigenbrod, F., et al., 2015. Biodiversity and resilience of ecosystem functions. Trends Ecol Evol 30 (11), 673–684.
O'Farrell, P.J., Anderson, P.M.L., Le Maitre, D.C., Holmes, P.M., 2012. Insights and opportunities offered by a rapid ecosystem service assessment in promoting a conservation agenda in an urban biodiversity hotspot. Ecol Soc 17 (3), 27.
Paloniemi, R., Niemelä, J., Soininen, N., Laatikainen, T., Vierikko, K., Rekola, A., et al., 2018. Environmental justice for the governance of aquatic environments. Local Environ 23 (3), 366–377.
Peh KS-H, Balmford AP, Bradbury RB, Brown C, Butchart SHM, Hughes FMR, et al. Toolkit for Ecosystem Service Site-Based Assessment (TESSA). Version 2.0 Cambridge, UK.
Patton, M.Q., 2015. What to observe: sensitizing concepts. In: Qualitative Research & Evaluation Methods: Integrating Theory and Practice, pp. 358–363.
Persic, A., Martin, G.J., 2008. Links between Biological and Cultural Diversity-Cconcepts, Methods and Experiences, Report of the 2007 International Workshop. United Nations Educ Sci Cult Organ Paris.
Peters, K., 2010. Being together in urban parks: connecting public space, leisure, and diversity. Leis Sci 32 (5), 418–433.
Peters, K., Elands, B., Buijs, A., 2010. Social interactions in urban parks: stimulating social cohesion? Urban For Urban Green 9 (2), 93–100.
Peterson, G., Allen, C.R., Holling, C.S., 1998. Ecological resilience, biodiversity, and scale. Ecosystems 1 (1), 6–18.
Pickett, S.T.A., Cadenasso, M.L., Childers, D.L., McDonnell, M.J., Zhou, W., 2016. Evolution and future of urban ecological science: ecology in, of, and for the city. Ecosyst Heal Sustain 2 (7).
Pretty, J., Adams, B., Berkes, F., De Athayde, S.F., Dudley, N., Hunn, E., et al., 2009. The intersections of biological diversity and cultural diversity: towards integration. Conserv Soc 7 (2), 100.
Rapport, D.J., Hildén, M., 2013. An evolving role for ecological indicators: from documenting ecological conditions to monitoring drivers and policy responses. Ecol Indic 28, 10–15.
Saaty, R.W., 1987. The analytic hierarchy process—what it is and how it is used. Math Model 9 (3–5), 161–176.
Salick, J., Konchar, K., Nesbitt, M., 2014. Curating Biocultural Collections: a Handbook. Kew Publishing.
Scerri, A., James, P., 2010. Accounting for sustainability: combining qualitative and quantitative research in developing 'indicators' of sustainability. Int J Soc Res Methodol 13 (1), 41–53.
Schebella, M.F., Weber, D., Schultz, L., Weinstein, P., 2019. The wellbeing benefits associated with perceived and measured biodiversity in Australian urban green spaces. Sustainability 11 (3), 802.
Schlaepfer, M.A., 2018. Do non-native species contribute to biodiversity? PLoS Biol 16 (4) e2005568.
Scotland, G., 2008. Greenspace Quality: a Guide to Assessment, Planning and Strategic Development. Greensp Scotland, Stirling.
Seaman, P.J., Jones, R., Ellaway, A., 2010. It's not just about the park, it's about integration too: why people choose to use or not use urban greenspaces. Int J Behav Nutr Phys Act 7, 78.
Shugart, H.H., 1998. Terrestrial Ecosystems in Changing Environments. Cambridge University Press, Cambridge, UK. Cambridge.
Sikor, T., He, J., Lestrelin, G., 2017. Property rights regimes and natural resources: a conceptual analysis revisited. World Dev 93, 337–349.
Smaldone, D., 2007. The role of time in place attachment. In: Burns, R., Robinson, K. (Eds.), Proceedings of the 2006 Northeastern Recreation Research Symposium. Newtown Square, PA: U.S., pp. 47–56
Soga, M., Gaston, K.J., 2016. Extinction of experience: the loss of human–nature interactions. Front Ecol Environ 14 (2), 94–101.
Southworth, M., 2005. Designing the walkable city. J urban Plan Dev 131 (4), 246–257.
Space, C., 2004. Green Space Strategies: a Good Practice Guide.
Sterling, E.J., Filardi, C., Toomey, A., Sigouin, A., Betley, E., Gazit, N., et al., 2017a. Biocultural approaches to well-being and sustainability indicators across scales. Nat Ecol Evol 1 (12), 1798.
Sterling, E., Ticktin, T., Morgan, T.K.K., Cullman, G., Alvira, D., Andrade, P., et al., 2017b. Culturally grounded indicators of resilience in social-ecological systems. Environ Soc 8 (1), 63–95.
Stokland, J., Siitonen, J., Jonsson, B., 2012. Biodiversity in Dead Wood (Ecology, Biodiversity and Conservation). Cambridge University Press, Cambridge, UK.
Tuan, Y.-F., 1975. Place: an experiential perspective. Geogr Rev 151–165.
Tweed, C., Sutherland, M., 2007. Built cultural heritage and sustainable urban development. Landsc Urban Plan 83 (1), 62–69.
Van Herzele, A., Wiedemann, T., 2003. A monitoring tool for the provision of accessible and attractive urban green spaces. Landsc Urban Plan 63 (2), 109–126.
Van Oijstaeijen, W., Van Passel, S., Cools, J., 2020. Urban green infrastructure: a review on valuation toolkits from an urban planning perspective. J Environ Manage 267, 110603.
Vierikko, K., Gonçalves, P., Haase, D., Elands, B., Ioja, C., Jaatsi, M., et al., 2020. Biocultural diversity (BCD) in European cities–Interactions between motivations, experiences and environment in public parks. Urban For Urban Green 48, 126501.
Voigt, A., Wurster, D., 2014. Does diversity matter? The experience of urban nature's diversity: case study and cultural concept. Ecosyst Serv 12, 200–208.
von Döhren, P., Haase, D., 2015. Ecosystem disservices research: a review of the state of the art with a focus on cities. Ecol Indic 52, 490–497.
Werner, P., 2011. The ecology of urban areas and their functions for species diversity. Landsc Ecol Eng 7 (2), 231–240.
Wilson, A., Kendal, D., Moore, J.L., 2016. Humans and ornamental plants: a mutualism? Ecopsychology 8 (4), 257–263.
Wong, C., 2003. Indicators at the crossroads: ideas, methods and applications. Town Plan Rev 74 (3), 253–279.

Wong, C., 2015. A framework for 'City Prosperity Index': linking indicators, analysis and policy. Habitat Int 45, 3–9.
Yin, H., Kong, F., Hu, Y., James, P., Xu, F., Yu, L., 2016. Assessing growth scenarios for their landscape ecological security impact using the SLEUTH urban growth model. J Urban Plan Dev 142 (2), 5015006.
Yli-Pelkonen, V., Kohl, J., 2005. The role of local ecological knowledge in sustainable urban planning: perspectives from Finland. Sustain Sci Pract Policy 1 (1).
Zhang, Y., 2017. How Urban Green Spaces Relate to Health and Well-Being. University of Groningen.
Zuniga-Teran, A.A., Orr, B.J., Gimblett, R.H., Chalfoun, N.V., Going, S.B., Guertin, D.P., et al., 2016. Designing healthy communities: a walkability analysis of LEED-ND. Front Archit Res 5 (4), 433–452.