Land Use Policy 91 (2020) 104319

Contents lists available at ScienceDirect

Land Use Policy

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

Urban green space qualities: An integrated approach towards GIS-based assessment reflecting user perception

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ARTICLE INFO

Keywords:
Urban green space
Ecosystem services
Environmental quality
GIS
Brussels

ABSTRACT

For city dwellers urban green space is the primary source of contact with nature. Qualitative green space is increasingly perceived as an important factor for quality of life in urban areas and a key component of sustainable urban design and planning. In this study, the relation between different features of urban green spaces and perception of green space qualities was analyzed by combining the outcome of a survey on green space perception with GIS-based spatial metrics. A survey has been conducted among residents of the Brussels Capital Region and surroundings to assess the relative importance residents assign to different qualities of urban green spaces and how they value these qualities within visited spaces. Quietness, spaciousness, cleanliness and maintenance, facilities and feeling of safety are identified as important qualities of public green spaces, while naturalness, historical and cultural value are perceived as less important qualities. A GIS-based model was developed to infer naturalness, quietness and spaciousness as perceived by users of public green spaces from green space properties. Using variables describing biological value, land-cover composition, green space area and shape, good correlations were obtained between GIS-based assessment of naturalness and spaciousness and how green space users perceive these qualities. The model proposed may be useful for simulating green space development and improvement scenarios and assess their impact on perceived quality. Thus it may serve as a spatial decision support tool for improving the quality of urban green spaces.

1. Introduction

Positive perceptions of green and open space are only surpassed by dwelling characteristics as important predictors of high levels of neighborhood satisfaction (Douglas, Russell et al. 2018). A proper assessment of the role and benefits of green spaces (GS) for urban residents is an important concern in the emerging area of urban ecosystem services (ES). Since the last decennium of the 20th century, the concept of ES has gained an important role in the debate on sustainability and quality of life (Lappé, 2009; Burkhard, Petrosillo et al. 2010). Neßhöver et al. (2007) consider ES as the missing link between ecosystems and human wellbeing. Also on the policy level more attention and action is directed to the dependence of man on nature and its ecosystems. In urban areas, the aspect of non-material benefits or cultural ES is highly relevant (Chang, Qu et al. 2017) and GS quality is a major factor for how people receive cultural ES. In order to reinforce this link in urban areas, an understanding of the quality and management of urban ecosystem services is required to ensure sustainable urban planning (Luederitz, Brink et al. 2015) and general wellbeing.

Urban green spaces (UGS) have been the subject of a wide range of studies, yet correlations with assumed benefits have been often based on their presence or abundance, and less based on their qualities (Kabisch and Haase, 2013; Haaland and van den Bosch, 2015). Several recent studies, however, point to the importance of assessing urban green space quality (Velarde, Fry et al. 2007; Bertram and Rehdanz, 2015; de la Barrera et al., 2016; Ode Sang, Knez et al. 2016; Hedblom, Knez et al. 2017; Zhang, Van den Berg et al. 2017; Madureira, Nunes et al. 2018). Rather than a biased preoccupation with green-space acreage and tree counts, planners should also consider the geometry of the green network and the quality of the greenery (Jim, 2004) and the various aspects of GS quality (Bertram and Rehdanz, 2015). Many studies on urban green quality are health-related and yield mixed

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https://doi.org/10.1016/j.landusepol.2019.104319
Received 26 March 2018; Received in revised form 17 May 2019; Accepted 19 October 2019
Available online 13 December 2019

results. For example, Hillsdon et al. (2006) and Schipperijn, Bentsen et al. (2013) found no associations between access to urban GS on the one hand, and recreational physical activity on the other hand. However, the latter determined associations between the presence of features and physical activity. Annear, Cushman et al. (2009) found that residents of an area with a poor quality physical and social environment appear to engage in leisure time physical activity less frequently than those living in a higher quality area of the same city. Regardless of their availability to residents, lower quality areas of green space may be less conducive to facilitating physical activity or a restorative experience (Annear, Cushman et al. 2009). Van Dillen et al. (2012) concluded that for neighborhood green space, quality indicators tend to have added predictive value for health indicators and naturalness of a place has been linked to higher general wellbeing (Knez, Ode Sang et al. 2018). As such, green space quality may be a better predictor of health than quantity alone (Richardson, Pearce et al. 2010).

The concept of ‘quality’ of GS is complex and multi-dimensional (Khan, Moulaert et al. 2014). Moreover, there is a lack of robust and scientific methodologies for the assessment of green space quality, especially from the user's perspective. Most studies are geared towards the monetary or benefit valuation of green space (Morancho, 2003; De Ridder, Adamec et al. 2004; Kong, Yin et al. 2007), or discuss a specific aspect of green space quality (e.g. visual or acoustic). Cohen et al. (2014) state that the small number of studies on quality assessment of UGS does not base their assessment on the analysis of in-situ objective measurements and their cumulative impact in a specific location. For a large study area (metropolitan), a full in-situ analysis may not be feasible though and GIS data may be a useful substitute for in-situ measurements. Until now, little work has been done coupling GIS-based assessment of green space quality to how GS are perceived by users. Integrative approaches combining GIS-derived quality indicators with users' experience of GS might offer interesting prospects for the planning, design and management of GS in urban areas (Khan, Moulaert et al. 2014; Kothencz and Blaschke, 2017).

Urban growth and transformation presents numerous challenges for the maintenance of UGS, and consequently also for human health and well-being (Tzoulas, Korpela et al. 2007). In the context of the Brussels Capital Region (BCR), an expected population growth of 14,000 per year on a population of 1,167,951 in 2015 (FOD Economie, 2013), makes well-informed densification strategies a pressing issue. Maintenance and improvement of accessibility and quality of GS is a crucial part of developing such strategies. With the aim of developing an integrated approach for the assessment of UGS qualities, this study is based on a survey that is conducted among residents of the BCR to assess perceived importance of GS qualities contributing to the provision of cultural ES. Cultural ES are usually defined as the intangible and nonmaterial benefits provided by nature (Hirons, Comberti et al. 2016). A GIS-based model is then developed to infer quality indicators, such as, naturalness, quietness and spaciousness from spatial properties of GS. The model relates GIS-based metrics describing GS properties to the survey outcomes on the perception of GS quality. Integrating different components of green space quality, the model may be useful as a decision support tool for planners, designers and policy makers and may provide valuable insights for the design of public GS and qualitative urban development.

2. Study area and materials

2.1. Study area

The study area defined for this research is the territory of the BCR and its surroundings (Fig. 1, continuous line), corresponding to an area of 26 by 26 km. The study area includes the dense city centre, as well as the surrounding lower density areas. It also includes major natural entities in the landscape (e.g. vast forest areas). Two regions are included: the BCR (161 km^2), with an average population density of 7025 inhabitants per km^2 and a continuous built-up area spread over 19 communes; and part of the surrounding area of Flanders characterised by urban sprawl, with an average population density of 477 inhabitants per km^2 (calculated from spatial CENSUS data (FOD Economie, 2011)). To allow correct calculation of GS indicators on the edge of the study area, a buffer of 5 km was added in each direction (Fig. 1, dashed line). The topography of the area is dominated by the valley of the Zenne river flowing from the undulating south – referred to as Middle Belgium – to the flat north – referred to as Low Belgium. Several small tributary valleys connect transversally and form the natural basis for the GS structure in less dense areas. There are several concentrations of very large GSs, such as the medieval Forêt de Soignes, which is situated on the divide of the Zenne valley and the Dijle valley, the royal domain (or gardens), which are not open to the public, and continuous stretches of agricultural and privately owned land.

2.2. Materials

The data on which this study is based is threefold. Firstly, definitions of GS quality were collected from 20 peer-reviewed essays, revealing 168 quality attributes (Table 1). The papers were selected based on a search for the term ‘green space quality’, and further selected based on studies that describe or include multiple characteristics contributing to quality. The focus was on generic aspects of green space quality and less on detailed or highly specific characteristics up- or downgrading people’s perception of green spaces, e.g. presence of flowerbeds, or exercise trails. Grouping of these variables served as a basis for defining seven GS sub-qualities that are assumed in this study (see section 2.4). Secondly, an online and on-site questionnaire in three languages (English, French, Dutch; see section 0) was conducted to assess users’ opinions on public green space quality, with 371 valid responses. Thirdly, several GIS data layers were prepared: the delineation of publicly accessible GS and the data that served for the assessment of sub-qualities of these spaces by combining questionnaire output with GIS modelling (Table 2). The latter set of layers was probed on all locations that were geo-tagged during the entry of a questionnaire and the retrieved data was added to the questionnaire responses. All types of GS were included in the analysis, the sole criterion for selection being their public character. The types range from 19th century formal GS, public areas of housing projects, to GS developed in cooperation with locals, including allotment gardens and spaces for community activities.

Both the Flemish Region and the BCR apply their own standards for the registration of GIS data, with the exception of European data (e.g. EU Habitat Directives). Therefore, thematic maps were produced by merging data derived from various sources (Table 2, purpose b). Next to administrative and environmental data in vector format (Table 2), a vegetation map distinguishing between dense/woody and herbaceous vegetation was obtained from a Quickbird remotely sensed image through NDVI thresholding (Van de Voorde, Canters et al. 2010). Contours of public GS were derived from the shapes present in the available GIS layers (e.g. forests, habitat directive areas, natural reserves, biologically valuable areas) (Table 2, purpose a).

3. Methodology

3.1. General approach

The proposed method for GS quality assessment is based on the premise that perceived green space quality can be conceived as being the outcome of an appreciation of various sub-qualities of GS, which may have different importance to the user. Various scholars claim that people experience a landscape as a system, in which things are structurally and functionally related to each other, in accordance to holistic landscape views. Therefore, the appreciation of a landscape is context dependent (Coeterier, 1987; Antrop, 1989; Coeterier, 2000). In this

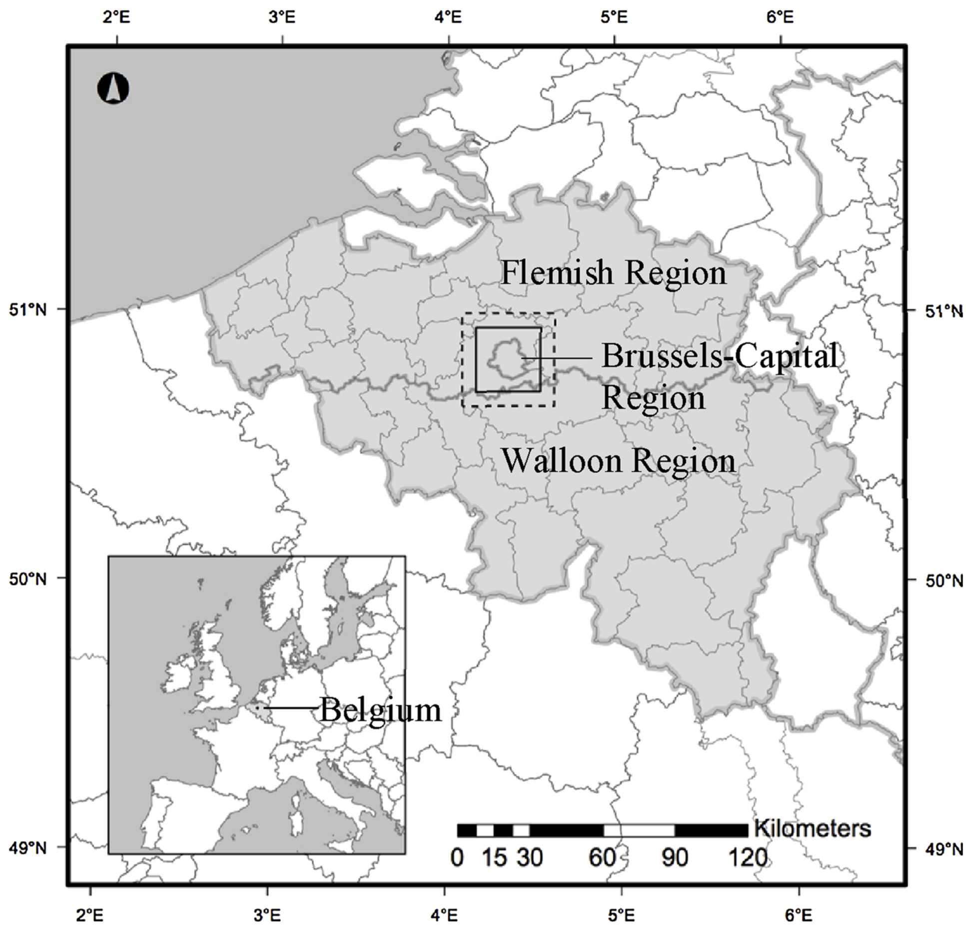

Fig. 1. Indication of the study area (continuous line) and calculation area of the model (dashed line). Belgium is marked in grey.

Table 1
Studies exploring quality attributes used for assessing qualitative or successful green space 1984–2015, (with permission, based on Abdul Malek et al., 2010).

Source	Country	Site categorization	Research type	# quality attributes or character- istics	# vari-ables
Bertram and Rehdanz (2015)	EU	Urban green space	Empirical	4	21
Grahn and Stigsdotter (2010)	SE	Urban green space	Empirical	8	65
Sugiyama et al. (2009)	UK	Neighborhood open space	Empirical	14	–
Doick et al. (2009)	UK	Urban green space	Case study	14	–
Chen et al. (2009)	CN	Urban green space	Empirical	8	–
Sanesi and Chiarello (2006)	IT	Urban green space	Empirical	11	–
Hillsdon et al. (2006)	UK	Public parks	Empirical	8	–
Caspersen et al. (2006)	DK	Green spaces	Theory	7	38
Eng and Niininen (2005)	UK	Public parks	Empirical	25	–
CABE (2005)	UK	Green spaces	Theory	8	–
Van Herzele and Wiedemann (2003)	BE	Urban green space	Theory	5	30
Mens en Ruimte (1999)	BE	Green spaces	Theory	1	–
Gobster (1998)	US	Public park / neighborhood boundary parks	Empirical	7	–
Smith et al. (1997)	CA	Urban Community	Theory	6	28
Coeterier (1996)	BE	Landscapes	Empirical	8	–
Grahn (1991)	SE	Green spaces	Empirical	8	–
Burgess et al. (1988)	UK	Local public parks / Neighborhood parks	Theory and empirical	13	–
Bradley and Millward (1986)	UK	Parks / Green open space	Empirical	6	–
Kaplan (1984)	US	Urban nature	Theory	7	–

study though, we will assume that for GIS-based analysis the benefits of decomposing GS quality into measurable sub-qualities - resulting in a simple and easily reproducible overall quality indicator - outweigh the disadvantage of not taking full account of a more holistic view on the landscape.

Based on a literature review to indicate quality attributes of GS, a classification of main aspects of green space quality (so-called sub-qualities) is proposed. Sub-qualities, which may be inferred from GIS data, were used as variables in a multi-criteria assessment of overall quality using a weighted linear modelling approach. Overall quality and sub-quality appreciation of GS, as well as perceived importance of sub-qualities were obtained through questionnaire input from users (see: 3.3). The questionnaire was developed as a web application, in order to serve as an online questionnaire and as a smartphone interview tool. The majority of responses were collected on-site.

The relation between overall quality and sub-qualities on the one

Table 2
GIS input maps (all are in vector format, except for (*), which is in raster format).

Type	Source	Date	Coverage	Purpose
Natural reserves	IV	2002	Flanders	a, b
Natural reserves	BE	9999	Brussels	a, b
Forests	IV	2000	Flanders	a
Forests	URBIS	2013	Brussels	a
Natura 2000 habitat zones	IV	2008	Flanders	a, b
Natura 2000 habitat zones	BE	9999	Brussels	a, b
Parks	IV	2014	Flanders	a
Parks	URBIS	2013	Brussels	a
Water bodies	IV	2015	Flanders	a
Water bodies	URBIS	2013	Brussels	a
Biological value	IV	2010	Flanders/Brussels	a, b
Protected landscapes	IV	2001	Flanders/Brussels	a, b
Roadside green	URBIS	2013	Brussels	a
Noise map railways day/evening/night	LNE	2011	Flanders	b
Noise map roads day/evening/night	LNE	2011	Flanders	b
Noise map (combined)_5m	BE	9999	Brussels	b
Vegetation map * (water, bare, low veg., dense vegetation)	Van de Voorde, Canters et al. (2010)	2010	Flanders/Brussels	b
Composed green space delineation	comp.	–	Flanders/Brussels	b
IV (Informatie Vlaanderen)	https://download.vlaanderen.be			
URBIS (Brussels Urban Information System)	http://cibg.brussels/nl/onze-oplossingen/urbis-solutions/download			
BE (Brussels Environment)	https://wfs.environnement.brussels/belb?			
LNE (Environmental department of the Flemish Region)	https://www.mercator.vlaanderen.be/zoekdienstenmercatorpubliek/			
Purpose:	a) green space delineation; b) quality assessment			

hand, and between perception of sub-qualities and GIS-based indicators describing each of these sub-qualities on the other hand, is modelled and validated based on the questionnaire responses. This will provide an insight on the extent to which features of GS have an influence on people's opinions about the quality of GS, and whether a simple additive model is suited for assessing overall quality as perceived by GS users.

3.2. Determining relevant aspects of green space quality

Human-environment studies in various western countries have shown with remarkable consistency cross-cultural universal patterns in people's preferred environments (Van Herzele, 2005). In recent years many studies have focused on residents' preferences of GS characteristics (Madureira, Nunes et al. 2018). In order to determine GS qualities that are relevant, and how these qualities contribute to overall quality of UGS as perceived by GS users, 20 essays and case studies from the last three decades were reviewed for their proposed variables (Table 1). The literature survey was done with the following goals: a) come up with a comprehensive, yet manageable set of clearly distinct quality aspects; b) cluster quality aspects into larger themes; c) unravel the meaning of complex definitions of qualities such as e.g. 'wilderness' (Caspersen, Konijnendijk et al. 2006), 'contextual integrity' (Van Herzele and Wiedemann, 2003) or 'legibility' (CABE, 2005); d) define underlying qualities such as 'cleanliness', which is for example present in the descriptions of the dimensions 'nature', 'prospect' and 'refuge' in the classification by Grahn and Stigsdotter (2010); e) define useful variables to measure the proposed qualities and check for compatibility with available GIS data layers. The 165 quality aspects obtained from the literature survey could be classified into fifteen larger themes (Table 3). Although great similarities are found in terms of qualities considered in different studies, not all studies cover all the themes identified.

Seven major themes have been distinguished for this study, which from now are referred to as sub-qualities of UGS. These seven sub-qualities are split into two main groups: a) 'inherent sub-qualities' (*INH*) comprising nature and biodiversity (*NAT*), quietness (*QUI*), historical and cultural value (*HIS*), spaciousness (*SPA*); and b) 'use-related sub-qualities' (*USE*) comprising cleanliness and maintenance (*MNT*), facilities (*FAC*), and feeling of safety (*SAF*). Indicators that are derived from thematic GIS layers can describe inherent qualities. Use-related qualities can only be valued through on-site or online surveys.

3.2.1. NAT

The level of naturalness is a factor that has positive effects on both human well-being (Stigsdotter and Grahn, 2011; Ode Sang, Knez et al. 2016; Knez, Ode Sang et al. 2018) and biodiversity (e.g. Sandström, Angelstam et al. 2006), and high perceived naturalness leads to more activities and attributed aesthetic values (Ode Sang, Knez et al. 2016). It is an expression of the similarity to ecosystems with small human impact (Peterken, 1996) and thus refers to a sense of wilderness and freedom (Grahn and Stigsdotter, 2010). Many preference studies of outdoor recreation environments, by e.g. Kaplan and Kaplan (1989), have found that a strong manifestation of nature is perhaps the most essential experience dimension of UGS. Presence of wooded area has a significant effect on physical activity (Kaczynski, Potwarka et al. 2009; Schipperijn, Bentsen et al. 2013). Wilderness-like areas can generate a strong preference among users, but also a fear or feeling of vulnerability (Jorgensen, Hitchmough et al. 2007; Jansson, Fors et al. 2013).

3.2.2. QUI

The choice for a green environment is also influenced by its degree of peacefulness (Grahn, 1991), quietness (Mens en Ruimte, 1999) and relaxation (Sanesi and Chiarello, 2006). For both inhabitants that have access to a quiet garden and those without, availability of nearby green areas reduces long-term noise annoyances and prevalence of stress-related psychosocial symptoms (Gidlöf-Gunnarsson and Öhrström, 2007). According to Van Herzele and Wiedemann (2003), "the degree of congruence between sound and the spatial, cultural or social context in which it is produced, plays an important part in defining this subjective response (López Barrio and Carles, 1995)."

3.2.3. HIS

The historical and cultural value of GS has a landscape dimension and an artifact dimension which deliver satisfaction through understanding the surrounding environment in terms of nature or culture. An area with tangible heritage (physical historical evidence) promotes feelings of time depth and belonging (Caspersen, Konijnendijk et al. 2006). According to several authors, green space quality is influenced by landscapes being protected, having contextual integrity, being

Table 3
Thematic clustering of quality aspects relevant to the assessment of quality of green open spaces (*) for combining GS quality and proximity in a GS provision model, see: (Stessens et al., 2017a,b).

Sub-qualities [CODE]	Variables from the essays mentioned in Table 1 (duplicates and synonyms were left out)	Data origin
1. Preconditions for use (not included in this study)*		
Accessibility (*ACC*)	proximity to the residence, accessibility, and connection, barrier-free, amount of green spaces	n.a.
2. Sub-qualities (subject to this study)		
2.A. Inherent sub-qualities (INH) (informed by GIS data and by questionnaires)		
Nature and biodiversity (*NAT*)	naturalness, wilderness, biodiversity, forest, natural setting, non-materialistic, air quality, nature conservation, scenic beauty, environmental functions, possibility for involvement with nature, varied topography	GIS (Quest.)
Quietness (*QUI*)	quietness, auditory factors, relaxation, peacefulness	GIS (Quest.)
Historical and cultural value (*HIS*)	continuity of culture reflected in the landscape, dense pattern of characteristic elements, contextual integrity, relics of traditional landscapes, cultivated, old	GIS (Quest.)
Spaciousness (*SPA*)	space, unity, spatiality, legibility, landscape, vista	GIS (Quest.)
2.B. Use-related sub-qualities (USE) (informed by questionnaires)		
Facilities (*FAC*)	lots of seating, quality of paths and walkability, challenging play space, outdoor amenities, recreational facilities, sport facilities, enclosure, signage and lighting, supporting exercise, square-like, quality in design	Quest.
Cleanliness and maintenance (*MNT*)	cleanliness, good maintenance, park management, funding	Quest.
Feeling of safety (*SAF*)	safety and security, supervisions of users, well established advisory council, enclosure, human scale	Quest.

considered as heritage, or by parks with a significant age containing artifacts referring to a past time (Van Herzele and Wiedemann, 2003; Caspersen, Konijnendijk et al. 2006; Grahn and Stigsdotter, 2010).

3.2.4. SPA

People's preference for spacious and un-fragmented areas (Grahn and Stigsdotter, 2010) can be explained by the quality of the feeling of being away from all rules of the town and forgetting about limits, time and space (Kaplan, 1990). Criteria involve free movement and unawareness of limited dimensions of the green space (Grahn, 1991). Therefore, both the size (area), as well as the degree of irregularity - or inversely, compactness - relate to spaciousness. Other variables mentioned in literature related to spaciousness are legibility (CABE, 2005), unity and spatiality, or the degree of coherence (Coeterier, 1996).

3.2.5. FAC

The sub-quality 'facilities' indicates the balanced provision, decent state and qualitative design of outdoor amenities such as qualitative and sufficient paths contributing to walkability (Doick, Sellers et al. 2009), sufficient seating (Smith, Nelischer et al. 1997), recreational facilities such as a challenging play space (CABE, 2004), sport facilities (Sanesi and Chiarello, 2006) or exercise supporting facilities (Doick, Sellers et al. 2009). Amenities also include signage and lighting (Eng and Niininen, 2005), restrooms (Grahn and Stigsdotter, 2010) and enclosure (CABE, 2005).

3.2.6. MNT

Also contributing to perceived green space quality are cleanliness (CABE, 2004; Jim and Chen, 2010) and good maintenance (Burgess, Harrison et al. 1988; Eng and Niininen, 2005). They result from decent park management (Coeterier, 1996; Gobster, 1998; Sanesi and Chiarello, 2006; Doick, Sellers et al. 2009) and sufficient funding, as well as user behavior. Cleanliness involves shared responsibility by users and managing institutions.

3.2.7. SAF

CABE Space (2005) found that what bothers the public most about GS is when they are not kept clean or safe. A low personal safety level influences the appreciation by frequent users as well as occasional users, and is particularly important for older people's quality of life (Sugiyama, Thompson et al. 2009). Certain fears have a particular importance for specific population groups (Madge, 1997). The feeling of safety is influenced by individual and social factors, as well as factors in the environment, including the type of vegetation (Jorgensen and Anthopoulou, 2007; Jansson, Fors et al. 2013), although the individual factors are the most influential (Sreetheran and van den Bosch, 2014).

Accessibility (*ACC*), defined here as the proximity of public GS to the place of residence is not considered as a sub-quality of GS, but rather as a precondition for use (Van Herzele and Wiedemann, 2003) and is therefore not included in this study. Quality and proximity can be combined in a green space provision model though (Stessens et al., 2017a,b).

3.3. Perceived green space quality

During the months of August, September and October of 2015 and 2016, a survey in the form of an online and on-site questionnaire was carried out in three languages (English, French, and Dutch) to gather data on GS visitors' perception of overall quality, as well as perceived importance and rating of sub-qualities of GS. GS for on-site data gathering were selected in such as way as to ensure a proper balance between central vs. peripheral locations, different levels of neighbourhood prosperity and representativeness of size. Participants of the on-site survey were approached randomly during daytime visits (9:00-21:00). Green space visitors willing to answer questions were asked to complete the questionnaire. Each GS was surveyed for a total of 4 – 6 h, at different moments of the day (morning, afternoon, evening), during weekdays and weekends.

The same online form supported both the on-site and online questionnaire, which included rating scales, multiple-choice questions, and map input (GS location). On-site, the interviewer read out the questions to the interviewee, while online, the interviewees completed the process by themselves. To stimulate online participation, an announcement of the survey was distributed via different mailing lists (contacts of Brussels Environment, citizen action groups, neighbourhood committees). The online questionnaire was open during the period of on-site data collection.

Table 4 gives an overview of the topics addressed in the questionnaire. The main questions and responses used in this study pertain to the earlier described GS sub-qualities. Regarding each sub-quality, two questions were asked: "How do you feel about the [e.g. quietness] in this green space?" (7-step score from 'very unsatisfied' over 'neutral' to 'very satisfied') and "How important is [e.g. quietness] for you in a green space?" (4-step score from 'not important' to 'decisive'). Apart from information on perception of GS quality, participants were also asked about their GS proximity preferences, frequency of GS visits, the presence of green and the access to green in their neighbourhood of residence, yet this information was not used for the present study. As the respondents had to indicate their age and gender, the sample of respondents could be verified for representativeness in relation to the demographic structure of the BCR.

Table 4
Questionnaire content.

Personal impression of a single visited green space		
Inquired aspect	appreciation	importance
Overall quality	x	
Cleanliness and maintenance	x	x
Naturalness and biodiversity	x	x
Quietness	x	x
Historical and cultural value	x	x
Spaciousness	x	x
Facilities	x	x
Feeling of safety during the day	x	
Feeling of safety during the evening	x	
Feeling of safety		x
Rating scales	1) very unsatisfied; 2) unsatisfied; 3) slightly unsatisfied; 4) neutral; 5) slightly satisfied; 6) satisfied; 7) very satisfieddd	0) not important; 1) somewhat important; 2) important; 3) decisive
Usage of a single visited green space		
Visiting interval		days
Transport mode		multiple choice
Green space usage or activities		string (text)
Personal information about the respondent		
Gender		multiple choice
Age		integer [years]
Cultural background*		multiple choice
Secondary cultural background*		multiple choice
Residence of the respondent and personal preferences		
Residence location		(map indication converted to) WGS84 coordinates
Garden access		Y/N
Aspiration to a garden		multiple choice
The hypothetic choice for a shared garden		multiple choice
Having children		Y/N
Greenness of neighborhood		scale 1-7
Average quality of neighborhood green space		scale 1-7
Maximum preferred traveling time towards g reengreen space on the scale of the:		
- neighborhood		integer [minutes]
- city		integer [minutes]
- metropolitan area		integer [minutes]
Questionnaire information		
Location of submission		WGS84 coordinates
Time of submission		date and time [YYYY/MM/DD hh:mm]

* The question of cultural background is aimed at identifying articulations across social groups that live in Brussels and that identify with a certain culture, and was described as the country the respondent felt culturally most connected to. Therefore ‘Belgian’ could be answered by a range of individuals from ‘having Belgian roots’, up to ‘immigrated a few years ago’.

3.4. Modelling reported green space quality

The purpose of the modelling work in this study was two-fold. First, we wanted to establish a relation between the overall quality of GS as perceived by users and the way these users rate different sub-qualities using a weighted linear modelling approach:

$$q = \sum_{i=1}^{I+K} w_i q_i \tag{1}$$

where q refers to overall quality, w_i are the sub-quality weights, and q_i are the sub-quality ratings. I is the number of inherent sub-qualities, K the number of use-related sub-qualities included in the analysis. The weights were obtained through multiple linear regression (MLR) without an intercept (MLR in Fig. 2). The analysis was restricted to GS with a minimum of ten responses, resulting in a training set of 256 questionnaire responses (25 GS) and a holdout validation set of 93 responses (9 GS). Seven-point ratings of overall quality and sub-quality appreciation (see Table 4) were stretched on a range from 0 to 100. The sub-quality weights (coefficients) obtained through MLR were compared to the reported importance of the sub-qualities, as inquired through the questionnaires, in order to validate the outcome of the modelling.

Next, for all inherent sub-qualities, the relation was modelled between GIS-based metrics derived from relevant data layers, describing different GS properties, and sub-quality user ratings. To do so, the detail of analysis was altered from the visitor level to the level of GS, again focusing on GS with minimum ten responses and using the same training and validation data as above. Average reported sub-quality ratings for each GS, obtained through the questionnaires were used as the dependent variable, GIS-based metrics as independent variables:

$$q_i = u_i + \sum_{j=1}^{J} v_{ij} x_{ij} \tag{2}$$

where q_i is the average rating for sub-quality i, obtained from the questionnaire, x_{ij} are the values of the GIS-based GS metrics j describing sub-quality i, v_{ij} are the model coefficients and u_i is the intercept (MLR* in Fig. 2). Different metrics potentially explaining the variance of the sub-quality ratings were first selected. Products of metrics were included to deal with possible metrics interaction. A stepwise regression approach was applied to remove non-significant variables from the

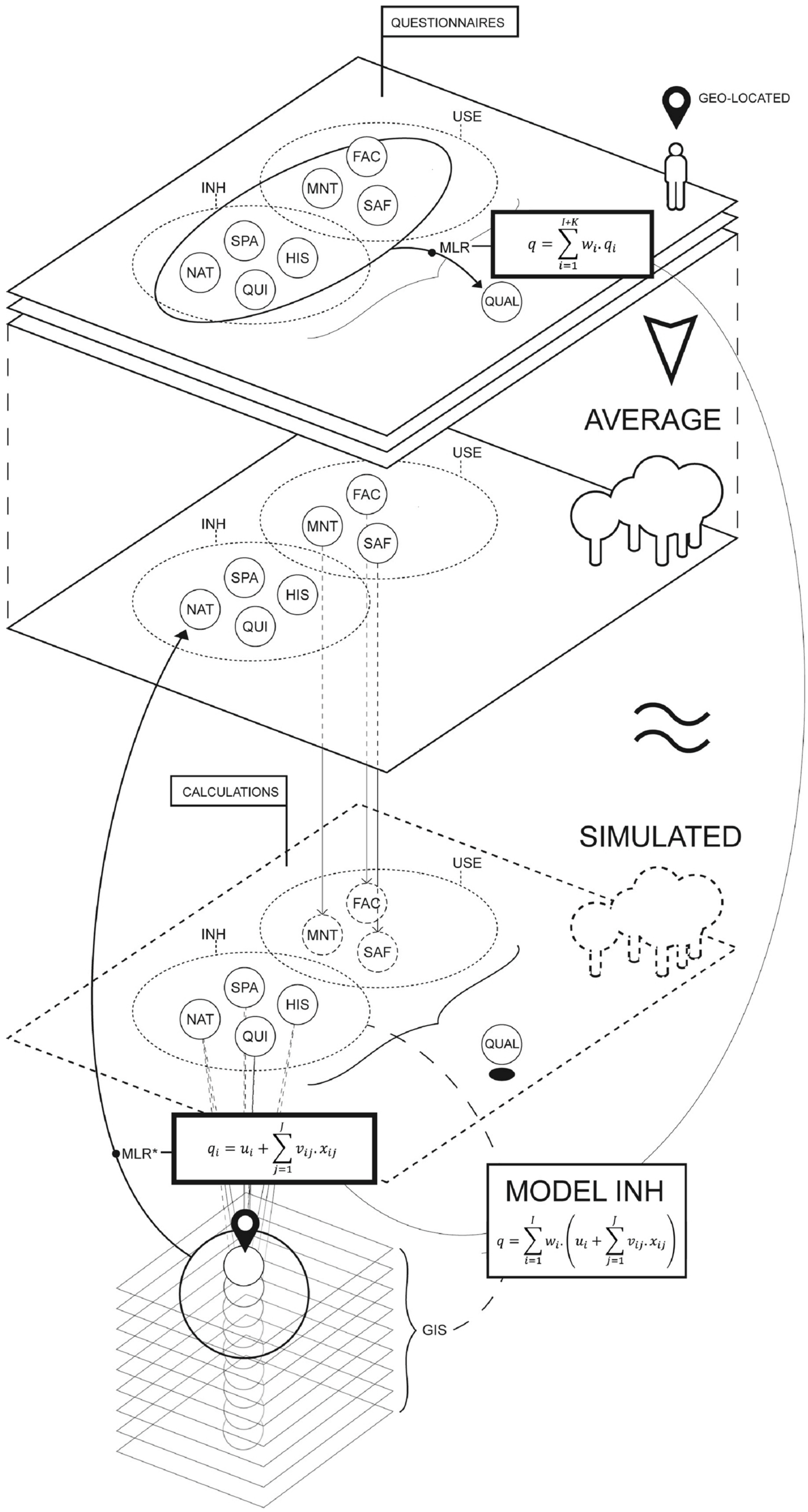

Fig. 2. Conceptual scheme of the proposed approach for assessment of green space quality. The top layers represent questionnaire responses, from which the sub-quality weights are derived through MLR. The average sub-quality ratings per GS (middle layer) constitute the dependent variables for the second MLR (*) with GIS-based metrics as independent variables. The model for inherent GS quality is obtained by integration of both regression models (GIS-based) and approximates the average inherent quality from the user's perspective (questionnaire-based.

regression equation (p-level verification with $\alpha = 0.05$).

Both steps in the modelling were then coupled, translating GIS-based metrics into an assessment of inherent quality of each green space in the study area (MODEL INH in Fig. 2):

$$q_{INH} = \sum_{i=1}^{I} w_i \left(u_i + \sum_{j=1}^{J} v_{ij} x_{ij} \right) \tag{3}$$

The GIS-based assessment of GS quality is limited to the level of inherent quality instead of overall quality because use-related sub-qualities are not informed by GIS data. However, the ratings of use-related sub-qualities q_k can be included in the assessment of overall quality for the GS where they are known:

$$q = q_{INH} + q_{USE} = \sum_{i=1}^{I} w_i \left(u_i + \sum_{j=1}^{J} v_{ij} x_{ij} \right) + \sum_{k=1}^{K} w_k q_k \tag{4}$$

4. Results

4.1. Questionnaire results

The survey resulted in 371 responses of which 349 entries were considered complete and valid, and being part of a group of 10 or more responses per GS. The campaigns of 2015 and 2016 resulted in 51 % and 49 % of the total number of responses respectively. The majority of the responses were gathered on site (87 %). Since exactly the same interface and questions were used for the online and on-site questionnaires, the matching of samples from both surveys was deemed justifiable. Per GS, 3–5 respondents on 10 indicated to identify most with a non-Belgian country. In each GS maximum two of these identified with the same country. While the question of cultural affinity is not the same as inquiring about nationality, the percentage of non-Belgian nationalities throughout the different communes in the Brussels-Capital Region (18%–49%) corresponds to these values in a broad sense (Statistiek Vlaanderen, 2018). The overall rate of male to female in the sample is 49:51 and maximally varies between 1:2 and 2:1 per GS.

4.2. Perceived importance of sub-qualities and relation to cultural differences and gender

Table 5 shows each sub-quality's importance, as rated by the questionnaire participants. In this table, the ratings were scaled from the questionnaire format (0–3) to the scale 0-1. It appears that the average respondent rates naturalness and biodiversity, and historical and cultural value as substantially less important than the other sub-qualities. For people not culturally identifying with Belgium or with Catholic-European culture, ratings for naturalness and biodiversity and for historical and cultural value are even lower. It should be mentioned though that the sample size of people identifying with countries other than Belgium is too low to draw firm conclusions about cultural variations in the reported importance of different sub-qualities, even when clustered in groups from the Inglehart-Welzel classification, i.e. nine clusters worldwide (Inglehart and Welzel, 2010). The reason is that 165 respondents chose not to disclose the optional information about cultural background. Large clusters are Catholic-European ($n = 160$) versus people not from this group ($n = 46$), as well as Belgian ($n = 125$) versus non-Belgian respondents ($n = 81$). The strongest differences in reported importance for Belgian versus other than Belgian respondents pertain to naturalness and biodiversity ($\Delta_{avg} = 0.28$), historical and cultural value ($\Delta_{avg} = 0.13$), and cleanliness and maintenance ($\Delta_{avg} = 0.09$). These differences are all significant when subjected to a T-test with $\alpha = 0.05$ (Table 5), while the differences reported for other sub-qualities are not significant. The former two qualities are more important to Belgian respondents than to 'other than Belgian' respondents, while the latter, cleanliness and maintenance, is more important to 'other than Belgian' respondents. All sub-qualities are rated slightly more important by women than by men, with the difference in rating for feeling of safety and quietness being most pronounced. However, only the difference in importance of the quality 'feeling of safety' seems to be indicative of a possible gender effect, although not significant at the 0.05 level.

Table 5
Average rating of a sub-quality by respondents of the survey from 'not important' (0), over 'somewhat important' and 'important' to 'decisive' (1). (*, **) indicates regions to which respondents feel culturally most connected and does not depict nationalities. (**) is a clustering of nations according to the Inglehart-Welzel classification. Significance of differences is indicated by the p-value of an unpaired t-test comparing average ratings for different subgroups of the population.

Importance according to respondent	*NAT*	*QUI*	*HIS*	*SPA*	*MNT*	*FAC*	*SAF*
Average	**0.46**	**0.69**	**0.30**	**0.62**	**0.75**	**0.64**	**0.67**
Women	*0.47*	*0.71*	*0.31*	*0.62*	*0.75*	*0.64*	*0.68*
Men	*0.46*	*0.67*	*0.29*	*0.61*	*0.73*	*0.64*	*0.64*
Belgian*	0.62	0.69	0.37	0.63	0.71	0.62	0.65
Catholic European**	0.57	0.68	0.34	0.61	0.72	0.63	0.65
Other than Belgian*	0.34	0.71	0.24	0.63	0.80	0.67	0.68
Other than Catholic European*	0.31	0.71	0.22	0.66	0.80	0.65	0.67
t test p-value women-men	*0.27*	*0.20*	*0.18*	*0.10*	*0.28*	*0.56*	*0.09*
t test p-value Belgian-other than Belgian	< 0.01	0.25	0.03	0.18	0.05	0.26	0.46

4.3. Modelling of sub-quality weights

MLR analysis without intercept was conducted to predict the overall quality of GS as perceived by the user from the questionnaire ratings of the different sub-qualities. First, a collinearity test was performed between all pairs of variables, which indicated little ($r \leq 0.30$) to low ($0.30 < r \leq 0.50$) correlation (Hinkle, Wiersma et al. 2003) for all combinations (Table 6), with the highest correlation for *SPA* vs. *QUI*, and *SAF* vs. *MNT* and *FAC*. This relates to verbal feedback from questionnaire participants stating that spaciousness generates quietness while cleanliness and maintenance or decent facilities generate a feeling of safety. *NAT* and *HIS* have the lowest correlation with the other variables. In the MLR, *HIS* appeared to be not significant, so the variable was removed (Table 7). Without *HIS*, a correlation of $r = 0.74$ between predicted and perceived overall quality was obtained. This relatively low correlation can be attributed to differences in judgment between individuals on the relative importance of the various GS sub-qualities. When the coefficients obtained are applied to the average response per GS, the correlation reaches $r = 0.92$ (Fig. 3) and $r = 0.82$ for the validation set. Hence, the valuation of sub-qualities provides a good explanation of overall quality as reported by the respondents. This implies that overall quality can be conceptualized as a weighted combination of sub-quality ratings with weights obtained through MLR.

When we assign responsibilities to the different sub-qualities, one can say that city maintenance services have a strong responsibility for the sub-quality facilities (20 % of total weight) and an influence on - or

Table 6
Collinearity of variables (Pearson correlation).

[r]	*MNT*	*NAT*	*QUI*	*HIS*	*SPA*	*FAC*	*SAF*
MNT	1	–	–	–	–	–	–
NAT	0.19	1	–	–	–	–	–
QUI	0.27	0.18	1	–	–	–	–
HIS	0.17	0.29	0.01	1	–	–	–
SPA	0.28	0.11	0.49	−0.01	1	–	–
FAC	0.34	0.17	0.31	0.03	0.36	1	–
SAF	0.42	0.10	0.34	0.05	0.23	0.38	1

Table 7
MLR coefficients and relative weight of sub-qualities.

	MLR coefficients, no intercept	Normalized MLR coefficients (weights)
NAT	0.11	0.10
QUI	0.15	0.14
HIS	n.a.	n.a.
SPA	0.18	0.16
Share INH	**40%**	**40%**
MNT	0.33	0.31
FAC	0.22	0.20
SAF	0.09	0.09
Share USE	**60%**	**60%**

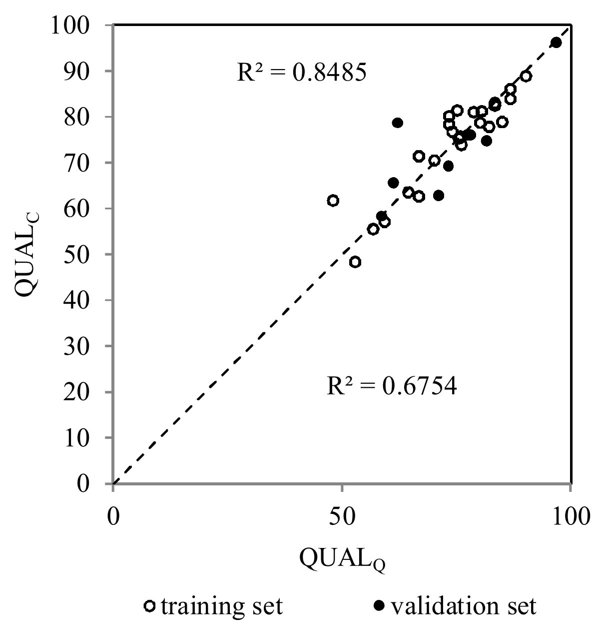

Fig. 3. Correlation between reported overall quality ($QUAL_Q$) and GS quality calculated from reported sub-quality ratings ($QUAL_C$), based on MLR of overall quality. Coefficients of determination indicated above the 45° line refer to the training set (model fit), below refer to the validation set (model validation).

shared responsibility for – naturalness, maintenance and cleanliness, and the feeling of safety (50 %) (Table 7). Users have a shared responsibility for cleanliness and maintenance, and the feeling of safety (40 %). Designers and developers of public space construction codes have a unique responsibility for the sub-qualities spaciousness and quietness (30 %), and an influence on all sub-qualities (100 %).

4.4. Inherent quality assessment using GIS-based indicators

To predict questionnaire-based sub-quality ratings from GIS data, first a selection was made of indicators potentially contributing to the assessment of *NAT*, *SPA* and *QUI* (Table 8). The selection of variables includes cross-product terms to deal with possible interaction effects between some of the indicators. Using backward elimination, the variables with the highest p-level were removed until for each remaining variable the null hypotheses could be rejected ($\alpha < 0.05$). As explained in the method section, to calibrate and validate the models for *NAT*, *SPA* and *QUI*, an independent training set of 256 questionnaire responses (25 GS) and a holdout validation set of 93 responses (9 GS) were used. Table 9 shows the model definition for each of the inherent sub-qualities. For use-related sub-qualities, which cannot be assessed from the available GIS-data, the average sub-quality ratings of minimum 10 questionnaires per park were used to define use-related quality (*USE)* for each GS.

Table 8
Variables included in the modeling. The variable selection method is backward elimination, starting with variables indicated by 'x' and 'o', to arrive at variables indicated by 'x'.

Variable	*NAT*	*SPA*	*QUI*
Intercept	x	x	x
f_{BIO}	x		
f_{GRE}	x		o
f_{TRE}	x	x	o
f_{WAT}	x		o
$f_{BIO} \cdot f_{TRE}$	x		
$f_{BIO} \cdot f_{GRE}$	o		
$f_{BIO} \cdot f_{WAT}$	x		
R_{inscr}	x	o	x
A	x	x	x
$\sqrt{A}$		o	
P		o	
$\sqrt{P}$		o	
$A.\ f_{TRE}$	o	x	
$P.\ f_{TRE}$		o	
$R_{inscr} \cdot f_{TRE}$		x	
NOI_{avg}			x
NOI_{min}			o

For predicting the sub-quality 'naturalness and biodiversity', the relevant variables appear to be the following: the fraction of land containing biologically valuable areas, the fraction of water area, the fraction of land covered by different vegetation types, and shape-related variables i.e. area and largest inscribed circle. In terms of model fit between reported and estimated quality, an R^2 value of 0.60 is obtained for the calibration data, 0.45 for the validation set (Fig. 4). The sub-quality 'spaciousness' appears to depend on area and shape variables, as well as on the fraction of dense vegetation and how it interacts with shape and area. The R^2 value is 0.52 and 0.47 for the calibration and validation set respectively.

'Quietness' appears more difficult to model. In this study, traffic noise was singled out by using the modeled sound pressure level for road, rail and air traffic (LNE, 2009). The addition of other sounds such as birds or running water may mask traffic sounds, resulting in a reduced loudness and increased perception of pleasantness of the soundscape (Coensel, Vanwetswinkel et al. 2011), but were not taken into account in this study. With a mere R^2 value of 0.21 for the calibration set, it seems that the model, including averaged day/evening/night simulated sound pressure level NOI_{AVG} and area/shape-related variables, does not predict the reported quietness well. This can mainly be explained by a lack of adequate data to properly characterize noise levels as experienced by the visitors of GS at the moment the survey took place. Instead of relying on reported quietness, it was therefore decided to calculate quietness based on the Dutch standard for health effect screening (Fast, van den Hazel et al. 2012), which proposes a scientifically substantiated link between the combined simulated sound pressure level of road, rail and air traffic and a simple nine-level rating ranging from 'very bad' to 'very good'. This rating was translated to a scale from 0 to 100 (Eq. 5).

$$QUI_{C,ALT} = -2{,}857.\ NOI_{AVG} + 208 \tag{5}$$

With NOI_{AVG} being the average sound pressure level over the green space considered. Using MLR-deduced weights, the GIS-based inherent quality of a green space is finally calculated as:

$$INH_C = 0.10\ .\ NAT_C + 0.16\ .\ SPA_C + 0.14\ .\ QUI_C \tag{6}$$

The models enable us to extrapolate the relationships established between GIS-based metrics and perceived green space qualities for *NAT* and *SPA* to all GS in the study area and, as such, to assess both sub-qualities of these spaces taking user perception into account. The standard model used for *QUI* also enables us to assess perceived noise

Table 9
Relation between overall quality (QUAL), inherent (INH) and use-related (USE) quality and sub-quality ratings as perceived by users of GS, as well as relations between GIS-based metrics describing properties of GS and inherent green space sub-quality ratings (ratings vary between 0–100).

Code	Sub-quality equations
$QUAL$	$= INH + USE$
where:	
INH	$= 0.10.\ NAT_C + 0.16.\ SPA_C + 0.14.\ QUI_C$
USE	$= 0.31.\ MNT_Q + 0.20.\ FAC_Q + 0.09.\ SAF_Q$
where:	
NAT_C	$= a + b.\ f_{BIO} + c.\ f_{TRE} + d.\ f_{GRE} + e.\ f_{WAT} + f.\ f_{BIO}.\ f_{TRE} + g.\ f_{BIO}.\ f_{WAT} + h.\ A + i.\ R_{inscr}$
SPA_C	$= j + k.\ A + l.\ f_{TRE} + m.\ A.\ f_{TRE} + n.\ R_{inscr}.\ f_{TRE}$
QUI_C	$= o + p.\ NOI_{avg} + q.\ A + r.\ R_{inscr}$ (later replaced by $QUI_C = -2{,}857.\ NOI_{avg} + 208$)
MNT_Q	Average rating of min. 10 questionnaires/park on a scale of 0-100
FAC_Q	Average rating of min. 10 questionnaires/park on a scale of 0-100
SAF_Q	Average rating of min. 10 questionnaires/park on a scale of 0-100
where:	
f_{BIO}	Fraction of biologically valuable zones and/or composed zones with presence of biologically valuable elements
f_{GRE}	Fraction of land covered by vegetation
f_{TRE}	Fraction of land covered by dense vegetation or tree canopies
f_{WAT}	Fraction of land occupied by water
NOI_{avg}	GS average of the combined simulated sound pressure level of air, rail and road traffic (Lden) [dB]
A	GS area [m^2]
R_{inscr}	Radius of the largest possible inscribed circle in the GS [m]

levels throughout the whole study area. When the three models are applied to all public GS in the BCR, the maps in Fig. 5 are obtained. The maps give an idea of how different urban parks score on each of the three quality aspects considered (*NAT, QUI, SPA*). Fig. 5D shows an assessment of inherent quality for all public GS, as obtained by applying Eq. 6 and rescaling values to the 0–100 interval. By summing inherent quality (INH_C) and use-related quality (USE) indicators, as in Eq. 4, overall quality can be calculated for all GS when questionnaire data are available ($QUAL_C$). A comparison with the average overall quality per GS, as obtained from the questionnaire ($QUAL_Q$) shows a strong relationship between modelled and observed quality assessment (Fig. 4, bottom right), with R^2 values of 0.76 and 0.66 for the model calibration and model validation dataset respectively.

5. Discussion

Improving our understanding of how people experience UGS and how they value UGS qualities is important for policy makers and planners, as it may inform them how to design and manage UGS that meet user needs (Wan and Shen, 2015; Lindholst, Konijnendijk van den Bosch et al. 2016; Chang, Qu et al. 2017). Our survey results demonstrate that cleanliness and maintenance, quietness and safety are perceived as the most important qualities of UGS in the BCR, followed by the presence of adequate facilities and spaciousness. The important role of what we have referred to in this study as use-related qualities (cleanliness and maintenance, safety, facilities) in green space perception is confirmed by many other studies. In a comparative analysis on four European cities, Bertram and Rehdanz (2015) identified cleanliness and low crime as the most important characteristics determining park visitors' perception of UGS. A recent study on preferences for UGS characteristics in three Portuguese cities highlights cleanliness and maintenance as the most important attribute of UGS (Madureira, Nunes et al. 2018). Earlier studies by Jim and Chen (2006) and Qureshi et al. (2013) also point at the importance of cleanliness and maintenance in the use and valuation of UGS. Gender differences in perceived importance of use-related qualities prove to be weak, which is also found in other studies (Jim and Shan, 2013). Only with respect to safety a slight gender effect is observed. This corroborates the findings of other work indicating that women are more concerned about security in UGS than men (Burgess, Harrison et al. 1988; Sanesi and Chiarello, 2006; Sreetheran and van den Bosch, 2014), unless the spaces have a cultural understanding as 'safe' in specific countries (Jansson, Fors et al. 2013).

Of the inherent GS qualities identified in our study quietness and spaciousness are perceived as most important, while naturalness and biodiversity as well as historical and cultural value receive lower importance ratings. The relatively low importance attached to naturalness contrasts with the results of other studies on perception of GS characteristics (Bertram and Rehdanz, 2015; Kothencz, Kolcsár et al. 2017; Madureira, Nunes et al. 2018). It draws attention to the fact that, while some GS characteristics may be valued similarly in different cities, beliefs about the importance of GS features may also differ depending on local context. Indeed, while observed differences in importance of sub-qualities between studies and cases can be partly attributed to the chosen methodology and questionnaire setup, several studies have also emphasized that preferences for GS may be strongly influenced by complex interactions between GS supply and demand, and benefits which residents obtain from GS (Voigt, Kabisch et al. 2014; Zhang, van Dijk et al., 2015; Kremer, Hamstead et al. 2016). Such interactions may depend on multiple factors, including the physical characteristics and accessibility of GS (Bertram and Rehdanz, 2015) and the size, density and morphology of the surrounding urban area (Kothencz and Blaschke, 2017). Madureira, Nunes et al. (2018) hypothesize that city size may be a factor in explaining the preference for some sub-qualities of GS, indicating that quietness - which came out as the most important inherent quality of GS in our study - seems to be rated as more important in larger, densely populated cities. The fact that naturalness is perceived as less important by GS visitors in our study may have to do with the inclusion of both small and larger GS. Naturalness seems to be considered as more important in larger GS (Bullock, 2008). Verifying this hypothesis would require a more detailed study, focusing on use and valuation of GS of different size, offering different facilities. Also socio-demographic characteristics of park visitors, social practices and cultural context affect the way in which people use GS and experience and value their contacts with nature (Plieninger, Dijks et al. 2013; Voigt and Wurster, 2015; Camps-Calvet, Langemeyer et al. 2016). This may also play a role in the perceived importance of naturalness. As our results show, GS users that culturally identify as non-Belgian – which represent a large group – perceive naturalness as less important, while "Belgian"

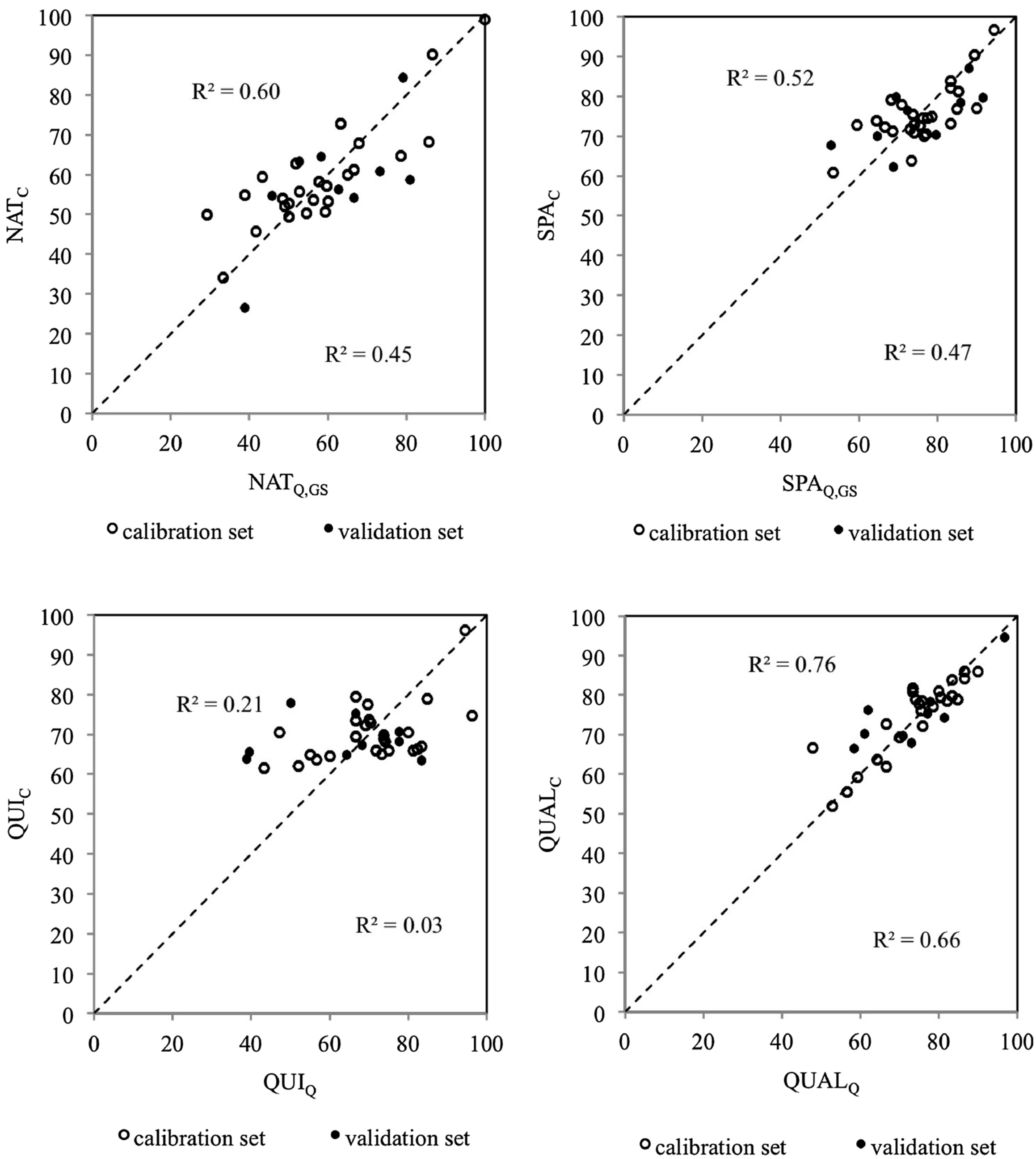

Fig. 4. Scatter plots of questionnaire-reported (Q) against calculated (C) (sub-) quality ratings for naturalness and biodiversity (*NAT*), spaciousness (*SPA*), quietness (*QUI*) and overall quality (*QUAL*). Coefficients of determination indicated above the 45° line refer to the calibration set (model fit), the ones below the line refer to the validation set (model validation).

GS users rate naturalness equally high as spaciousness and presence of adequate facilities. As indicated in other recent studies, generic assumptions about GS preferences should be avoided (Madureira, Nunes et al. 2018). Given the diversity of preferences, a one size fits all approach for the design and management of UGS will not meet the general publics' needs and desires (Howley, 2011). Ultimately, public GS design should be tailored to various cohorts of citizens, as it relates directly to the citizen's quality of life.

In our study we also demonstrated that the overall appreciation of GS, as indicated by their users, can be related to user's ratings on a set of inherent and use-related sub-qualities by conceptualizing overall quality as a weighted sum of important sub-quality components. Use of a simple, additive sub-quality-based approach for valuing GS provides useful insights for the improvement of GS through design, planning and policy interventions, as it allows identifying underperforming sub-qualities per green space, per area legislative or management unit, or for the study area in general. It should be kept in mind though that while GS can be improved with a focus on specific sub-qualities, solutions should always be approached in an integrated way, taking in account context and situation, which is one of the main qualities of design as a discipline.

Following the concept of the ES cascade model, biophysical properties of GS may provide ES that potentially offer benefits to GS users (Haines-Young and Potschin, 2010). Results of our study show that the inherent sub-qualities naturalness and biodiversity as well as spaciousness of GS can be informed by GIS data and that relationships between measured and reported quality, obtained from a representative sample of public GS, can be extrapolated over a larger area, using GIS-based descriptions of GS properties. The appreciation of naturalness proves to be well correlated with biological value, land-cover

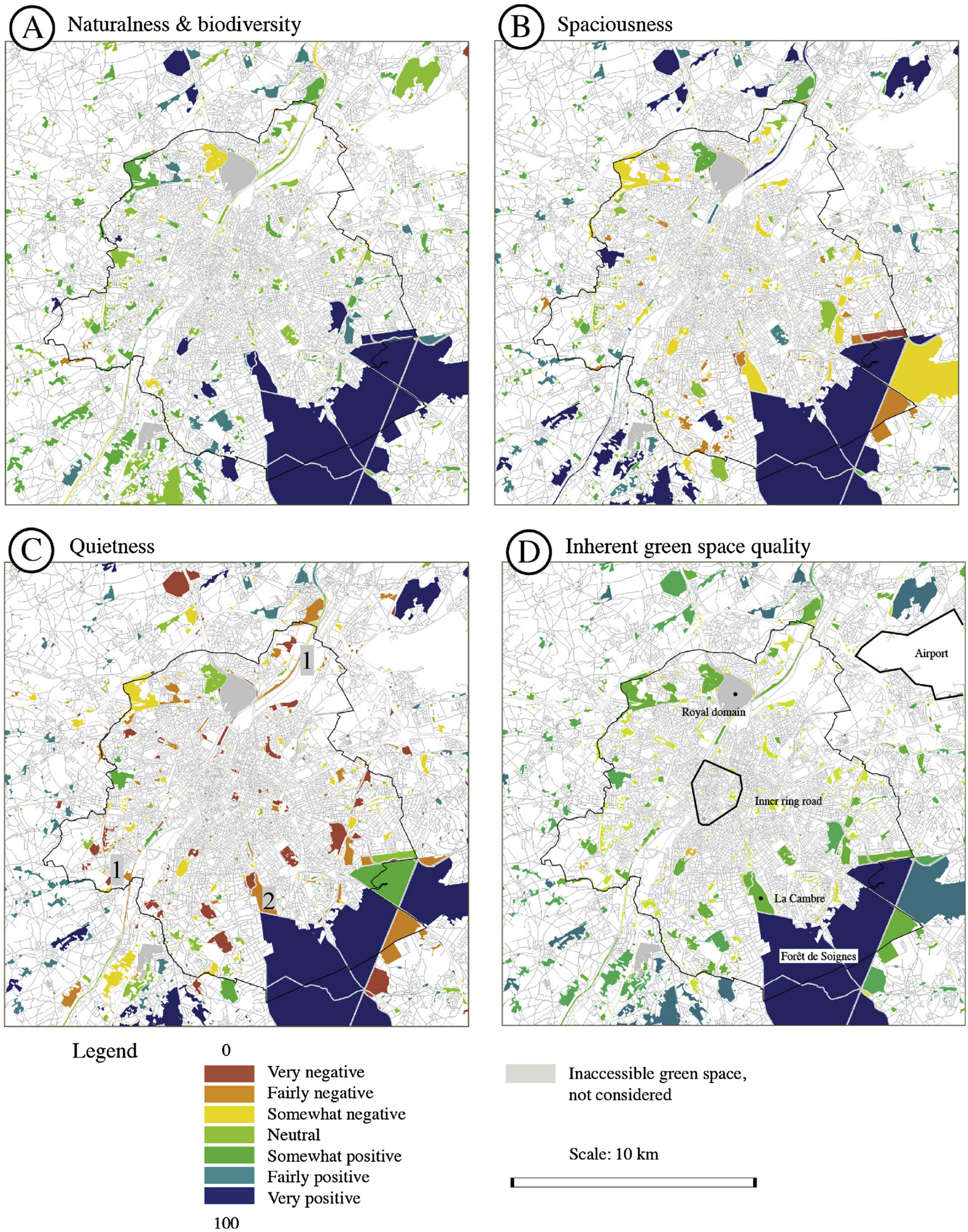

Fig. 5. Naturalness and biodiversity, spaciousness, quietness and inherent quality of green spaces in Brussels. The outline shown represents the Brussels-Capital Region, surrounded by the Flemish Region.

composition, and area-shape characteristics of parks. Naturalness and biodiversity might be improved in smaller urban parks, as well as for surroundings of (social) housing complexes or in formal parks, by introducing more local species of plants, which in turn attract more living species (Bastian, 2013). Spaciousness, on the other hand, seems not only dependent on surface area, but also on shape of the area and tree cover fraction. The influence of tree cover corresponds to the statement of Grahn (1991) that the feeling of space depends on the unawareness of limited dimensions of GS. Knowledge on how the physical and spatial structure of the landscape affects user valuation is instrumental for urban planners and green space managers and may help in guiding improvements to parks that either exist already or are envisioned for the future.

Perceived quietness proved harder to model based on GIS data. The low correlation observed between modelled and reported quietness may be due to various reasons: a) the inquired ratings of quietness (QUI_Q) were obtained at varying points in time, thus with significantly differing noise levels depending on the hour, day of the week and various contingencies, unlike the GIS-based maps which describe sound pressure level averages based on estimated traffic volumes for 24 h weekdays; b) the rating of quietness may be more dependent on specific locations in the park than the rating of naturalness and spaciousness; c) the masking effect by pleasant sounds leading to a decreased perceived loudness (Coensel, Vanwetswinkel et al. 2011) could not be taken into account; d) aircraft noise has been found to be more annoying and railway noise less annoying than noise caused by car traffic (Miedema and Vos, 1998), however, the conversions proposed in the "Genlyd" Noise Annoyance Model (Pedersen, 2007) could not be applied here since the noise map for the BCR does not include separate values for road, rail and air traffic. Simulated sound pressure maps for different source types based on models calibrated for different moments of the day might increase the correlation between GIS-based noise analysis and the quietness sub-quality as perceived by GS users.

In terms of naturalness and biodiversity, ratings obtained for the BCR are especially high for larger areas or stream-bound GS (Fig. 5A). Spaciousness for areas of the same size is higher in (semi-)rural areas. In urban areas, small to medium sized parks in the center and the 19th century belt tend to score low on spaciousness (Fig. 5B). Although the larger share of parks in the Brussels area is not influenced by highway noise (Fig. 5C), special attention should be given to peripheral GS crossing the Brussels Ring (Fig. 5C-1), since they connect the city to the hinterland, in the case of Brussels often as part of a tributary valley. Currently, noise shielding is rarely present for GS. This technique is mostly used for lowering the impact of traffic noise on residential areas, but could also be used to improve quietness in GS. Scenic roads through forested areas, e.g. the La Cambre park (Fig. 5C-2), take their toll on the parks' quietness, but equally on their spaciousness, as they split up the parks in smaller segments (Fig. 5C-1).

In general, inherent quality appears to be high in either large GS or peri-urban GS. Therefore, the proposed model is especially useful for improving small to medium scale urban GS. For peripheral GS, a more specific green space valuation process is needed that would evaluate the role of agricultural land use in green space perception. The valuation of GS in this study does not reflect the recreational use of agricultural areas, where perceived GS constitutes a combination of publicly accessible roads or paths and privately owned farmland. Defining a green space valuation method that includes the way farmland contributes to the experience of GS could alter the modelling of spaciousness for peripheral GS, as well as other green space qualities.

Within the proposed methodology, more detailed surveys can improve the models proposed. Striving for a full inventory on use-related qualities will allow the modelling approach to be extended to an assessment of the overall quality of GS. The research would also benefit from including community and social diversity related aspects, regularly cited in other studies on the valuation of GS (e.g. Germann-Chiari and Seeland, 2004; Kingsley and Townsend, 2006; Arnberger and Eder, 2012; Bertram and Rehdanz, 2015). Currently, model parameters are based on the average questionnaire respondent, yet a more extended survey dataset would allow for including parameters pertaining to spatially explicit cultural differences among green space users. This is especially relevant for Brussels, due to the strong cultural differences between and within neighborhoods. With culturally articulated weightings, policy and design proposals can better serve the local population.

Future research should also involve proximity between residents and the GS they visit as a precondition for use, as well as explore the potential of the generated indicators for urban design, planning and policy making through design research or design charettes and scenario-based simulation workshops.

6. Conclusions

A new approach for green space analysis in an urbanized environment has been presented in the form of a tool for mapping perceived quality of GS. The approach builds on qualitative definitions of quality and sets up a quantitative framework for questionnaire-supported analysis and modelling of green space quality as perceived by users.

The objective of this study was to assess the impact of different features of UGS on how GS are perceived and to enable GIS data for green space valuation and design, matching the user's perspective. The proposed methodology conceptualizes the perceived quality of UGS as being the result of an appreciation of several sub-qualities. Through a literature study, seven sub-qualities were defined: three use-related (*MNT*, *FAC*, *SAF*) and four inherent sub-qualities (*NAT*, *SPA*, *QUI*, *HIS*). All sub-qualities as well as their relative importance can be informed by means of questionnaires. Based on questionnaire output, a model was proposed describing the perceived quality of GS as a weighted linear combination of the sub-qualities identified.

Results of the research demonstrate that the user's perception of inherent qualities such as 'naturalness and biodiversity' (*NAT*) and 'spaciousness' (*SPA*) can be modelled by available GIS-based data, with model results showing a clear correspondence with quality rankings as perceived by citizens. The GIS-based models allow for an extrapolation of questionnaire-based quality assessments of a selection of parks to all public GS in the area studied. The developed model and the proposed green space quality indicators can support planners, designers and policy makers to imagine scenarios for improving GS and test these scenarios spatially for their predicted impact on perceived quality. This is a valuable asset, since development strategies which fail to provide for properly planned GS may be detrimental to neighborhood quality of life (Douglas, Russell et al. 2018). Scenarios may encompass the spaces themselves, as well as external features such as traffic regulation, management strategies and user involvement. Hopefully the actors will adopt a more integrated approach for the development of recreational UGS and enhancing their cultural ecosystem services in general based on the provided quantitative decision support.

The model is still limited as to its ability to describe use-related sub-qualities. It also does not incorporate community and social diversity related aspects. However, through a more extensive survey targeting specific population groups, and with the emergence of more citizen involvement in local GS, this hiatus can be addressed. GS quality assessment can also be coupled to a proximity and accessibility model (precondition for use) to assess how local residents are served in terms of public urban green, as reported in Stessens et al., 2017a,b.

Declaration of Competing Interest

None.

Acknowledgements

This study receives financial support from the Government of the Brussels Capital Region through the Prospective Research for Brussels programme of Innoviris, the Institute for Promotion of Scientific Research and Innovation in Brussels. The authors are very grateful to the reviewers for their constructive feedback and to those who took part in the questionnaire, as well as to Ms Elisa Tasev, Mr Sebastiaan Willemen, Mr Juan Guillermo Robayo Méndez, and Ms Laura Denoyelle, who helped to collect the questionnaire data.

References

Abdul Malek, N., Mariapan, M., Mohd Shariff, M.K., Aziz, A., 2010. Assessing the Quality of Green Open Spaces: A Review. Healthy Parks Healthy People: International Congress, Melbourne Convention Centre, Melbourne, Australia.

Annear, M.J., Cushman, G., Gidlow, B., 2009. Leisure time physical activity differences among older adults from diverse socioeconomic neighborhoods. Health Place 15 (2), 482–490.

Antrop, M., 1989. Het Landschap Meervoudig Bekeken. DNB/Pelckmans, Kapellen.

Arnberger, A., Eder, R., 2012. The influence of green space on community attachment of urban and suburban residents. Urban For. Urban Green. 11 (1), 41–49.

Bastian, O., 2013. The role of biodiversity in supporting ecosystem services in Natura 2000 sites. Ecol. Indic. 24, 12–22.

Bertram, C., Rehdanz, K., 2015. Preferences for cultural urban ecosystem services: comparing attitudes, perception, and use. Ecosyst. Serv. 12, 187–199.

Bradley, C., Millward, A., 1986. Successful green space — do we know it when we see it? Landsc. Res. 11 (2), 2–8.

Bullock, C.H., 2008. Valuing urban green space: hypothetical alternatives and the status quo. J. Environ. Plan. Manage. 51 (1), 15–35.

Burgess, J., Harrison, C.M., Limb, M., 1988. People, Parks and the urban green: a study of popular meanings and values for open spaces in the city. Urban Stud. 25 (6), 455–473.

Burkhard, B., Petrosillo, I., Costanza, R., 2010. Ecosystem services – bridging ecology, economy and social sciences. Ecol. Complex. 7 (3), 257–259.

CABE, 2004. The value of public space. In: Woolley, H., Rose, S., Carmona, M., Freedman, J. (Eds.), How High Quality Parks and Public Spaces Create Economic, Social and Environmental Value. CABE Space, London.

CABE, 2005. In: Cowan, R., Hill, D. (Eds.), Start With the Park: Creating Sustainable Urban Green Spaces in Areas of Housing Growth and Renewal. CABE Space, London.

Camps-Calvet, M., Langemeyer, J., Calvet-Mir, L., Gomez-Baggethun, E., 2016. Ecosystem services provided by urban gardens in Barcelona, Spain: insights for policy and planning. Environ. Sci. Policy 62, 14–23.

Caspersen, O.H., Konijnendijk, C.C., Olafsson, A.S., 2006. Green space planning and land use: an assessment of urban regional and green structure planning in Greater Copenhagen. Geografisk Tidsskrift-Danish J. Geogr. 106 (2), 7–20.

Chang, J., Qu, Z., Xu, R., Pan, K., Xu, B., Min, Y., Ren, Y., Yang, G., Ge, Y., 2017. Assessing the ecosystem services provided by urban green spaces along urban center-edge gradients. Sci. Rep. 7 (1), 11226.

Chen, B., Adimo, O.A., Bao, Z., 2009. Assessment of aesthetic quality and multiple functions of urban green space from the users' perspective: The case of Hangzhou Flower Garden, China. Landsc. Urban Plan. 93 (1), 76–82.

Coensel, B.D., Vanwetswinkel, S., Botteldooren, D., 2011. Effects of natural sounds on the perception of road traffic noise. J. Acoust. Soc. Am. 129 (4), EL148–EL153.

Coeterier, J.F., 1987. De waarneming en waardering van landschappen. Landbouwuniversiteit Wageningen.

Coeterier, J.F., 1996. Dominant attributes in the perception and evaluation of the Dutch landscape. Landsc. Urban Plan. 34 (1), 27–44.

Coeterier, J.F., 2000. Hoe beleven wij onze omgeving? Resultaten van 25 jaar omgevingspsychologisch onderzoek in stad en landschap.

Cohen, P., Potchter, O., Schnell, I., 2014. A methodological approach to the environmental quantitative assessment of urban parks. Appl. Geogr. 48, 87–101.

de la Barrera, F., Reyes-Paecke, S., Banzhaf, E., 2016. Indicators for green spaces in contrasting urban settings. Ecol. Indic. 62, 212–219.

De Ridder, K., Adamec, V., Bañuelos, A., Bruse, M., Bürger, M., Damsgaard, O., Dufek, J., Hirsch, J., Lefebre, F., Pérez-Lacorzana, J.M., Thierry, A., Weber, C., 2004. An integrated methodology to assess the benefits of urban green space. Sci. Total Environ. 334–335, 489–497.

Doick, K.J., Sellers, G., Castan-Broto, V., Silverthorne, T., 2009. Understanding success in the context of brownfield greening projects: the requirement for outcome evaluation in urban greenspace success assessment. Urban For. Urban Green. 8 (3), 163–178.

Douglas, O., Russell, P., Scott, M., 2018. Positive perceptions of green and open space as predictors of neighbourhood quality of life: implications for urban planning across the city region. J. Environ. Plan. Manag. 1–21.

Eng, T.-Y., Niininen, O., 2005. An integrative approach to diagnosing service quality of public parks. J. Serv. Mark. 19 (2), 70–80.

Fast, T., van den Hazel, P.J., van de Weerdt, eD H.J., 2012. gezondheidseffectscreening, Gezondheid en milieu in ruimtelijke planvorming - Handboek voor een gezonde inrichting van de leefomgeving. In: Milieu, M., van Volksgezondheid, W.M. (Eds.), Den Haag, Bureau Medische Milieukunde en Fast Advies, pp. 346.

FOD Economie, 2011. CENSUS 2011 Open Data, Federaal Planbureau België. Federale Overheidsdienst Economie, KMO, Middenstand en Energie. Algemene Directie Statistiek en Economische Informatie.

FOD Economie, 2013. Bevolkingsvooruitzichten 2012-2060, Federaal Planbureau België. Federale Overheidsdienst Economie, KMO, Middenstand en Energie. Algemene Directie Statistiek en Economische Informatie.

Germann-Chiari, C., Seeland, K., 2004. Are urban green spaces optimally distributed to act as places for social integration? Results of a geographical information system (GIS) approach for urban forestry research. For. Policy Econ. 6 (1), 3–13.

Gidlöf-Gunnarsson, A., Öhrström, E., 2007. Noise and well-being in urban residential environments: the potential role of perceived availability to nearby green areas. Landsc. Urban Plan. 83 (2–3), 115–126.

Gobster, P.H., 1998. Urban parks as green walls or green magnets? Interracial relations in neighborhood boundary parks. Landsc. Urban Plan. 41 (1), 43–55.

Grahn, P., 1991. Landscapes in our minds: people's choice of recreative places in towns. Landsc. Res. 16 (1), 11–19.

Grahn, P., Stigsdotter, U.K., 2010. The relation between perceived sensory dimensions of urban green space and stress restoration. Landsc. Urban Plan. 94 (3–4), 264–275.

Haaland, C., van den Bosch, C.K., 2015. Challenges and strategies for urban green-space planning in cities undergoing densification: a review. Urban For. Urban Green. 14 (4), 760–771.

Haines-Young, R., Potschin, M., 2010. The links between biodiversity, ecosystem services and human well-being. In: Raffaelli, D., Frid, C. (Eds.), Ecosystem Ecology: A New Synthesis. CUP, Cambridge, pp. 110–139.

Hedblom, M., Knez, I., Ode Sang, Å., Gunnarsson, B., 2017. Evaluation of natural sounds in urban greenery: potential impact for urban nature preservation. R. Soc. Open Sci. 4 (2), 170037.

Hillsdon, M., Panter, J., Foster, C., Jones, A., 2006. The relationship between access and quality of urban green space with population physical activity. Public Health 120 (12), 1127–1132.

Hinkle, D.E., Wiersma, W., Jurs, S.G., 2003. Applied Statistics for the Behavioral Sciences.

Hirons, M., Comberti, C., Dunford, R., 2016. Valuing cultural ecosystem services. Annu. Rev. Environ. Resour. 41 (1), 545–574.

Howley, P., 2011. Landscape aesthetics: assessing the general publics' preferences towards rural landscapes. Ecol. Econ. 72, 161–169.

Inglehart, R., Welzel, C., 2010. Changing mass priorities: the link between modernization and democracy. Perspect. Politics 8 (2), 551–567.

Jansson, M., Fors, H., Lindgren, T., Wiström, B., 2013. Perceived personal safety in relation to urban woodland vegetation—a review. Urban For. Urban Green. 12 (2), 127–133.

Jim, C., 2004. Green-space preservation and allocation for sustainable greening of compact cities. Cities 21 (4), 311–320.

Jim, C.Y., Chen, W.Y., 2006. Recreation–amenity use and contingent valuation of urban greenspaces in Guangzhou, China. Landsc. Urban Plan. 75 (1), 81–96.

Jim, C.Y., Chen, W.Y., 2010. External effects of neighbourhood parks and landscape elements on high-rise residential value. Land Use Policy 27 (2), 662–670.

Jim, C.Y., Shan, X., 2013. Socioeconomic effect on perception of urban green spaces in Guangzhou, China. Cities 31, 123–131.

Jorgensen, A., Anthopoulou, A., 2007. Enjoyment and fear in urban woodlands – does age make a difference? Urban For. Urban Green. 6 (4), 267–278.

Jorgensen, A., Hitchmough, J., Dunnett, N., 2007. Woodland as a setting for housing-appreciation and fear and the contribution to residential satisfaction and place identity in Warrington New Town, UK. Landsc. Urban Plan. 79 (3), 273–287.

Kabisch, N., Haase, D., 2013. Green spaces of European cities revisited for 1990–2006. Landsc. Urban Plan. 110, 113–122.

Kaczynski, A.T., Potwarka, L.R., Smale, B.J.A., Havitz, M.E., 2009. Association of parkland proximity with neighborhood and park-based physical activity: variations by gender and age. Leis. Sci. 31 (2), 174–191.

Kaplan, R., 1984. Special issue nature in the CityImpact of urban nature: a theoretical analysis. Urban Ecol. 8 (3), 189–197.

Kaplan, R., Kaplan, S., 1989. The Experience of Nature: A Psychological Perspective. Cambridge University Press, Cambridge; New York.

Kaplan, S., 1990. In: Sorte, G.J. (Ed.), Parks for the Future: A Psychological Perspective. Parks for the Future. Sveriges Lantbruksuniversitet, Alnarp, pp. 85.

Khan, A.Z., Moulaert, F., Schreurs, J., 2014. Understanding spatial quality: a relational epistemology and transdisciplinary perspectives in planning and urban design: JUD special issue. J. Urban Des. 19, 393–510.

Kingsley, J., Townsend, M., 2006. 'Dig in' to social capital: community gardens as mechanisms for growing urban social connectedness. Urban Policy Res. 24 (4), 525–537.

Knez, I., Ode Sang, Å., Gunnarsson, B., Hedblom, M., 2018. Wellbeing in urban greenery: the role of naturalness and place identity. Front. Psychol. 9 (491).

Kong, F., Yin, H., Nakagoshi, N., 2007. Using GIS and landscape metrics in the hedonic price modeling of the amenity value of urban green space: a case study in Jinan City, China. Landsc. Urban Plan. 79 (3–4), 240–252.

Kothencz, G., Blaschke, T., 2017. Urban parks: visitors' perceptions versus spatial indicators. Land Use Policy 64, 233–244.

Kothencz, G., Kolcsár, R., Cabrera-Barona, P., Szilassi, P., 2017. Urban green space perception and its contribution to well-being. Int. J. Environ. Res. Public Health 14 (7).

Kremer, P., Hamstead, Z., Haase, D., McPhearson, T., Frantzeskaki, N., Andersson, E., Kabisch, N., Larondelle, N., Rall, E.L., Voigt, A., Bar, F., Bertram, C., mez-Baggethun, E., Hansen, R., Kaczorowska, A., Kain, J.-H., Kronenberg, J., Langemeyer, J., Pauleit, S., Rehdanz, K., Schewenius, M., van Ham, C., Wurster, D., Elmqvist, T., 2016. Key insights for the future of urban ecosystem services research. Ecol. Soc. 21 (2).

Lappé, F.M., 2009. Questions to ask strategies to save our planet. Solutions 1 (1), 34–35.

Lindholst, A.C., Konijnendijk van den Bosch, C.C., Kjøller, C.P., Sullivan, S., Kristoffersson, A., Fors, H., Nilsson, K., 2016. Urban green space qualities reframed toward a public value management paradigm: the case of the Nordic Green space award. Urban For. Urban Green. 17, 166–176.

LNE, 2009. In: Overheid, V. (Ed.), Richtlijn Omgevingslawaai. Geluidskaarten en actieplannen in Vlaanderen. LNE, Brussel, pp. 52.

Luederitz, C., Brink, E., Gralla, F., Hermelingmeier, V., Meyer, M., Niven, L., Panzer, L., Partelow, S., Rau, A.-L., Sasaki, R., Abson, D.J., Lang, D.J., Wamsler, C., von Wehrden, H., 2015. "A review of urban ecosystem services: six key challenges for future research. Ecosyst. Serv. 14, 98–112.

Madge, C., 1997. Public parks and the geography of fear. Tijdschrift voor economische en sociale geografie 88 (3), 237–250.

Madureira, H., Nunes, F., Oliveira, V.J., Madureira, T., 2018. Preferences for urban green space characteristics: a comparative study in three portuguese cities. Environments 5 (2).

Mens en Ruimte, 1999. Maatschappelijke Waardering van Groen en Landschap. Ministerie van de Vlaamse Gemeenschap, Brussel. Unpublished (in Dutch). Ministerie van de Vlaamse Gemeenschap, Brussel.

Miedema, H., Vos, H., 1998. Exposure-response relationships for transportation noise. J. Acoust. Soc. Am. 104 (6), 3432–3445.
Morancho, A.B., 2003. A hedonic valuation of urban green areas. Landsc. Urban Plan. 66 (1), 35–41.
Neßhöver, C., Beck, S., Born, W., Dziock, S., Görg, C., Hansjürgens, B., Jax, K., Köck, W., Rauschmayer, F., Ring, I., 2007. Das millennium ecosystem assessment-eine deutsche perspektive. Natur und Landschaft 82 (6), 262–267.
Ode Sang, Å., Knez, I., Gunnarsson, B., Hedblom, M., 2016. The effects of naturalness, gender, and age on how urban green space is perceived and used. Urban For. Urban Green. 18, 268–276.
Pedersen, T., 2007. The “Genlyd” Noise Annoyance Model: Dose-Response Relationships Modelled by Logistic Functions. DELTA Acoustics & Electronics, Hørsholm, Denmark.
Peterken, G.F., 1996. Natural Woodland : Ecology and Conservation in Northern Temperate Regions. Cambridge University Press, Cambridge; New York.
Plieninger, T., Dijks, S., Oteros-Rozas, E., Bieling, C., 2013. Assessing, Mapping, and Quantifying Cultural Ecosystem Services at Community Level.
Qureshi, S., Breuste, J.H., Jim, C.Y., 2013. Differential community and the perception of urban green spaces and their contents in the megacity of Karachi, Pakistan. Urban Ecosyst. 16 (4), 853–870.
Richardson, E., Pearce, J., Mitchell, R., Day, P., Kingham, S., 2010. The association between green space and cause-specific mortality in urban New Zealand: an ecological analysis of green space utility. BMC Public Health 10 (1), 1–14.
Sandström, U.G., Angelstam, P., Mikusiński, G., 2006. Ecological diversity of birds in relation to the structure of urban green space. Landsc. Urban Plan. 77 (1–2), 39–53.
Sanesi, G., Chiarello, F., 2006. Residents and urban green spaces: the case of Bari. Urban For. Urban Green. 4 (3–4), 125–134.
Schipperijn, J., Bentsen, P., Troelsen, J., Toftager, M., Stigsdotter, U.K., 2013. Associations between physical activity and characteristics of urban green space. Urban For. Urban Green. 12 (1), 109–116.
Smith, T., Nelischer, M., Perkins, N., 1997. Quality of an urban community: a framework for understanding the relationship between quality and physical form. Landsc. Urban Plan. 39 (2–3), 229–241.
Sreetheran, M., van den Bosch, C.C.K., 2014. A socio-ecological exploration of fear of crime in urban green spaces – a systematic review. Urban For. Urban Green. 13 (1), 1–18.
Statistiek Vlaanderen, 2018. Lokale Inburgerings- en Integratiemonitor. D. K. e. Bestuur. Vlaamse Statistische Autoriteit, Brussel, pp. 6.
Stessens, P., Khan, A., Huysmans, M., Canters, F., 2017a. Analysing urban green space accessibility and quality: a GIS-based model as spatial decision support for urban ecosystem services in Brussels. Ecosyst. Serv.
Stessens, P., Khan, A.Z., Huysmans, M., Canters, F., 2017b. Analysing urban green space accessibility and quality: a GIS-based model as spatial decision support for urban ecosystem services in Brussels. Ecosyst. Serv.
Stigsdotter, U.K., Grahn, P., 2011. Stressed individuals’ preferences for activities and environmental characteristics in green spaces. Urban For. Urban Green. 10, 295–304.
Sugiyama, T., Thompson, C.W., Alves, S., 2009. Associations between neighborhood open space attributes and quality of life for older people in Britain. Environ. Behav. 41 (1), 3–21.
Tzoulas, K., Korpela, K., Venn, S., Yli-Pelkonen, V., Kaźmierczak, A., Niemela, J., James, P., 2007. Promoting ecosystem and human health in urban areas using green infrastructure: a literature review. Landsc. Urban Plan. 81 (3), 167–178.
Van de Voorde, T., Canters, F., Cheung-Wai Chan, J., 2010. Mapping Update and Analysis of the Evolution of Non- Built (green) Spaces in the Brussels Capital Region. Vrije Universiteit Brussel, Brussels, pp. 35.
Van Dillen, S.M.E., de Vries, S., Groenewegen, P.P., Spreeuwenberg, P., 2012. Greenspace in urban neighbourhoods and residents’ health: adding quality to quantity. J. Epidemiol. Community Health 66 (6) e8-e8.
Van Herzele, A., 2005. ‘A Tree on Your Doorstep, a Forest in Your Mind’ Greenspace Planning at the Interplay Between Discourse, Physical Conditions, and Practice.
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.
Velarde, M.D., Fry, G., Tveit, M., 2007. Health effects of viewing landscapes – landscape types in environmental psychology. Urban For. Urban Green. 6 (4), 199–212.
Voigt, A., Kabisch, N., Wurster, D., Haase, D., Breuste, J., 2014. Structural diversity: a multi-dimensional approach to assess recreational services in Urban Parks. AMBIO 43 (4), 480–491.
Voigt, A., Wurster, D., 2015. Does Diversity Matter? The Experience of Urban Nature’s Diversity: Case Study and Cultural Concept.
Wan, C., Shen, G.Q., 2015. Salient attributes of urban green spaces in high density cities: the case of Hong Kong. Habitat Int. 49, 92–99.
Zhang, Y., Van den Berg, A., Van Dijk, T., Weitkamp, G., 2017. Quality over quantity: contribution of urban green space to neighborhood satisfaction. Int. J. Environ. Res. Public Health 14 (5), 535.
Zhang, Y., van Dijk, T., Tang, J., Berg, A., 2015. "Green space attachment and health: a comparative study in two urban neighborhoods. Int. J. Environ. Res. Public Health 12 (11), 14342.