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Analysis of urban open space ecology in the perception of social fitness and comfort

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ABSTRACT

This study aimed at examining the influence of urban open spaces in facilitating the social fitness and comfort of urban dwellers in their quest to recreate. To achieve this, measures, contemporary articles, published on urban open space and social fitness and comfort, highlighting researches that attempted to quantify biodiversity and other open space perceptions significant to urban ecological restoration and conservation, were investigated. The researchers conducted a wide range of assessment of existing literature to ascertain forms of urban open space and social fitness and comfort features, and employ a study charting format to identify study priorities and gaps. The researchers thus established a more detailed analysis of designated studies that engage various and advanced approaches to ascertain further ecological phases of urban open space and then appraise the usefulness of these methods in evolving urban restoration concepts and performances influencing both man and his environment.

Keywords: Urban open space, biodiversity, social fitness, comfort, urban ecology, green infrastructure.
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INTRODUCTION

Sequel to the trend of dearth of urban recreational open space in the developing world, there is the need to examine the need and usefulness of urban open spaces, especially in ensuring social fitness and comfort of urban users. Terry (2013) in his recent findings on the non-functionality of urban open spaces in Nigeria noted with dismay that most urban dweller's preference for open spaces and recreational interests is fast dwindling due to lack of fitness and comfort. This, according to him, was as a result of improper facility management and factors relating to location and distance.

Furthermore, it is a common sight for urban dwellers to resort to hoteling and ancillary services in a bid to recreate and this has led to the decay of available urban open space services, even on a daily basis (Richard, 2016). Talman (2013) in his findings on urban open space, submitted that the lack of due consultation and consideration by the open space providers in order to put in place the users taste, comfort and social inclinations, do contributes immensely to the none participation of urban residents in recreational matters, especially, as most of the policies are inconsequential and lacks foresight and forethought in the provision and design of urban open spaces. It is against this backdrop that this study is being conducted to synthesize the influence of urban open space in ensuring social fitness and comfort of urban users, especially in the developing countries.

The advantages of nature to social fitness and wellbeing, in the western world, dates back, at least, to two eras, until the advent of landscape perception and analysis in the 1960s which considered the benefits very subjective in terms of data quantification. Berger-Ford and Anthony (2012) measured people's inclinations for natural over urban sights, afterward, researchers started developing models to predict open space preferences centered on the biophysical, psychological, and artistic properties of

vegetation and other landscape elements (Bicano, 2015). These included psycho-evolutionary models that suggested humans preferring savannah-like landscapes characterized by open glades with smooth ground texture, enclosed by clusters of mature trees (Brown, 2008), and that vegetation type are associated with more bio-diverse landscapes like rough ground cover, woodland edge, or scrub were generally lower in preference (Bolivar and Henniker, 2014).

In this study, the researchers took a first step in addressing these objectives by examining how researchers have measured predominantly urban open space in the context of social fitness and comfort with reference to a broad spectrum of urban open spaces, but especially the more structurally complex and bio-diverse natural environments associated with ecological restoration. Our approach relies on an assessment of recent research literature, classifying the types of open space measures that are being used and mapping them with measures of social fitness and comfort also under consideration. As well as mapping the open space measures against social fitness and wellbeing outcomes, the researchers considered the effectiveness of these measures in enhancing user's health and comfort. If urban areas are to bring the possible benefits from a range of open spaces within its milieu, it is necessary that pertinent and expressive open space strategies be established.

Research on urban open spaces and social fitness and wellbeing has gone beyond its traditional emphasis on landscape preference, thus social and public health scholars have been investigating how various aspects of social fitness and comfort are influenced by exposure to open spaces (Bicano, 2015; Colman and Roberto, 2016).

Open space, open land, and its somatic concealment form the dominant part of urban ecosystems. To improve the role and maintenance of urban ecosystems, ecologists and land managers contend that open space must be more than the trimmed grass and decorative tree plantings that characterizes managed open space in most cities (Stacts et al. 2014). But while restoration establishes a set of principles and practices for increasing the ecological values of urban open space, those involved in urban ecological restoration are becoming increasingly aware of the need to take into account its social values, including the health and comfort dimension (Brown, 2008).

In the same vein, there has been a growing focus on the ecological health of urban systems more generally, and researchers in urban ecology, urban ecological restoration, and other fields have developed concepts and practices for measuring and managing urban land cover to maintain hydrological function, promote air quality, regulate microclimate, sequester carbon, and preserve species and habitat diversity (Bolivar and Henniker, 2014). A major obstacle connecting these two lines of research has been the lack of suitable metrics to measure the characteristics of open spaces against the full range of desired human and ecological benefits (Francisco, 2017).

This study is fashioned at examining the influence of urban open spaces in facilitating the social fitness and comfort of urban dwellers in their quest to recreate. The objectives of this study, therefore, are: (1) To determine how urban open spaces directed at social fitness and comfort are theorised and measured? (2) To ascertain the use of open space concepts and measures in line with human benefit and outcomes? (3) To determine the methods that are most beneficial in the academic study of urban green (open space) ecology?

METHODOLOGY

The review of related works and analysis was consequent upon a sample of recently published studies on urban open space and social fitness and wellbeing relationships. As described earlier, urban open spaces establish many human and environmental benefits, and a recent review by Catherine and Thompson (2012) divided the literature search into five broad categories: health and comfort, social and community, economic values, environmental quality, and planning and design (including perceptions and preferences). While the economic and environmental aspects are clearly crucial in building a more holistic view of human-open space relationships, the other three categories identified by Bell et al. (2016). We developed a three-step strategy to identify the study sample. First, we conducted an electronic search of the literature using the Scopus database. Therefore, as a second step in identifying the study sample, the researchers adopted a more purposive approach by assembling a collection of literature already known about and then supplemented it by using "snowballing" techniques such as scanning reference lists of articles for promising citations.

To analyse study objectives 1 and 2 of the study, the researchers developed preliminary terminology for categorizing open space and social fitness and comfort measures. The researchers read a portion of the sample studies and for each paper wrote a short description of its open space and human measures along with coding classification. We discussed the coding and adjusted our nomenclature until we felt comfortable that they were meaningful and could be used consistently. These nomenclatures are set out in Tables 1 and 2. To help make sense of the findings from this classification coding, we used a variant of the research mapping process described by Christopher et al. (2017). For this process, coding information for the studies was tabulated in an open space by human benefit matrix. According to Bicano (2015) examining the distribution of studies across the various cells of the matrix can help reveal research priorities and gaps.

Table 1. Classification of Open space Measures.

Code	Definition
None	Open space is the focus of study but no attempt is made to measure, vary, or describe its characteristics.
Urban versus natural	Research design compares exposure to urban and natural settings.
Descriptive/ narrative	Qualitative description of open space by research participant without categorization.
Area/Distance	Quantity or proximity of open space, usually with reference to research participants' homes. Objective measure or self-report.
Biophysical	Presence/quantity of specific landscape elements (e.g. vegetation, % open land) or interventions with different landscape outcomes (e.g. forest management plans). Covers most physical measures falling short of biodiversity. Objective and/or self-report. May be inherent in the stimulus (e.g. % vegetation manipulated in the research design) or explicit in the measure (e.g. vegetation density within a given area).
Human perceptual	Categorizations based on cultural constructs/descriptors/values (e.g., quality of open space, naturalness (unless linked to a biodiversity measure), openness). Landscape types. May be inherent in the stimulus or explicit in the measure or both. Objective measure or self-report.
Biodiversity	Objective measure of plant/animal diversity (or close proxy), or where the concept of "biodiversity" is being evaluated.

Source: Anna and Paul, (2010).

Table 2: Classification of Social Fitness and Comfort Measures Code Definition.

Code	Definition
Preference	Participants are asked to rate the attractiveness of different landscape scenes or scenarios, or their suitability for a particular activity.
Attitudes, Meanings, and Values	Spans a range of methodologies from quantitative, in which participants are asked for their level of agreement with attitudinal statements, to qualitative approaches, in which underlying meanings and values are explored.
Psychological Benefits	Self-rated or objectively measured psychological health or other psychological measure including restoration and affective responses to landscape.
Physical health	Self-rated or objectively measured physical health.
Behaviour	Behavioural patterns or changes e.g. physical activity, walking.
Mixed	Several human measures with no overall focus on one aspect.
Others	Other human measures (e.g. socio-economic variables, etc).

Source: Anna and Paul, (2010).

To examine research objectives 3, the researchers selected 30 studies from among the 182 that we felt represented diverse and innovative approaches to measuring the more ecological aspects of urban open space and conceptualizing the issues. By reading and discussing these studies, we aimed to highlight in a more qualitative way the major methodological approaches, assess their success and limitations and suggest ways in which current and future work can develop holistic measures that function in an interdisciplinary context to address both the social and ecological dimensions of urban open space.

Inventory as a measure was engaged in the least number of studies (n=9) and was spread across human measures of psychological benefits and behaviour and in studies with mixed measures. They entailed of a somewhat heterogeneous list of items, many of which did not relate to open space at all. The study used the descriptive/narrative open space measure (n=21) to categorize qualitative studies where the open space measures or themes were derived from the research participants rather than imposed by the investigators.

On the last note, the word comfort has been giving many explanations. For instance, Richard (2016) limited health and wellbeing literature to the health domain, whereas in Colman and Roberto (2016) comfort specified a much wider range of human benefits, including cultural values, to which ecosystem services depends. Therefore, health and comfort in this study center on literature that relates to health and comfort, social and community health and comfort, perceptions and preferences.

RESULTS and DISCUSSION

Following the aim of the study, the results of the study in

Table 3. Open space by social fitness and comfort.

Measures	Preference	Attitudes, meanings and values	Psychological benefits	Physical health	Behaviour	Mixed	Other	Total
None	1	23	3	3	1	3	0	34
Urban versus natural	1	2	15	0	1	1	0	20
Inventory	1	0	3	0	3	2	0	9
Descriptive/narrative	0	12	3	0	3	2	1	21
Area/distance	0	2	1	11	4	1	3	22
Biophysical	14	4	2	0	2	0	2	24
Human perceptual	8	6	4	2	1	2	0	23
Biodiversity	10	14	1	0	0	1	3	29
All measures	35	63	32	14	17	12	9	182

Table 3, suggests some clear associations between the open space and social fitness and comfort measures, with each open space measure, mapping predominantly onto one or two closely-related human domains. For instance, the accruable benefits of social fitness and comfort that open space provides are lacking generally, and this has affected attitudes, meanings and values that urban dwellers place on the available urban open space. Also, studies without any open space measures (*none*, n=34) tends to map with human measures of *attitudes, meanings, and values.* Within this grouping, the emphasis was on understanding attitudes toward a range of issues, both in relation to specific sites and to more generic conceptualizations of open space and nature. For example, Hope and Katy (2015) examined the non-physical traditions that Australian immigrant groups have toward nature in the context of the Georges River park site in southwest Sydney, Australia; Peterson (2017) assessed urban dwellers' beliefs, attitudes, and awareness toward the idea of urban ecological restoration in Chicago, USA; and Petrane and Bose (2017) looked at how activities in nature were rated by students in relation to housing and leisure activities. The *urban against natural* measures (n=20) were used mainly in studies of the *psychological benefits* derived from exposure to environmental settings. Across this sample of studies, the dichotomy was operationalized in a variety of ways, including comparing the benefits of running in urban or rural settings (Stacts et al. 2014); or indoors on a treadmill and outside in natural surroundings (Talman, 2013); of being in rooms with tree views or no views (Richard, 2016); and exposure to urban as opposed to natural settings depicted in videos (Paulson and Samuela, 2017), or slides (Talman, 2013).

Inventory as a measure was used in the least number of studies (n=9) and was spread across human measures of *psychological benefits* and *behaviour* and in studies with *mixed* measures. They consisted of a somewhat eclectic list of items, many of which did not relate to open space at all. For example, Terry (2013) used a 26-item neighbourhood open space scale, which included *trees and plants that are attractive*, to identify neighbourhood attributes that predicted the level of walking in people above the age of 65. We used the *descriptive/narrative* open space measure (n=21) to categorize qualitative studies where the open space measures or themes were derived from the research participants rather than imposed by the investigators. Most studies using this type of open space measure mapped with studies of *attitudes, meanings, and values*.

Table 3 shows that the accruable benefits of social fitness and comfort that open spaces provide, lacks is generally lacking, and this has affected attitudes, meanings and values that urban dwellers place on the available urban open space. The studies covered a wide range of research topics and consequently, there was very little consistency in the themes reported. "*Area/distance*" (n=22) was used as an open space measure mainly in studies examining people's "*physical health*" and "*behaviours*," wherein this context behaviours referred to physical activity, especially walking. In this cluster of studies, open space was measured either in terms of its proximity to the residence of a research participant (Cochrane et al., 2009; Takano et al., 2012), or its quantity in terms of area or amount of open space within a given radius from one's residence (Thomas, 2015; Brown, 2008; Hope and katy, 2015) or within an administrative district that included residences (Wallington, 2013). In some studies, measures of area and distance were combined (Bicano, 2015).

Biophysical measures (n=24) mapped predominantly to studies of human *preference* and, to a lesser extent, *attitudes, meanings, and values*. For studies coded in this open space category, the focus was on assessing preferences for or acceptability of specific approaches and practices of landscape planning and management.

Table 4. Dominant Approaches in Determining Ecological Aspects of Urban Open Space.

Domain/Variable	Score	% (0.0)
Human perception	4	13.3
Descriptive/narrative	1	3.3
Biodiversity	18	60.0
Biophysical	7	23.4
Total	30	100

Biophysical measures included the percentage of open land in the view and the size of landscape *rooms* in a study of landscape scale (Xenia and Ditropan, 2016), the spatial arrangement of trees in brownfield rehabilitation scenarios (Paulson and Samuela, 2017), and the specification of different options for managing urban forests (Velarine et al. 2017). As in the case of biophysical measures, human perceptual measures of open space (n=23) mapped mainly to studies of *preference* and *attitudes, meanings, and values*.

As cultural constructs of physical open space characteristics, human perceptual measures were not objectively measured or systematically manipulated in the research design, and for our sample of studies were either predefined by the investigator (in the case of *preference* studies), or identified by the investigator or the participant (in studies of *attitudes, meanings, and values*). These measures thus ranged from participant-defined and context-specific to more abstract and generalized. For example, Hope and Katy (2015) mapped residents' perceptions of the qualities of their local woodlands (for instance, tranquillity, the feeling of being in a forest, and naturalness), and Peterson (2017) asked participants to rate photographs of different landscape types for preference and naturalness. The more generalized investigator-defined measures included dimensions based on Thomas (2015) preference matrix (Colman and Roberto, 2016) principles for the aesthetics of ecological design (Francisco, 2017), and the presence of human influence (Petrane and Bose, 2017) and signs of care in the landscape (Terry, 2013).

Lastly, *biodiversity* open space measures (n=29) also mapped mainly to studies of *preferenc*e and *attitudes, meanings, and values*. Biodiversity included measures of actual plant and animal diversity (Brown, 2008; Berger-Ford and Anthony, 2012), as well as surrogate measures used in remote sensing, such as NPP (Net Primary Productivity) as an indicator of species diversity and biological productivity (Bolivar and Henniker, 2014), and the NDVI (Normalized Differential Vegetation Index) as an indicator of the percentage of vegetated area per setting (Christopher et al., 2017). Other proxies for biodiversity included structural complexity, evaluated at a site level by Wallington (2013) to study preferences for open spaces around social housing; and landscape heterogeneity, mapped by Richard, (2016) at a landscape scale using remote sensing to study aesthetic appreciation/experience and cultural heritage values.

Another approach was to contrast preferences or attitudes toward various scenarios for the enhancement of biodiversity in different contexts, such as the design of residential subdivisions in the United States (Catherine and Thompson, 2012) or business sites in the Netherlands (Peterson, 2017). A further approach was to assess the impact of levels of structural alteration in naturally-occurring vegetation communities on viewer preference (Velarine et al., 2017) and judgments of naturalness (Lamb and Purcell, 1990). As applied to our sample of the literature, the research mapping exercise established characterization of how urban open space has been theorised and measured to address issues of social fitness and comfort. While our narrative focused on the dominant conceptual combinations in our sample, the matrix in Table 3 also shows areas where there has been less research activity. These gaps, according to Francisco (2017), can suggest priorities for future research. There has, for example, been virtually no research into the impact of biodiversity in open spaces on psychological benefits, including psychological restoration, physical health, or behaviour, with the notable exception (Stacts et al., 2014).

From the samples, we selected for in-depth analysis a shortlist of 30 studies that made used innovative approaches to address the ecological aspects of urban open space in the context of social fitness and comfort or highlighted some of the key issues in using open space measures in inter-disciplinary research. Table 4 shows these studies were dominated by *biodiversity* (n=18) measures of urban open space, but also included measures from the *biophysical* (n=7), *human perceptual* (n=4), and *descriptive/narrative* (n=1) domains. In terms of the human measures, they mapped mainly onto *preference* and *attitudes, meanings, and values.* The following discussion focuses on how open space characteristics are measured and how alternatives for open space design and management are represented to people for evaluation.

In terms of the way biodiversity is measured in our shortlisted sample of papers, a rough distinction can be made between approaches that seek to measure biodiversity on-site and those deploying landscape metric proxies for biodiversity. Examples of the former approach

include Peterson (2017), in which 6 different measures of biodiversity were used to study the association between biodiversity and the income level of residents in the 36 metropolitan boroughs of Christopher et al. (2017), in which plant and bird diversity were mapped against the income levels of residents of Phoenix, Arizona, U.S.A., in which urban parks along a transect in Sheffield, U.K. were sampled, inter alia, for plant and bird species richness to explore the links between biodiversity and the psychological benefits experienced by park users.

The main advantages of site-based biodiversity measures seem to be accuracy and site specificity. However, there is no single readily identifiable measure of biodiversity. In human dimensions research, there is an additional question as to which indicator or combination of indicators has a measurable impact on humans. This may be a question of scale: if the measures are too fine (e.g. where the organisms under investigation are too small, too specialized, or the sampling too localized) or too coarse (e.g. where the spatial unit of measurement is too big), they may be outside the scale of human comprehension (Bicano, 2015). Paulson and Samuela (2017) found that wetland visitors' reports of the frequency with which they saw wildlife were highly correlated with expert-based plant and bird species richness values.

Boliva and Henniker (2014) concluded that open space users were able to perceive species richness of well-known higher taxa, but also hypothesized that users detect biodiversity indirectly: gross structural habitat heterogeneity might cue the perceptions and benefits of biodiversity. There is considerable support for this more broadly based *structural heterogeneity* hypothesis, including Australian studies which have found that viewers (students and storekeepers) were able to discriminate between different naturally-occurring structural vegetation types and different forms of structural alteration within those types (Velarine et al., 2017).

Perhaps one of the greatest drawbacks of a site sampling approach to biodiversity measurement in social science research is its resource intensiveness. Francisco (2017) protocol for measuring herbaceous plant species richness involved sampling 15 open spaces using 20 quadrats per habitat type up to a maximum of 7 habitat types—a hypothetical maximum of 2,100 quadrats. Woody plant species were sampled using a similar protocol, adding to the sampling load. Another limitation is that if landscape change is to be monitored, the whole sampling procedure has to be repeated.

In contrast to on-site measures of biodiversity, our shortlist also included a number of proxy approaches to biodiversity using remote sensing and GIS. Some of these approaches have already been mentioned in our findings on the full sample of studies (Brown, 2008; Hope and Katy. 2015). Other remote sensing approaches have used structural heterogeneity or equivalent measures as key variables, lending additional support to Francisco (2017) structural heterogeneity hypothesis. Hope and Katy (2015) used the Normalized Difference Vegetation Index (NDVI) method applied to IKONOS multispectral images to measure the impact of fragmentation, distance, permeability, variability, and connectivity of tree patches on neighbourhood satisfaction. In an ambitious multidisciplinary study, Terry (2013) used mapped landscape heterogeneity as a proxy for biodiversity in assessing aesthetic and cultural heritage values in the landscape.

While proxy approaches have obvious pragmatic advantages in terms of being able to use remote sensing data that is often readily available and regularly updated, the Colman and Roberto (2016) study also highlight two problems in using such approaches in interdisciplinary landscape research. The first is that of moving from a two-dimensional, map-based worldview to a ground-level representation that relates to the normal human experience of landscape. While landscape heterogeneity and cultural heritage values may be mapped in two dimensions in the GIS, human aesthetic landscape values derive from being able to experience or at least see, that landscape at a specific location. The second problem is that while GIS can store and display complex information about large-scale, spatially-related resources, human perception tends to operate at a much smaller scale and is constrained by factors not ordinarily recognized in the GIS, such as visual barriers or structures affecting physical movement. In the previously mentioned study by Brown (2008), the authors state that not enough is known about the critical scales at which humans experience their residential environment, and the same critique can be extended to virtually any environment.

Peterson (2017) attempted to address these problems by asking a small sample of students to evaluate the aesthetic value of typical ground-level images of the landscapes included in the GIS analysis. But the content of such images is clearly crucial, and sampling must be done systematically, or images must be digitally manipulated, to ensure that the landscape is thoroughly and consistently represented. The latter approach was used by Petrane and Bose (2017), who used computer-generated visualizations of a hypothetical landscape containing pasture and broadleaved woodland to explore the relationships between viewer preference and three landscape-level indicators of naturalness - the level of succession, number of woodland patches, and shape index of edges. Preference was strongly related to the level of succession and number of woodland patches, and more weakly with the shape index of edges. This work seems to address some of the difficulties in translating mapped landscape indicators into visually comprehensible representations that people can respond to. Presumably, if we can use remote sensing data and GIS to extract the critical metrics of landscapes, we can

construct a virtual landscape based on those metrics.

Christopher et al. (2017) also exemplify what may broadly be termed the scenario manipulation approach. These scenarios used visual images to present open space planning, design, and management alternatives to study participants for evaluation (usually expressed in preference ratings). The scenarios ranged from highly structured alternatives where open space images were digitally manipulated in a systematic way along one or more variables, to less structured approaches that presented people a range of real-world examples illustrating alternatives without systematic measurement or control of extraneous variables. Hands and Brown (2008) also used digitally altered images to assess employees' reactions to different ecological rehabilitation scenarios of their workplace in Niagara Falls, Canada, demonstrating how visual images and biodiversity or biophysical measures can be used in a focused way to systematically study practical interventions at a site level.

Examples of a less structured, photo-based approach includes studies by Velarine et al. (2017), who used 24 photographs to represent a rough gradient of landscapes with differing natural/urban content and different levels of management in a study of preference and attitudes toward quotidian landscapes around the workplace in Wallington (2013); and Xenia and Detropan (2016), who used a set of 24 photographs to represent different urban forest management options, demonstrating how the scenario manipulation approach may be used in participatory planning. Talman (2013) used a structured approach to compare expert ratings of ecological quality and public evaluation of visual attractiveness in the context of river restoration. The authors comment on the lack of suitable reference scales for varying states of ecological integrity. In this case they used the concept of eco-morphological quality (essentially the structural state of river reaches), an approach to river restoration based on the pre-existing module-step concept (Bicano, 2015) as the basis for constructing a series of digitally manipulated photographs depicting a river in an artificial, semi-artificial, semi-natural, and near-natural condition. The study is noteworthy for a number of reasons.

Some of the scenario manipulation approaches in our sample also examined cultural and demographic differences in preference as a function of vegetation density and biodiversity. Hope and Katy (2015) measured Norwegian urban residents' recreational preferences for urban park landscapes using photographs varying in vegetation density and examined preference variations as a function of demographic and environmental value orientations. Paulson and Samuela (2017) asked Swiss residents to rate visualizations of potential landscape developments under four different scenarios representing a variety of biodiversity management and reforestation options and to answer a number of text items dealing with biodiversity concepts and values.

The final example in our shortlisted set of studies by Richard (2016) relied entirely on a textual description. In the study, a mail survey was used to elicit views about the types of nature that people distinguish and the levels of naturalness ascribed to these types of nature; the images that people hold of the appropriate relationship between people and nature and the level of adherence to these images; and people's preference of broadly defined landscape types. This study fills a gap between landscape preference studies and people's views of nature. While at first glance the textual measures used seem somewhat abstract, like in Terry (2013) and Bicano (2015), this open-ended approach can help assess the complex cultural *visions of nature* that underpin open space preferences. Their abstraction allowed participants to introduce their own content into the descriptions. This technique may have wider applications in terms of situating people's open space preferences and values within a broader cultural context.

This study aimed at examining the influence of urban open spaces in facilitating the social fitness and comfort of urban dwellers in their quest to recreate. The researchers explored recent researches on urban open space in the context of social fitness and comfort. The result of the study shows an association between the open space and social fitness and comfort measures, with each open space measure mapping predominantly onto one or two closely-related human domains. It was further discovered that the accruable benefits of social fitness and comfort that open spaces provide, lacks generally, and this has affected attitudes, meanings and values that urban dwellers place on the available urban open space.

The analysis further revealed a range of relatively intricate measures being used to assess the biophysical, human perceptual, and biodiversity characteristics of urban open space, most of the work examined were focused on a relatively narrow range of social fitness and comfort dimensions, particularly in the areas of preference and attitudes, meanings, and, values. In contrast, most works on psychological and physical benefits, and behaviour (especially studies of physical activity) have relied on relatively simple open space measures such as natural versus urban or area/distance (Catherine and Thompson, 2012; Thomas, 2015; Terry, 2013

According to Bolivar and Henniker (2014), these gaps suggest priorities for future research, and while we generally believe this to be a productive strategy, some open space measures applicable to issues in urban ecological restoration may not readily transfer across all domains of social fitness and comfort. For instance, Petrane and Bose (2017) examined the relationship between social fitness, urbanity, and the amount of open space within one and three kilometres of people's homes. While some broad distinctions were made between different types of open space - urban green, agricultural green, and forests and nature areas), only agricultural

green was significant for all the health indicators used in the study. The authors deduced that this is not because agricultural green is inherently better, but because it exceeded other forms of green in the study. In other words, it is the amount of open space that may be crucial and not its particular characteristics, and even then the authors question whether the amount of green may just be another way of measuring the natural versus urban dimension.

Thus, it should not be assumed that all open space measures are salient across the entire spectrum of human benefits. A more productive strategy for future research into these benefit domains thus should seek to establish which types of open space promote particular comfort outcomes, and how interactions with different types of open space may be mediated by cultural and demographic factors. Indeed, much of what may loosely be termed landscape research is concerned with the need for integration between research disciplines, and between research and practice across the fields of landscape planning, design, and management (Brown, 2008; Richard, 2016). Interdisciplinary collaboration between the social and natural sciences involves the consideration of multiple parameters and multiple scales across the dimensions of time, spatiality, and process (Talman, 2013), and it, therefore, is unlikely that a single environmental measure would ever be capable of working effectively across the full range of these disciplines. Thus the development of more complex models is called for, and a number of authors, including Francisco (2017) and Stacts et al. (2014) have made significant progress in this direction.

Several of the shortlisted studies that we reviewed in-depth suggest that structural landscape heterogeneity may be one of the most promising open space measures, with the potential to integrate different disciplinary perspectives and scales. The evidence suggests that structural heterogeneity may be the principal means by which humans detect biodiversity in the landscapes around them (Brown, 2008) in that it can be used to integrate the assessment of different landscape values at a landscape scale using a GIS (Bicano, 2015) and be systematically represented in digital simulations to gauge public reaction to particular planning, design, or management outcomes (Richard, 2016; Xenia and Ditropan, 2016; Hope and Katy, 2015). The creation or retrofitting of green infrastructure as the basis for future sustainable urban development involves the establishment of multifunctional green networks, and it seems likely that structural landscape heterogeneity could become one of the principal means by which their effectiveness is measured against multiple parameters.

However, many of the studies that used a form of structural landscape heterogeneity as an environmental measure were conducted in a rural context, and it may prove to be less effective in urban areas, where parcels of open space are smaller, more fragmented, and vegetation communities are more disturbed (Velarine et al., 2017). To be truly effective, such models need to accommodate a paradigm shift that sees humans, not merely as an exogenous perturbing force, but as an interactive species on the landscape, structuring their surroundings to achieve a particular suite of environmental amenities (Christopher et al., 2017). As these authors point out, this involves recognizing that the social, political, economic, administrative, and cultural processes that have hitherto been considered separately from the ecology of the natural landscape are deeply implicated in its development and change.

As a final note, both the studies included in the research mapping exercise and the final shortlist were predominantly quantitative in their methodological approach, and many relied on what we have called the scenario manipulation approach, using mainly visual stimuli. This bias toward quantitative and visual studies was the outcome of our emphasis on explicit open space measures, which are often absent from qualitative research. In focusing on the former, the researchers accepted excluding some important aspects of social fitness and comfort and methodological approaches that rely on hands-on, multi-sensory experiential interaction with open space in order to avoid bias in the analysis (Berger-Ford and Anthony, 2012; Thomas, 2015 and Stacts et al., 2014).

Conclusion

Urban ecological renewal creates a set of ecologically-based models which are applicable and challenges urban managers to think of urban open space as more than simply green. By developing more structurally sophisticated ecology in a broad range of urban open spaces.

Thus, environmental scientist and open space managers can address a number of issues that are at the forefront of urban ecology, including sustainability, biodiversity, and the provision of ecosystem services (Terry, 213; Richard, 2016; Petrane and Bose, 2017). But there is also an important human side to urban ecological restoration, and as seen in this review of the recent literature, studies of open space and social fitness and comfort are using a diverse range of ways to measure the green in open space in ways that are relevant and meaningful to people. Work on human-open space interactions (Colman and Roberto, 2016) has generally shown a positive relationship between measures of biodiversity and preference, but it also shows important exceptions in different contexts, for different demographic and cultural groups, and for different domains of social fitness and comfort. Besides, cross-disciplinary research is needed as those working in urban ecological restoration seek to integrate social with ecological perception and applications.

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