Bigger, more diverse and better?
Mapping structural diversity and its recreational value in urban green spaces.

Emma Soy Massoni[1], David N. Barton[2], Graciela Rusch[3], Vegard Gundersen[4]
1 Landscape Analyses and Management Laboratory, Geography Department, University of Girona, Spain.
2 Corresponding author: Norwegian Institute for Nature Research (NINA), Gaustadalleen 21, 0349 Oslo, Norway. david.barton@nina.no
3 Norwegian Institute for Nature Research (NINA), Trondheim, Norway
4 Norwegian Institute for Nature Research (NINA), Lillehammer, Norway

Abstract

Are bigger green spaces more diverse in terms of their natural and manmade elements? Does higher diversity mean they are more attractive to users and encourage more diversity of activities, and thereby provide a wider range of recreational ecosystem services? We assessed and classified the recreational services in green urban spaces in the city of Oslo, by combining multidimensional biophysical mapping based on the structural diversity index (SDI), with users' importance scores as an approach to non-monetary valuation of urban parks. Our results reveal that size is a weak and non-linear determinant of structural diversity. On the other hand, stated preferences are correlated with structural elements. Urban green spaces classification could be improved by combining structural diversity indicators with structural preference studies. At the same time, our structural diversity measure did not cover the full range of recreational services across the spectrum of urban green spaces. We discuss potential extensions of the structural diversity index for urban green space in order to cover a wider range of green spaces - from cemetaries to peri-urban forest - and the recreational opportunities provided by them.

Keywords:
Urban green spaces, structural diversity, recreation, cultural ecosystem services, size.

1. Introduction

The presence of blue-green spaces and structures in cities contributes to the quality of life in many ways (Chiesura, 2004) involving a wide range of ecosystem services and benefits. Urban green spaces contribute to the quality of life in the city, such as aesthetic and recreation services (Bolund & Hunhammar, 1999; Martín-López, Gómez-Baggethun, Lomas, & Montes, 2009). In a global context where more than half the world's population lives in cities, compared with about 14% a century ago (United Nations, 2001), those services are crucial for population well-being (Kaplan & Kaplan, 1989, Elmqvist et al. 2015). Understanding social and cultural values of recreation is important for urban planning (La Rosa, Spyra, & Inostroza, 2016), but also complex to study because urban areas have high environmental, cultural and social diversity (Gómez-Baggethun & Barton, 2013). Our study focuses on urban recreational services in the city of Oslo, Norway.

Recreational value

Satisfying recreational experiences depends on the design of natural and manmade elements, and on amenities meeting visitors' interests and demands (Edwards et al., 2012; Manning et al., 2011). Recent studies dealing with the relationship between green urban areas' characteristics and visitors' activities

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and demands propose integrating methods to assess both the supply and demand of recreational services. For instance, integrated studies use indicators of preferences, use, and spatial composition of green spaces (e.g. Caspersen & Olafsson, 2010; Edwards et al., 2012; Tyrväinen, Mäkinen, & Schipperijn, 2007; Voigt, Kabisch, Wurster, Haase, & Breuste, 2014) which, when assessing the usability of urban green spaces requires high resolution of spatially explicit data (Farrugia, Hudson, & McCulloch, 2013; Sheate et al., 2012). Planning and designing green spaces' could be improved with better understanding of their characteristics and the relationship with use and enjoyment across diverse social groups of users (Arnold & Shinew, 1998; Chiesura, 2004; Faehnle, Bäcklund, & Tyrväinen, 2011; Schwab, 1993).

In recreation research, recreational quality is conceived as the degree to which environmental opportunities meet people`s preferences (Manning et al., 2011). Understanding the diversity of opportunities provided by urban green spaces is important since even participants in the same activity may differ in terms of their environmental preferences (Edwards et al., 2012; Gundersen, Tangeland, & Kaltenborn, 2015). Various research and planning efforts have elaborated systematic measurements of the recreational experience in urban green space. Based on how urban populations perceive and experience urban green spaces, concepts such as "park characteristics" (Grahn & Stigsdotter, 2010; Nordh, 2010), "social values" (Tyrväinen et al., 2007), "experience classes" (Caspersen & Olafsson, 2010), and 'sociotopes' (Ståhle, 2006) have been developed to help planners and designers understand the recreational qualities of these spaces. Many of the characteristics that have been identified to describe recreational quality of green spaces (such as "historicity", "visual scale", "coherence" and "ephemera" (Tveit, Ode, and Dry 2006)) are not possible to measure in a quantitative way. Thus, quantitative assessments that include the observable structural composition and diversity in recreational urban spaces, and their importance may be an alternative to map recreational values in an urban setting.

Structural elements of the urban green spaces and their value for recreation activities

Recreational services from urban green spaces are co-produced by biotic, abiotic and constructed structures, all contribute to enhance the recreational qualities of urban space: variety of opportunities and physical settings, sociability and cultural diversity (Burguess, Limb, & Harrison, 1988). Criteria such as land use, ground and water, historic character, naturalness and spaciousness (Coeterier, 1996), as well as size and the presence of facilities (Coles & Bussey, 2000) have an effect on the level of use. Regarding the elements of urban green spaces, several authors report trees, forest and wooded areas as important determinants of the recreational value (Cohen et al., 2006; Kaczynski & Henderson, 2008; Nordh, Alalouch, & Hartig, 2011; Shores & West, 2008; Voigt et al., 2014), but other land-uses with a diversity of flowers, birds and other wildlife can be highly valued as well (Shoard, 2003). Nordh and Ostby (2013) found that the structures that contribute the most to high ratings on psychological restoration in small urban green spaces were "natural" structures, including 'a lot of grass' followed by 'a lot of flowers/plants' and 'water features'. Dunnett, Swanwick, and Woolley (2002), Nordh and Ostby (2013), and Voigt et al. (2014) also found that proximity to water is highly valued. In addition to natural and water elements, other recreational infrastructures are also important for public use of green urban areas: sport facilities and pathways, toilet facilities, playgrounds, sitting features, lighting, dog facilities, drinking fountain and swimming areas, public transport access, and silence and tranquility areas (Gundersen & Frivold, 2008; Nordh and Ostby, 2013; Nordh et al., 2011; Voigt et al., 2014; and references therein). Presence of people can affect the suitability of green spaces for recreation both positively and negatively depending on various factors; e.g. the expectations of the visitors, crowdedness, behavior, and kind of activities that are conducted (Edwards et al., 2012; Grahn & Stigsdotter, 2010; Gundersen & Frivold, 2008; Nordh, 2010; Tveit et al., 2006; Tyrväinen et al., 2007). Negative perceptions of green urban areas also occur, such as fear of forested areas, especially among female users (e.g. Skår, 2010).

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Park quantity, measured as the percentage area covered by public parks, has been found to be a strong predictor of self-reported well-being in cities (Larson et. al 2016) and several studies reveal that the size of green urban areas influences the provision of ecosystem services. For instance, the provision of habitat quality for fauna depends on size (Bolund & Hunhammar, 1999), and a significant climatic function can only be expected when park size exceeds one hectare (Tyrväinen, Pauleit, Seeland, & de Vries, 2005). Urban forest size appears to increase the quality of space for humans, as revealed by house prices (Kong, Yin, & Nakagoshi, 2007). Studies in the UK have shown that urban parks have a minimum size of about two hectares to be attractive for visitors and that attractiveness increases when green spaces are connected by footpaths (Coles & Bussey, 2000). In addition, the literature suggests that the size of urban green spaces is related to the diversity of elements they contain (Voigt et al., 2014). However, the relationship between green urban areas' size and the diversity of structural elements present is not well studied.

Are bigger green spaces usually more diverse and if they are, does higher diversity mean that they are more attractive to users? Kaplan and Kaplan (1989) refer to the diversity of elements in green spaces as 'complexity', and suggest that preferences for complexity is bell-shaped, in thesense that too much diversity gives an impression of a "messy" environment and too little diversity of a "boring" experience. Therefore, more detailed knowledge of green spaces' functional diversity in terms of the recreational services perceived by urban dwellers should be useful for the establishment, maintenance and restoration of urban recreational areas.

A step in this direction is to systematize the information about the biophysical elements of urban green space. We followed the approach by Voigt et al. (2014) who proposed a classification of the structural elements in green spaces according to three dimensions: natural elements, abiotic site conditions and recreational infrastructure. To make the method rapid to implement in the field, the authors recorded structural elements as present/absent. Their method requires relatively modest data-collection effort at the same time as it provides sufficient detail for planning of urban green spaces, while covering a wide range of aspects of usability. We extended the approach by estimating a 'relative importance score' which combines the biophysical qualities and their functional importance for recreation as perceived by green space users. We discuss how the relative importance scores constitute a mapping of non-monetary values of recreational services from green spaces. The relative importance score for urban green space structures is inspired by functional diversity mapping (e.g. Craven, Filotas, Angers, & Messier, 2016).

We aimed to test four hypotheses about the recreational value of green spaces in Oslo: 1) whether there is an association between green space size and the diversity of biotic, abiotic and man-made elements. 2) If higher diversity of structural elements gives more opportunities to people with different recreational interests. 3) Whether people's activities and preferences for green space are associated to specific structural elements. 4) Whether the green space features and recreational opportunities are spatially structured in Oslo.

2. Methods

Study area

The City of Oslo's built-up area spans 15,270 ha, where 18.5% are urban green spaces, being 1% cementeries, 14.44% public open spaces and 3.1% parks. Parks are managed green spaces within the built zone. Public open spaces ("friområder" in Norwegian) are largely unmanaged green spaces within

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the built zone open to the public. In the following parks, public open space and cementaries are collectively referred to as “green space”.

Six percent of the Oslo Municipality is fresh water, with ten main streams running through the urban area. The city is situated at the end of the Oslo Fjord, and is surrounded by seawater and islands to the south, and boreal forests to the North and East (Oslo European Green Capital 2016 Application).

Oslo had 624,000 inhabitants in 2013, and population projections indicate that the city will number about 800,000 people in 2030 (Oslo Municipality, 2015). National and municipal protected areas for conservation make up almost 10 % of the area in Oslo municipality, and are located in the built-up area, on islands and in the surrounding forest. The fjord and the forests, combined with the city’s green spaces, waterways and islands, constitute a unique blue-green infrastructure, providing multiple ecosystem services for Oslo’s residents, including valuable habitats for biodiversity conservation in Norway (Fig. 1).

Since 1960s there has been numerous of research studies understanding the recreational value of fringe forest in Oslo (e.g. Gundersen et al., 2015), research on the recreational value of green spaces in the inner city in Oslo have been largely neglected (Barton, Vågnes-Traaholt, & Blumentrath, 2015). Oslo Municipality has recently joined a national effort to map and value recreational areas following guidance by the Norwegian Environment Agency (Norwegian Environment Agency, 2014). The guidance uses a broad classification scheme and non-monetary valuation based on expert judgement, informed by consultations with user interests. The methodology proposed in the guidance refers mainly to criteria of accessibility, but does not offer specific indicators of recreational area quality,

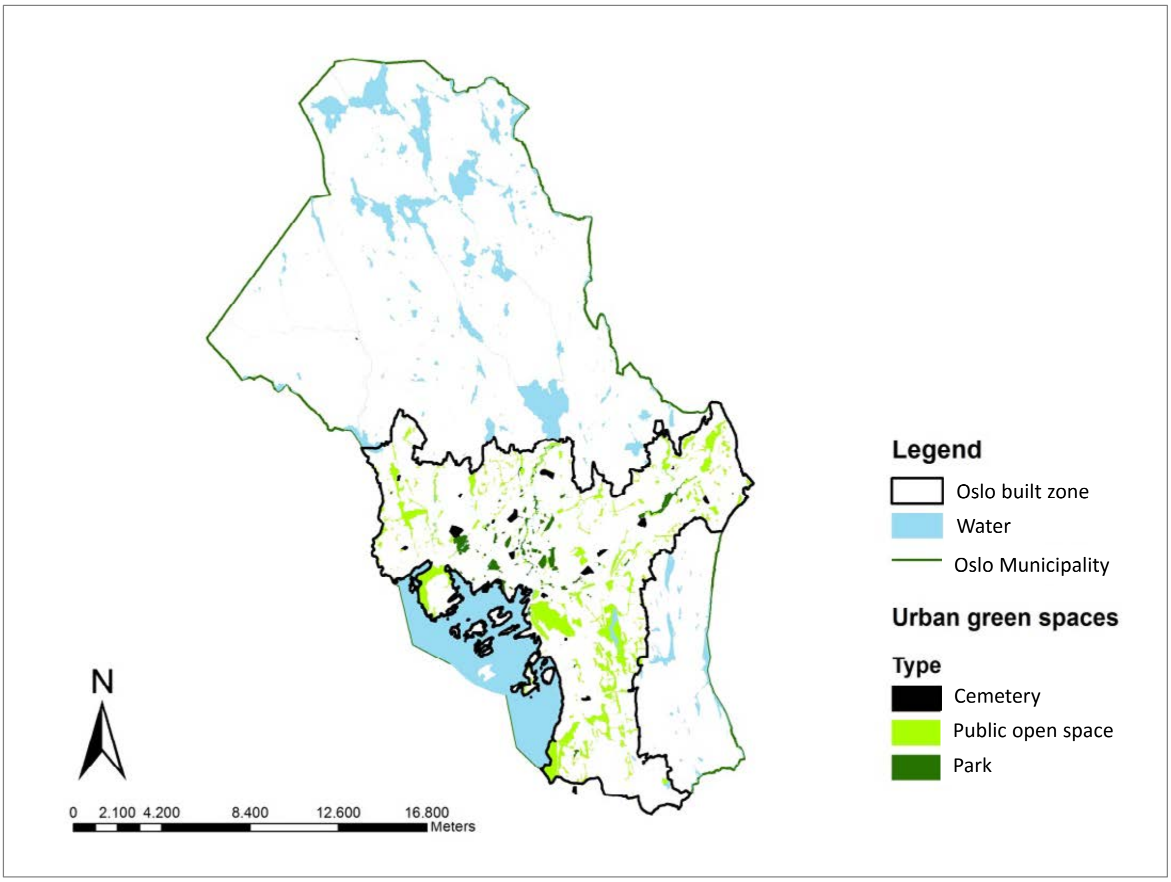

Figure 1. The study area defined as green spaces within the built zone of Oslo Municipality.

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which could be used to make a more informed expert judgement about relative value. The structural diversity index fills this gap, while our survey of a sample of green space users demonstrates a systematic approach to gathering non-monetary valuation data.

Oslomarka comprises the forested area bordering Oslo's built-up area. The Marka Act (2009) establishes that the forest be managed primarily for recreation. While forestry is permitted, development of further recreational infrastructure is strictly regulated and housing development generally prohibited.

Methodology approach

To test our four hypotheses about the recreational value of green spaces in Oslo, we used several methodological approaches, summarized in Table 1.

Table 1. Methods and analyses used to test each hypothesis formulated at the beginning of the study.

Hypothesis	Method and data analyses	
H1: ***Size-diversity.*** *Structural diversity will correspond positively with green space size*	Mapping structural elements and green space size	Spatial data analyses: Structural Diversity Index - SDI
H2: ***Diversity-opportunity.*** *Higher diversity of structural elements gives more opportunities to people with different recreational interests*	Mapping structural elements and interview survey	Statistical data analyses: PCA Analyses
H3: ***Preference and activity clustering****. Cluster of preferences and activities are associated with specific structural elements*	Interview survey	Statistical data analyses: PCA Analyses
H4: ***Spatial structure.*** *The composition and recreational opportunities of green spaces in Oslo are spatially structured.*	Mapping structural elements and interview survey	Spatial data analyses: Structural Diversity Index – SDI; Relative Importance Score – RIS; Moran's I test; and Hot Spot Analyses

a) Mapping structural elements

The mapping exercise recorded the presence of 30 structural elements occurring in green spaces in the inner city zone included in the study area (Figure 1). The selection of the elements was based following two criteria: the spatial data availability in the municipality and the importance for recreational value in urban green spaces as cited in the literature. The presence/absence of each of the elements shown in Table 2 was assessed in 547 green space polygons. The Municipality of Oslo facilitated the cartography in shapefile format (points, polygons or lines). In the case of the elements "public transport access" and "swimming areas" we considered their presence if the element was within a *buffer* area of 100m around each polygon. We included bus, tram, metro and train in public transport data. Different assumptions were made for the following landscape elements:

We defined *forest or grass dominance* when the forest or grass cover within the polygons occupied more than 60%, and we defined "balance" between forest and grass as both land covers being present in the same polygon with each occupying between 40 and 60% of the surface. *Potential congestion* was an indicator of the probability of the area of being crowded. We considered congestion to be "high" and "low" where the average population density within the polygon was higher and lower than 4600 inhabitants/km^2, respectively. We calculated street lighting point density and classified polygons into two levels: polygons where more than 50% of the area had low light points density (<10 points/ha) were classified as low light density, while polygons with more than 50% of area had light point density (>10 light points/ha) were classified as high light point density. We considered that "varied terrain" occurred when more than 30% of the green space surface had a slope of 20% or higher. Regarding

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"Silence and tranquility areas" we included 14 areas that Oslo Municipality has designated as blue-green quiet areas (The Noise Action Plan, 2008-2013), i.e. areas for outdoor recreation and cultural activities that are shielded from main sources of noise.

Table 2. Structural elements included in the mapping exercise of the green spaces in Oslo.

Biotic elements	Abiotic elements	Man-made elements	
Forest dominance	Fountain	Public transport access	Swimming area
Grass dominance	River/water course/stream	Sitting facility	Silence/tranquility area
Balanced forest/grass	Lake/pond	Grill/Picnic	Cultural/art element
Old/big tree	Varied terrain	Fishing area by the fjord	Urban agriculture area
Tree species diversity		Dog facility	High presence of people
Shrub		Playground	Low presence of people
Fruit tree		Walking/Cycle path	High intensity lighting
Flowerbed		Sport equipment	Low intensity lighting
Wild plants and animals		Bars/restaurant	

Table 2 in appendix provides a complete definition list of structural elements.

Note in Table 2 that the resolution of structural elements is limited in describing public open spaces with unmanaged vegetation – e.g. forest structure is limited to "forest dominance" and "tree species diversity". Similarly, special geological features have not been identified, or are partially considered in the category "varied terrain". Finally, the diversity of structures such as headstones in cemeteries are not identified, or limited to the category "cultural/art element".

b) Survey

In order to demonstrate a methodology for recreational preference assessment we conducted an in-person survey of students at the University of Oslo. Previous studies have argued that student samples from across university faculties are presentative of a diversity of aesthetic preferences (Stamps, 1999). However, our study deals with activity preferences that may differ considerably between students and other social groups. Our aim was to test the methodology by using a student sample that is low cost and, at the same time, sufficiently heterogeneous to demonstrate a preference survey methodology that could be used to assess preferences by the whole population.

We selected students to answer the questionnaire at different points of the *Blindern campus*, where most of the faculties of the University of Oslo are located. Interviews were conducted during the breaks and at entrance to highly frequented places (cantina, café, bar, park, library, etc.) with systematic random interception. The survey was conducted in November-December 2014 by a single interviewer. In total 85 questionnaires were completed for the purpose of testing the survey methodology. The questionnaire was divided into two main sections: (1) questions designed to assess the preference of respondents regarding structural elements of the urban green spaces in the study area (Table 2); (2) the activities that respondents conducted in parks. The list of structural elements of green spaces was determined based on available land cover data, and park management and infrastructure data provided the Urban Environment Agency. The first section of the questionnaire used a Likert-scale (Bernard, 2012) to record perceived importance on a scale from 0 to 10 (0= not important and 10= very important) following the question "*How important is the presence of the following elements when you decide to visit a park in Oslo?"* In the second section, we asked *"Which outdoor recreational activities do you practice on a regular basis when you visit parks?*. The predefined activity categories was based on a shortened list from Chiesura (2004): *1) to do sports, 2) to meet others, 3) to play with children, 4) to walk the dog, 5) to listen and observe nature, 6) to get inspiration and 7) other (specify)"* . The final open category captured uses such as to relax, study, and read.

c) Spatial data analyses

A spatial analysis was carried out using ArcMap10 (ESRI) for the following variables:
- Green spaces size.

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- A normalized value for structural diversity elements in each green space was calculated, hereafter called the Structural Diversity Index (SDI). The normalized value ranged from 0 to 1 and expressed the proportion of structural elements present in each area in relation to the total pool of structural elements. SDI was also calculated for each class of structural elements (biotic, abiotic and man-made structures).

SDI = (sum elements present in polygon)/(total nr elements (n=30)) (Equation 1)

- Respondents' preferences for structural elements reported for parks were used to calculate "relative importance scores" for structural elements in all green spaces, including cementaries and public open spaces. RIS is the sum of the structural elements present weighted by the average stated preference for each element based on Likert scale scores. This approach enables a non-monetary valuation of the recreation service provided by a given green space based on its structural diversity. It similar to importance-weighting of green structures used in methodologies to map recreational services such as ESTIMAP (Zulian, Paracchini, Maes, & Liquete, 2013; Zulian, Polce, & Maes, 2014).
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*RIS = sum (elements present * average stated preference) (Equation 2)*

To understand the spatial distribution of the SDI and RIS values across green spaces, we used Spatial Autocorrelation (Moran's I Test) and Hot Spot analyses available in ArcMap. Hot Spot Analyses identifies statistically significant spatial clusters of high values (hot spots) and low values (cold spots) across the study area. Moran's I provide a test of whether green spaces' structural diversity and relative importance are randomly distributed across Oslo or spatially clustered. The use of reported importances for structures in parks to predict importances in all green spaces represents an extrapolation of the survey data.

d) Statistical data analyses

We used Principal Component Analysis (PCA) to identify the main patterns in the respondents' preferences for structural elements in urban green spaces. The input table consisted of the structural elements in green spaces (30) and the scores given to these elements by the 85 respondents. Patterns would suggest whether respondents could be grouped according to element preference profiles. A second set of PCAs was conducted to identify which green space structures the individual respondents specifically associated with particular activities (i.e. the six specified activities, and the seventh category 'other'. We used a pseudo-canonical ordination algorithm to explore the relationship between preferred green space elements and the main activities conducted by the respondents in green spaces. In this analysis, recreational activities were introduced as supplementary variables after deriving the principal components from the respondents' preferences for structural elements. The most popular recreational activities were in decreasing order: *to meet others*, *to do sports*, *to get inspiration*, *activities with children*, *to walk the dog*, and *to listen to and observe nature*. To test the significance of the relationship between green space elements and the preferred activities we conducted a redundancy analysis (RDA) with forward selection and the Holm P-value correction method to account for multiple testing errors (ter Braak & Smilauer, 2012). The ordination analyses were conducted with CANOCO v. 5.04 (ter Braak & Smilauer, 2012).

3. Results

What is the relationship between the size of urban green spaces and the diversity of structural elements?

Figure 2 shows the relationship between the normalized value for structural diversity elements – SDI - (vertical) and green spaces' size in hectares (horizontal). There is a non-linear positive relationship between both variables below about 5 ha. Above this size of green space, the diversity of structural

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elements remains mostly constant between values of 0.3 and 0.6. Figure 2 also shows four examples of extreme cases where small green spaces can have low (1) or high (2) structural diversity, and similarly for big green spaces (3 and 4). However, green spaces bigger than 40 ha have a minimum structural diversity of 0.35.

To illustrate which kind of structural diversity is better represented across green space size (size classification based on Oslo Municipality, 2009), we calculated an index of structural diversity (SDI) for each type of biotic-, abiotic-, and built- structures included in the mapping exercise (Table 3). For all the green space size categories, man-made elements have the lowest representation in the SDI (lowest diversity of structures). Despite having the largest number of possible elements in the SDI, any one green space contains only a few of the possible built structures that could be present. 'Pocket green spaces' and 'small green spaces' cover almost the same biotic structural diversity as 'medium green spaces'. Biotic structural diversity is higher than abiotic diversity for pocket and small green spaces. Medium and big green spaces have larger abiotic structural diversity than pocket and small green spaces. By far, abiotic SDI was highest in the largest green spaces. In general, green spaces smaller than 0.5ha had similar biotic, abiotic and man-made structural diversity (Table 3).

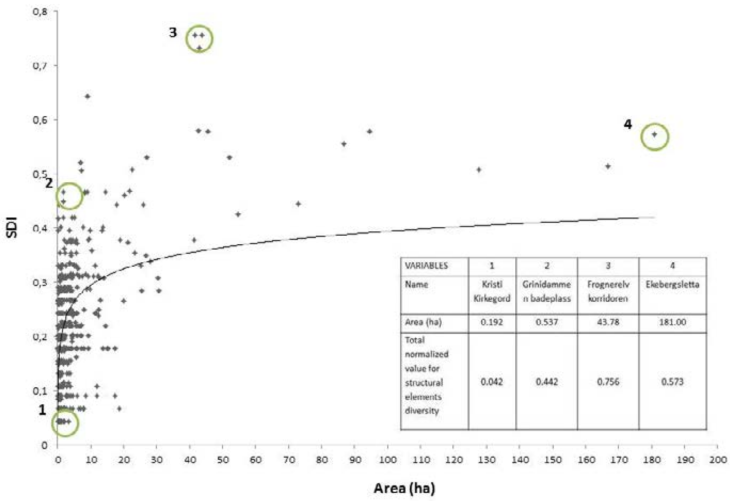

Figure 2. Relationship between the structural diversity index (SDI) (y) and green spaces' size in hectares (x). Extreme examples of green spaces: 1) small size and low structural diversity, 2) small size and middle-high structural diversity, 3) medium size and highest structural diversity, and 4) biggest size and middle-high structural diversity.

Table 3. Biotic, abiotic and man-made elements. Structural diversity index – SDI - across 5 categories of green spaces according to their size. Mean and 95% confidence interval

GREEN SPACE SIZE	BIOTIC ELEMENTS Mean SDI	95%CI	ABIOTIC ELEMENTS Mean SDI	95%CI	MAN-MADE ELEMENTS Mean SDI	95%CI
Pocket (<0.1ha)	0.170	0.145 - 0.196	0.106	0.040 - 0.173	0.071	0.047 - 0.096
Pocket (<0.3ha)	0.205	0.184 - 0.226	0.129	0.083 - 0.175	0.083	0.069 - 0.097
Small (0.1-0.5ha)	0.208	0.185 - 0.232	0.163	0.110 - 0.216	0.105	0.086 - 0.124
Medium (0.5-10ha)	0.226	0.215 - 0.236	0.274	0.249 - 0.300	0.146	0.135 - 0.156
Big (>10ha)	0.326	0.285 - 0.368	0.531	0.456 - 0.605	0.255	0.211 - 0.299

Note: partially overlapping definitions of pocket green spaces are used for comparability with definitions in Oslo Municipality (2009) and Nordh, H., & Østby, K. (2013). Green spaces include parks, cementaries and unmanaged public open spaces.

What are the preferences for different park structural elements?

Respondents indicated *public transport* as the most preferred element (Table 4), followed by *dominance of grass*, *balance between forest and grass* and *lake/pond*. The least valued elements are *dog facilities*, *fishing areas*, *high presence of people* and *playgrounds*. There is a positive relationship

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(R^2=0.13) between mean ranking of the preference score for the elements and their presence (%) in green spaces in Oslo. In other words, the most common park characteristics are generally the most preferred. Some elements (*lake/pond, forest dominance, old big trees*) are more highly ranked compared to their relative occurrence. On the other hand, there are very common elements that are not highly ranked (*low intensity lighting*).

Table 4. Respondent preference ranking of structural elements in parks.

Structural feature	Mean ranking	Std. deviation	% Presence	Structural feature	Mean ranking	Std. deviation	% Presence
Public transport access *(Transport)*	7.44	2.50	72.1	Silence/tranquility areas *(Silence)*	5.40	2.99	20.8
Grass dominance *(Grass)*	7.22	2.02	78.6	Tree species diversity	5.27	2.84	ND
Balanced forest/grass *(Balanced)*	6.89	2.28	19.9	Cultural/art element *(ArtCult)*	5.07	2.62	7.3
Lake/pond *(LakePond)*	6.63	2.52	5.8	Fountain *(Fountain)*	4.88	2.77	1.8
Sitting facility *(Sitting)*	6.62	2.69	39.3	Sport equipment (Sport)	4.85	3.10	11.5
River/stream *(Stream)*	6.52	2.48	44.4	Swimming area *(Swim)*	4.81	2.90	4.2
Forest dominance *(Forest)*	6.22	2.48	1.6	Urban agriculture area *(Agro)*	4.47	2.70	9.9
Walking/Cycle path *(WalkCycl)*	6.18	2.55	14.8	Fruit tree *(Fruit)*	4.34	2.59	3.1
Low presence of people *(LowCong)*	6.18	2.32	79.9	Bars/restaurant *(Bars)*	3.97	2.79	1.3
Old/big tree *(Old_big)*	6.14	2.75	6.4	Shrubs *(Shrub)*	3.95	2.13	44.4
High intensity lighting *(HighLigh)*	6.14	2.47	21.9	Low intensity lighting *(LowLight)*	3.81	2.18	78.1
Grill/Picnic *(Picnic)*	5.96	2.67	2.4	Playground *(Play)*	3.66	2.96	5.5
Flowerbed *(Flower)*	5.90	2.77	7.7	High presence of people *(HighCong)*	3.55	2.10	19.6
Wild plants and animals *(Wildlife)*	5.75	2.87	21.4	Fishing area by the fjord *(Fishing)*	2.74	2.48	2.0
Varied terrain *(Slope)*	5.56	2.28	23.7	Dog facility *(Dog)*	2.67	2.67	1.6

The relative importance score (RIS) weights the importance of structural diversity index in all green spaces by the stated relative preferences for each structural feature in parks. In other words, we transfer preferences observed for structural elements in parks to all green space types. RIS ranged from 14.58 to 97.17 and explains a gradient of recreation potential where high RIS values indicate more important structural diversity as valued by respondents. We found that high RIS values (>50) are concentrated in medium-sized and big green spaces (see Table 1 Appendix), thus "bigger" was both

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"more diverse" and "better" (more important). However the relationship between RIS/area and Area decreases exponentially when green spaces increase in size (log scale in Figure 3), indicating that pocket and small parks are 'cost-effective' providers of recreational opportunity (in terms of surface area).

The Global Moran's I statistics are positive and significant (p-value<0.01), indicating that SDI and RIS are spatially clustered. The Hot Spot Analyses shows that SDI is more homogenously distributed across Oslo than RIS. However, in general more structurally diverse parks are found towards the center of the built area, with more "SDI cold spots" in the built-up regions bordering the forest of Oslomarka (in blue). When stated preferences are considered, green spaces in the center have higher relative importance ("hot spot") than green spaces in the outskirts (in red) (Figure 4).

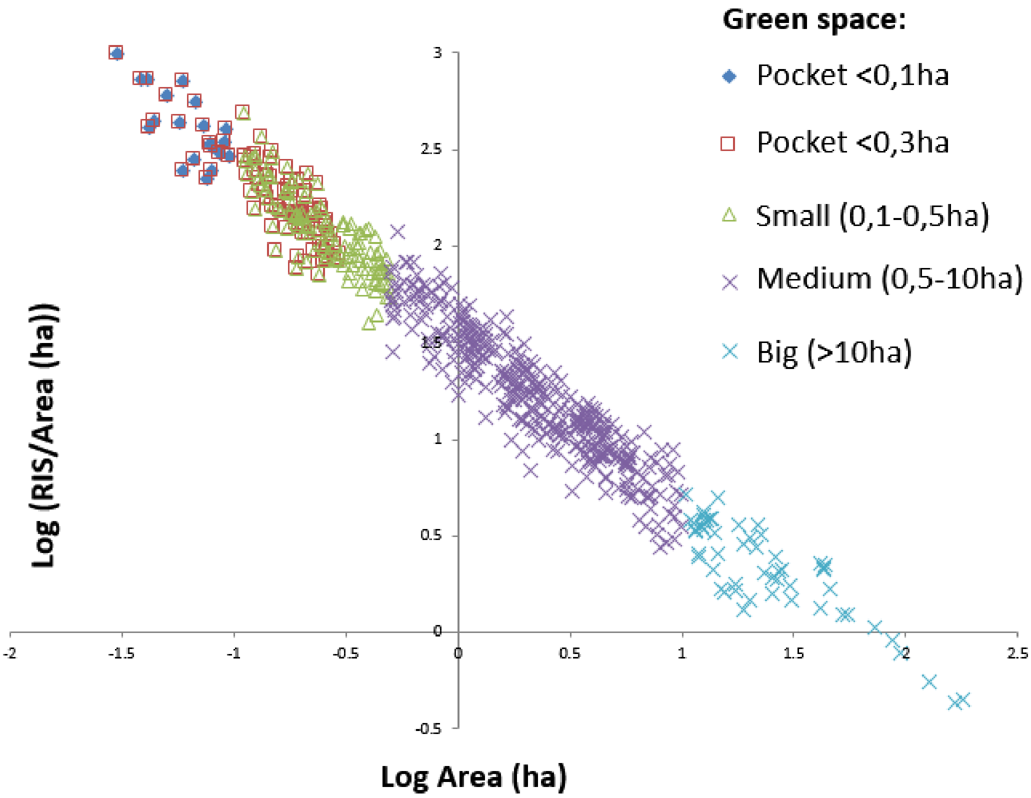

Fig 3. **Structural diversity per unit green space area for different sized green spaces.** Green space size classification based on Oslo Municipality (2009).

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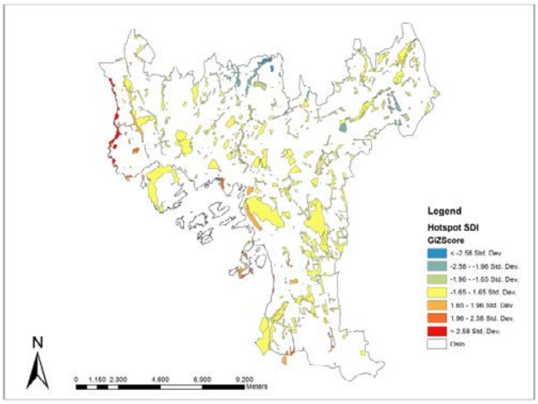
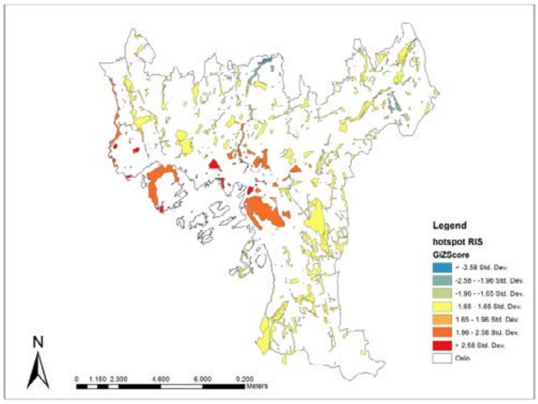
	SDI	RIS
Hot Spot Analysis		
Moran's Index	0.068839	0.068291
Expected Index	-0.001832	-0.001832
Variance	0.000052	0.000052
z-score	9.762744	9.689541
p-value	0.000000	0.000000

Fig 4. **Spatial distribution of the SDI (left panel) and RIS (right panel) across the green spaces.** Hot Spot Analyses ranged from cold spots (in blue) to hot spots (in red).

Is there an association between preferences and structural elements in parks?

Regarding the preferences for structures in parks we found two main tendencies explained by the PCA axes (Figure 5, left). The horizontal gradient explains preferences ranging from a high to a low diversity of elements in parks. Elements such as *walking and cycle path*, *silence* or *balance between forest and grass* highly explain this gradient. The vertical gradient explains preferences for high naturalization of parks (*forest, low congestion, low light, wildlife, varied terrain*, etc.) to a more urban preferences, characterized by the presence of human structures (*public transport, sitting, high congestion and high lightening, grass, bars,* etc.).

There are several correlations among preferences for elements (thin green arrows in Figure 5, left panel). Abiotic-aquatic elements (*stream, lake/pond, fishing and swimming areas*) have been scored similarly by the respondents, but not in the case of *fountain*. High correlation is also found among biotic feature (*forest, wildlife and old and big tree*) and among human structures related to social relations (*bars, sitting, picnic, transport,* etc.).

The distribution of the respondents along the PCA axis reflects a distinction between the two groups mentioned above (Figure 4, right panel). A greater concentration of respondents is located along the horizontal axis, with preferences varying from high structural diversity, to preferences for individual elements. The vertical axis distinguished between preferences towards “more urban” (down) and “more natural” (up) parks. A majority of the respondents indicate a preference for “more urban” parks. These are characterized by the presence of human-made elements such as *grass* and *high congestion of people*. Some extreme answers (top of right hand panel) show strong preferences for wild and natural green spaces with a medium or low structural diversity index.

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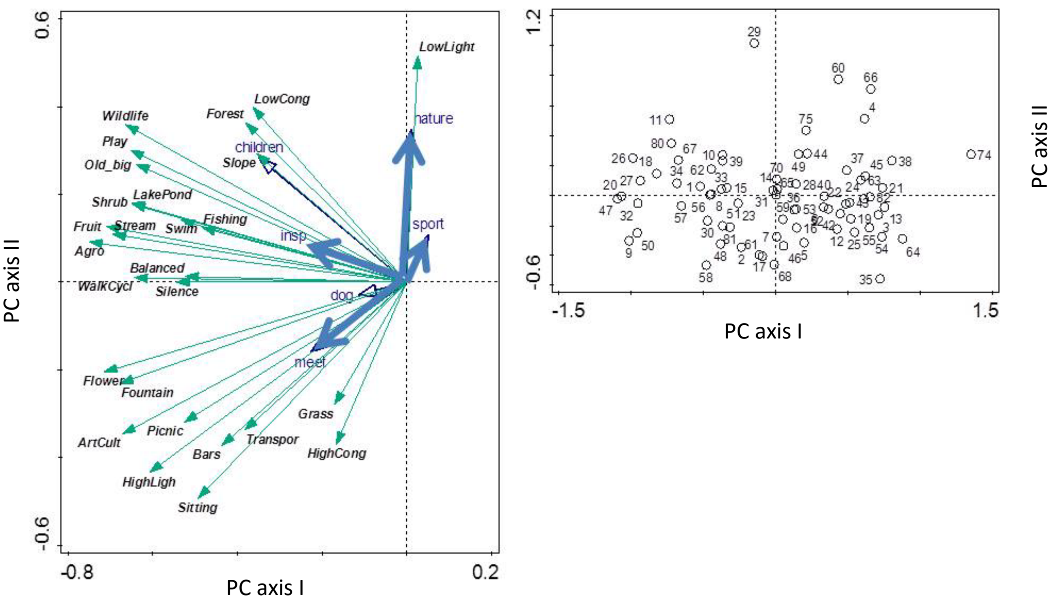

Figure 5: **Principle component (PC) ordination diagram of respondents' preference scores of green space structural elements.**

Left panel: The PC axis I indicates respondents' preferences for a few elements in green spaces (high PC axis I score) to a high diversity of elements (low PC axis I score). PC axis II shows groupings of elements (thin green arrows) according to preferences from high naturalization of parks(e.g. low light, low congestion, wildlife, old big trees) to more urban park preferences (e.g. high congestion, sitting, grass, transport, bars). Thick blue arrows indicate the preferred activities (6) reported by the responds. Activity variables were passive variables in the PCA analysis (not affecting the ordination of the element scores).

Full name of the structural elements can be found in Table 4. Full name of the variables are the following: to meet others (meet), to do sports (sport), to get inspiration (insp) and to listen and observe nature (nature)

Right panel: PC ordination diagram of the 85 respondents showing the spread along PC axis I and PC axis II according to their preference scores for each structural element. Some respondents scored a few elements very high and other very low (right section in the diagram), and others scored several elements high (left section in the diagram)

Are particular structures related to a particular activity in parks?

We included the most popular activities among the respondents (*to meet others*, *to do sports*, *to get inspiration* and *to listen and observe nature*) in the analyses and tested the association between activities and the structures that are preferred for these activities with the RDA (see Figure 1 – Appendix).

To meet with others is the only statistically significant activity in the model (P= <0.05) and is associated with the 'urban type' of green space elements (e.g. *picnic, sitting* and *grass* elements; see also Fig. 5). Other correspondence between activities and structural elements are not statically significant, but some trends can be observed (Fig. 5). *Slope, high light, walking and cycle paths* and *forest* appear to be important elements for engaging in sport activities in parks. *Slope* and *good lighting* are correlated, as well as *forest* and *walking and cycle paths*. This trend differentiates between i) daily sport activities, mainly related to running in a varied terrain and good illumination; and ii) sport activities in a forest habitat with wildlife and following a path. A high number of elements are similarly important for the respondents *to get inspiration* in green spaces, and those are the following: *old and big trees, forest, stream, lake/pond, wildlife, low congestion, low light, grass* and *art/cultural elements.*

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Two types of preferences are related to *getting inspiration from parks*: i) some respondents relate *inspiration* with sitting or walking/cycling surrounded by nature (*forest* or *grass*) with presence of *old and big trees* while ii) others relate inspiration with green spaces with presence of *water elements* and *wildlife*, and with solitude and a natural atmosphere. Elements considered important for *to listen and observe nature* are similar with *to get inspiration*: *stream, lake/pond, old and big trees, wildlife, forest* and *grass*. Respondents who prefer water elements differ from those with high preferences for biotic elements. Preference for water elements are highly correlated with *sitting features* and the preference for biotic elements with *walking and cycle paths*.
The results also indicate that different people choose different elements to conduct the same activity (e.g. some use 'park-like elements - sitting, grass, etc.' for inspiration, whereas other seeks *forest*, *low congestion, etc.)*. The only activity that corresponded significantly with structural elements is *to meet with others.*

Maps in Figure 2 – Appendix shows an application of the PCA results for parks with a ranking map of all green spaces' potential to satisfy each activity based on the elements present and their value as reported by the respondents. Following this approach all green spaces can be categorized into "experience classes" based on the structures present, illustrating the spatial complementarity of green spaces across the cityscape.

3 Discussion

Structural diversity and green space size

Some authors have found that size is an important factor for recreational service delivery of urban green spaces (Coles & Bussey, 2000; Tyrväinen et al., 2005). We evaluated this relationship in two steps; first the correlation between green space size and structural diversity; and second the relative importance of individual structures as observed for parks. Our results reveal that size is not a very good determinant of structural diversity. Green spaces with the same size can be very different in terms of composition. In Oslo, pocket, small and middle green spaces have similar biotic SDI values

On the other hand, when we combined SDI with stated preferences for structural elements as observed for parks, we found that the relative importance index increases exponentially with size, and that the highest RISs are achieved only in large green spaces. In terms of biotic elements, we can consider that pocket and small green spaces are substitutes for medium green spaces because they cover almost the same biotic structural diversity (Table 3). However, pocket and small green spaces fail to cover a considerable range of the preferences among respondents, especially because man-made elements are not well represented in small and pocket green spaces, and those were highly valued by a group of respondents (i.e. respondents who scored high elements such as bars, grass, transport, Fig. 5). As medium sized green spaces are relatively space consuming and have high opportunity costs from foregone property development, our findings can contribute to new districts design (e.g. the new urban conversion in Hovinbyen, Oslo). Pocket and small green spaces with high proportion of biotic structural make them key elements in a blue-green strategy for the city.

Based on the findings we also think that the urban green spaces classification based on size currently used by Oslo Municipality (2009) to conduct 'gap analysis' for green spaces could be improved by incorporating structural diversity indicators.

Structural diversity and recreation opportunities

All of our analyses support the assertion in the literature that preferences are highly heterogeneous (e.g. Edwards et al., 2012; Grahn & Stigsdotter, 2010; Gundersen & Frivold, 2008; Nordh, 2010; Tveit

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et al., 2006; Tyrväinen et al., 2007). We find this even for our demonstration sample of university students focusing on preferences for structures in parks. We therefore tested the hypothesis that what people seek in urban parks is a diversity of natural and man-made facilities that in turn encourage diversity of activities (Burgess et al., 1988; Van Herzele & Wiedemann, 2003). However, our results indicate that university students enjoy low structural diversity parks with some specific elements, especially parks with a high level of "natural" elements (*silence, walking and cycle path,* and *balanced between grass and forest*) as we have defined them in our study. Thus, structural diversity in itself is not such a good proxy of the recreational service provided by green space. Although complexity has been found to be an important factor for experience (e.g. Edwards et al., 2012; Kaplan & Kaplan, 1989; Tveit et al., 2006), there is evidence that preference value is low when complexity is both very low and very high (bell shaped). When complexity is very high, the readability of the environment is low; i.e. in a "messy" environment it could be difficult to orient oneself (Kaplan & Kaplan, 1989).

In addition, the indices we used (SDI and RIS), while appropriate for urban parks, do not capture the structural diversity of on the one hand, cementaries with a arge diversity of built structures, and the other hand unmanaged peri-urban forests, bogs, lakes, pastures with high biotic and abiotic structural diversity. Although the Oslomarka can be considered an area with low structural diversity in terms of the urban green space elements in our typology, it is highly valued for the opportunities it provides for traditional outdoor recreational activities and nature experiences in a peaceful and quite environment (Odden, 1998). In addition, natural structural diversity has been reported to have positive effects on mental health and creativity (Atchley, Strayer, & Atchley, 2012).

The Municipal Plan to 2030 proposed the designation of "activity zones" in the fringe of Marka along the built area, providing higher diversity of built elements and accessibility (Oslo Municipality, 2015). For the Oslo case study, the Marka forest can presently be considered an area offering recreational opportunities low on structural diversity of specifically urban green space elements. Other authors have reported that natural structural diversity has positive effects on mental health and creativity (Atchley et al., 2012). However, we note that the indices we used (SDI and RIS), while appropriate for urban green spaces, do not fully capture the structural diversity of natural and semi-natural ecosystems (forests, bogs, lakes, pastures etc.).

Use and preferences for certain structural elements

The spatial distribution of structural elements and their relative importance diverge. Including the preferences for the different structural elements and weighting of SDI, helped to understand the different recreational services provided by green structures in Oslo. We found that diverse green spaces with highly ranked elements are concentrated in the city center, while areas with relatively few such qualities – as measured by our SDI - are concentrated near the Marka forest. As mentioned above, the indices we used (SDI and RIS), are appropriate for urban parks, but fail to capture adequately the structural diversity of natural and semi-natural ecosystems, because built structures are over-represented in our typology compared to biotic and abiotic ones. Here, results are biased by the urban character of the SDI criteria. The typology could be refined to include a higher diversity of biotic and abiotic elements known to be appreciated in recreational activities (i.e. berry and mushroom picking, bird watching and listening, collecting plant parts (flowers, cones), climbing on trees and rocks). Some elements in urban green spaces are specifically related to particular activities, as Voigt et al. (2014) have found. The monumental and floral diversity of cementaries, and different cultural-religious norms regarding active and passive recreational uses also make it clear that cemetaries and parks should be differentiated in further mapping of preferences (Swensen et al. 2016).

Nevertheless, a core finding in our study is that different people choose different elements to conduct the same activity. This result is in line with earlier findings that those who participate in the same

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activity may differ in terms of environmental preferences (Gundersen & Frivold, 2008). Only '*to meet with others*' is consistently associated with certain structural elements. We found a distinction across types of green spaces preferences: more natural vs. with more human intervention, along a gradient of structural diversity (e.g. Kopomaa, 1995; Yli-Pelkonen, Pispa, & Helle, 2006) and across types of leisure activities (active/passive) (e.g. Voigt et al., 2014).

These findings are in agreement with previous studies which propose a classification of green spaces depending on the experience class they offer across a gradient of 'strongly man-made' to 'natural' elements (Caspersen & Olafsson, 2010; Gundersen et al., 2015; Zulian et al., 2013, Larson et al. 2016). Green space design and planning needs to consider whether green spaces should have a high diversity of elements per unit area or whether green spaces across a city should cover this variation of preferences. Our results support the idea of establishing zoning of uses across a natural continuum from man-made to nature dominated environment (Gundersen et al., 2015) and different functional levels of green spaces (Van Herzele & Wiedemann, 2003). In this sense, they are in line with the Municipal Plan to 2030 in Oslo that proposed a stronger zoning, with designation of "activity zones" in the fringe of Oslomarka along the built-up area, providing higher diversity of built elements and accessibility (Oslo Municipality, 2015).

Conclusions

This research proposed several methods to characterize urban green spaces that links green space qualities to citizens preferences for recreation services as a set of assessment tools that can capture the ranges of green space functionality. We argue that the coupling of biophysical qualities with data on use/preferences has not received sufficient attention in the urban recreation services mapping literature, and also a component seldom included in green space planning. To this end, we combined the 'structural diversity index' developed by Voigt et al. (2014) with visitors' activities and stated preferences. This allowed us to create a ranking of green spaces based on relative importance, a methodological approach of urban green structure valuation.

We found that size is not a proportional determinant of structural diversity of green spaces. Similar green space sizes offer a big variability of diversity of elements. Results reveal that in terms of the diversity of biotic elements, as defined in our study, pocket and small green spaces are partial substitutes for medium green spaces, but not for man-made elements. These findings support the establishment of pocket and small green spaces with more man-made infrastructures, where possible. We find that pocket and small green spaces are important supplements to existing green structure in the city of Oslo. Nevertheless pocket and small green spaces require a 'backbone' of larger green spaces with complementary uses.

A higher diversity of structural elements does not necessarily offer more opportunities for people with diverse recreational interests. Preferences are highly heterogeneous and low structural diversity with certain elements was also highly valued by a large number of respondents. Although we found a distinction across types of park preferences, people enjoy the same structural elements for a high number of different activities. Current typologies of urban parks, including the SDI, fail to adequately describe the richness of elements in all green spaces with a more natural character. These include larger areas used for recreation in urban fringes, forest and semi-natural habitat remnants within the build-up zone, as well as cemetaries. Since these areas are important and complementary in terms of the recreational services they provide, future research could develop a more comprehensive typology of urban green space qualities.

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Our results highlight the possibility of zoning, not of uses directly, nor of specific types of structures, but a "soft zoning" of structural diversity itself across a wilderness gradient. This would facilitate a diversity of activites compatible within an experience class, leaving people to choose where to carry them out, allowing a greater diversity of preferences to be expressed across the cityscape. By combining information on stated preference for structural elements with the structural diversity index we demonstrate how to distinguish the recreational potential of different green spaces.

We used a convenience sample of university students to demonstrate our approach. However, the methodology could be extended to other social groups to cover the social diversity of the urban population. Our results show a high diversity of preferences for different structural elements in green spaces and that these preferences are not too tightly related to specific activities in which urban dwellers commonly engage. The structural diversity index that we developed combined with preference data could provide provide better empirical support for the planned mapping and valuation of recreational areas by municipalities in Norway.

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Appendix

Green Space size classification	Relative Importance Score - RIS	Number of green spaces	% of green spaces	Number of hectares	% of hectares
Pocket (<0.1ha)	<25	7	31,82	0,42	16,54
	25-50	15	68,18	0,94	37,01
	51-75	0	0	0	0
	>75	0	0	0	0
Pocket (<0.3ha)	<25	30	29,41	5,11	30,69
	25-50	70	68,63	11,22	67,39
	51-75	2	1,96	0,32	1,92
	>75	0	0	0	0
Small (0.1-0.5ha)	<25	31	23,66	7,64	21,57
	25-50	98	74,81	27,46	77,53
	51-75	2	1,53	0,32	0,90
	>75	0	0	0	0
Medium (0.5-10ha)	<25	44	12,94	101,34	10,15
	25-50	245	72,05	681,5	68,30
	51-75	50	14,70	205,8	20,62
	>75	1	0,29	9,1	0,91
Big (>10ha)	<25	3	5,56	49,15	2,73
	25-50	20	37,04	321,32	17,83
	51-75	22	40,74	853,31	47,34
	>75	9	16,67	578,66	32,10

Table 1. RIS values across green spaces size classification based on Oslo Municipality (2009) (Pocket parks <0.1 has; Pocket parks <0.3ha; Small parks 0.1-0.5 has; Medium parks 0.5-10 has; Large parks >10 has)

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Table 2. Explanation of structural elements.

Structural feature	Explanation	Structural feature	Explanation
Public transport access *(Transport)*	bus, tram, metro and train within a *buffer* area of 100m around each park polygon	Silence/tranquility areas *(Silence)*	14 areas Oslo Municipality has designated as blue-green quiet areas
Grass dominance *(Grass)*	more than 60% of polygon	Tree species diversity	Tree species in managed parks
Balanced forest/grass *(Balanced)*	between 40 and 60% of polygon	Cultural/art element *(ArtCult)*	e.g. sculptures identified in parks
Lake/pond *(LakePond)*	presence	Fountain *(Fountain)*	presence
Sitting facility *(Sitting)*	Sitting facilities within green space	Sport equipment (Sport)	presence
River/stream *(Stream)*	presence	Swimming area *(Swim)*	within a *buffer* area of 100m around each polygon
Forest dominance *(Forest)*	more than 60% of polygon	Urban agriculture area *(Agro)*	designated
Walking/Cycle path *(WalkCycl)*	presence	Fruit tree *(Fruit)*	presence
Low presence of people *(LowCong)*	average population density lower than 4600 inhabitants/km^2	Bars/restaurant *(Bars)*	presence
Old/big tree *(Old_big)*	presence	Shrubs *(Shrub)*	Presence of managed bushes
High intensity lighting *(HighLigh)*	more than 50% of area had light point density (>10 light points/ha)	Low intensity lighting *(LowLight)*	less than 50% of area had light point density (>10 light points/ha)
Grill/Picnic *(Picnic)*	presence	Playground *(Play)*	presence
Flowerbed *(Flower)*	Presence of flowerbeds managed by municipality	High presence of people *(HighCong)*	average population density greater than 4600 inhabitants/km^2
Wild plants and animals *(Wildlife)*	Municipalliy designated wildlilfe viewing areas	Fishing area by the fjord *(Fishing)*	presence
Varied terrain *(Slope)*	more than 30% of the green space surface had a slope of 20% or higher	Dog facility *(Dog)*	presence

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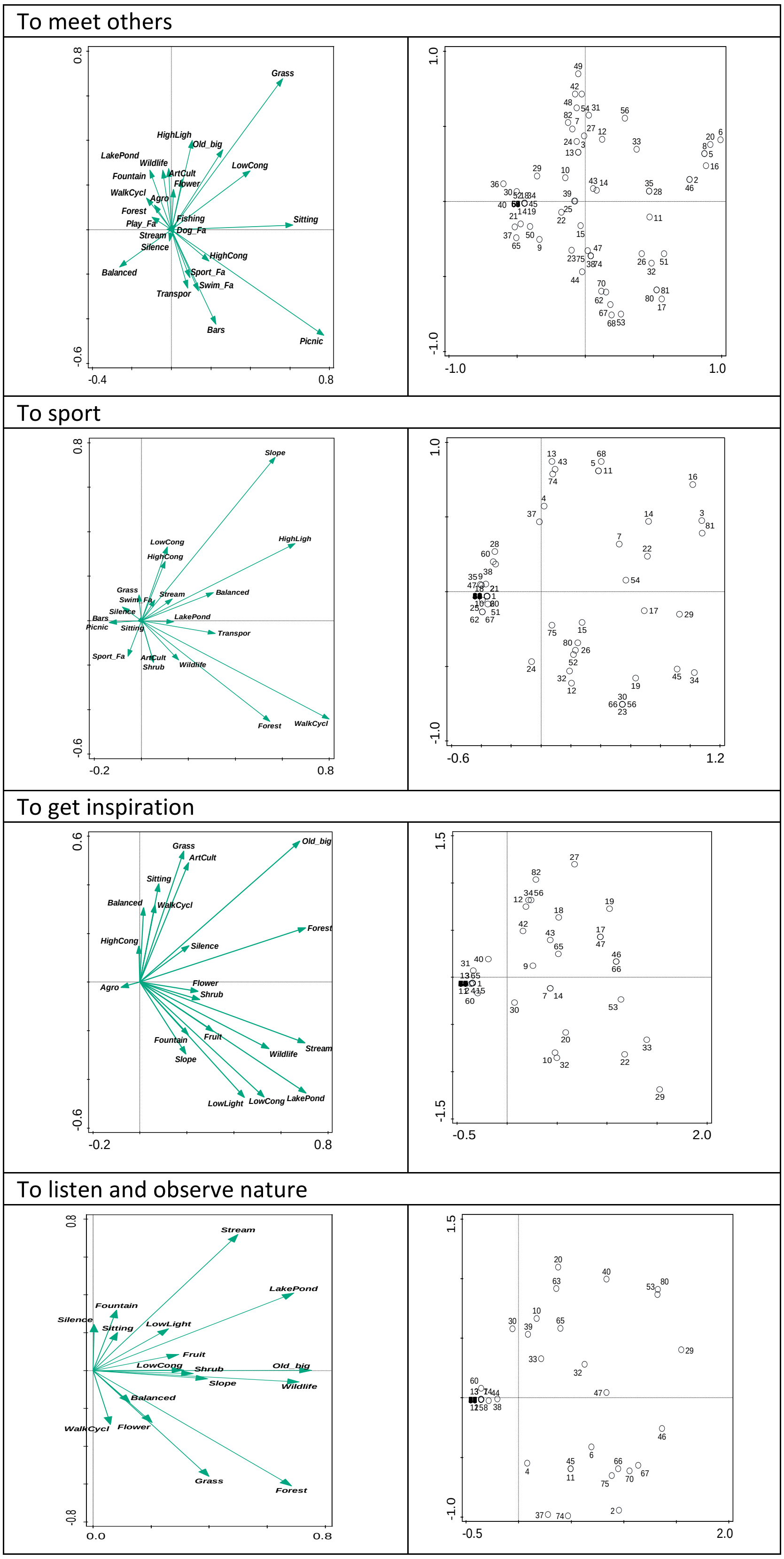

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Figure 1. Results of the PCA showing the relationship of elements in urban green space with the most popular recreational activities revealed by the respondents (to meet others, to sport, to get inspiration, and to listen and observe nature). To the left, a PCA plot of elements and their association with PCA axis I and II.. To the right, ordination of respondents along PCA axis I and II.

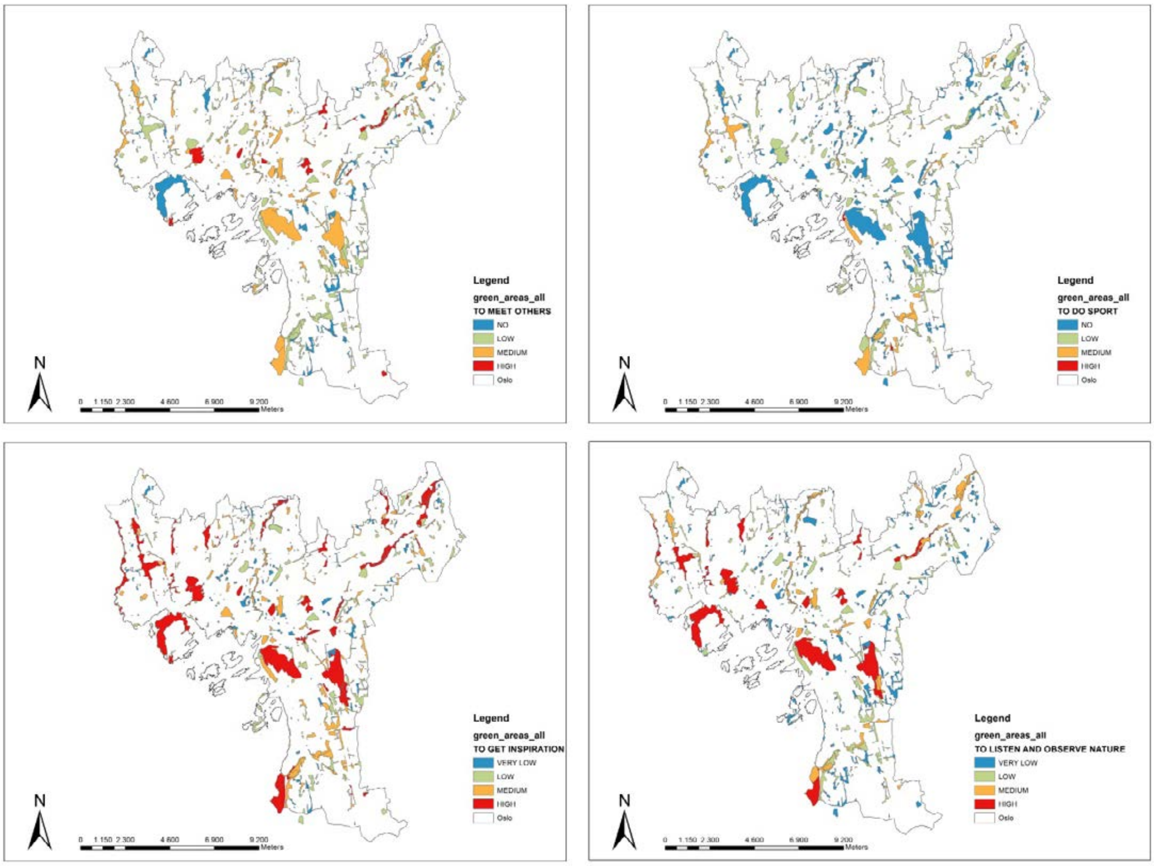

Figure 2. Ranking map of the green spaces potential to satisfy each activity based on the elements present and their value reported by the respondents.

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References

Arnold, M. L., & Shinew, K. J. (1998). The role of gender, race, and income on park use constraints. Journal of Park and Recreation Administration, 16(4), 39-56.

Atchley, R, Strayer, D. L., & Atchley, P. (2012). Creativity in the wild: Improving creative reasoning through emersion in natural settings. PLoS ONE, 7(12), 1-3. http://dx.doi.org/10.1371/journal.pone.0051474

Barton, D. N., Vågnes-Traaholt, N., & Blumentrath, S. (2015). Materials and methods appendix for valuation of ecosystem services of green infrastructure in Oslo. (NINA-Rapport 1115), Lillehammer: Norwegian Institute for Nature Research.

Bernard, H. R. (2012). Social research methods: Qualitative and quantitative approaches. USA: Sage.

Bolund, P., & Hunhammar, S. (1999). Ecosystem services in urban areas. Ecological Economics, 29(2), 293-301. http://dx.doi.org/10.1016/S0921-8009(99)00013-0

Burguess, J., Limb, M., & Harrison, C. (1988). Exploring environmental values through the medium of small groups. 2: Illustrations of a Group at Work. Environment and Planning, 20, 457–476. http://dx.doi: 10.1068/a200457

Craven, D., Filotas, E., Angers, V. A., & Messier, C. (2016). Evaluating resilience of tree communities in fragmented landscapes: linking functional response diversity with landscape connectivity. Diversity and Distributions, 22(5), 505-518. DOI: 10.1111/ddi.12423

Caspersen, O. H., & Olafsson, A. S. (2010). Recreational mapping and planning for enlargement of the green structure in greater Copenhagen. Urban Forestry & Urban Greening, 9(2), 101-112. http://dx.doi.org/10.1016/j.ufug.2009.06.007

Chiesura, A. (2004). The role of urban parks for the sustainable city. Landscape and urban planning, 68(1), 129-138. http://dx.doi.org/10.1016/j.landurbplan.2003.08.003

Coeterier, J. F. (1996). Dominant attributes in the perception and evaluation of the Dutch landscape. Landscape and urban planning, 34(1), 27–44. http://dx.doi:10.1016/0169-2046(95)00204-9

Cohen, D. A., Ashwood, J. S., Scott, M. M., Overton, A., Evenson, K. R., Staten, L. K., Porter, D., Mckenzie, T. L., & Catellier, D. (2006). Public parks and physical activity among adolescent girls. Pediatrics, 118(5), 1381–1389.

Coles, R. W., & Bussey, S. C. (2000). Urban forest landscapes in the UK—progressing the social agenda. Landscape and Urban Planning, 52(2-3), 181-188. http://dx.doi.org/10.1016/S0169-2046(00)00132-8

Dunnett, N., Swanwick, C., & Woolley, H. (2002). Improving urban parks, play areas and green spaces. London: Department for Transport, Local Government and the Regions.

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Edwards, D., Jay, M., Jensen, F. S., Lucas, B., Marzano, M., Montagné, C., Peacea, A., & Weissf, G. (2012). Public preferences for structural attributes of forests: Towards a pan-European perspective. Forest Policy and Economics, 19, 12–19. http://dx.doi.org/10.1016/j.forpol.2011.07.006

Elmqvist, T., Setälä, H., Handel, S.N., van der Ploeg, S., Aronson, J., Blignaut, J.N., Gómez-Baggethun, E., Nowak, D.J., Kronenberg, J. & de Groot, R. (2015). Benefits of restoring ecosystem services in urban areas. Current Opinion in Environmental Sustainability 14: 101-108.

Faehnle, M., Bäcklund, P., & Tyrväinen, L. (2011). Looking for the role of nature experiences in planning and decision making: a perspective from the Helsinki Metropolitan Area. Sustainability: Science, Practice, & Policy, 7(1), 45-55.

Farrugia, S., Hudson, M. D., & McCulloch, L. (2013). An evaluation of flood control and urban cooling ecosystem services delivered by urban green infrastructure. International Journal of Biodiversity Science, Ecosystem Services & Management, 9(2), 136-145. http://dx.doi.org/10.1080/21513732.2013.782342

Gómez-Baggethun, E., & Barton, D. N. (2013). Classifying and valuing ecosystem services for urban planning. Ecological Economics, 86, 235-245. http://dx.doi.org/10.1016/j.ecolecon.2012.08.019

Gundersen, V. S., & Frivold, L. H. (2008). Public preferences for forest structures: A review of quantitative surveys from Finland, Norway and Sweden. Urban Forestry & Urban Greening, 7(4), 241–258. http://dx.doi.org/10.1016/j.ufug.2008.05.001

Gundersen, V., Tangeland, T., & Kaltenborn, B. P. (2015). Planning for recreation along the opportunity spectrum: The case of Oslo, Norway. Urban Forestry & Urban Greening, 14(2), 210-217. http://dx.doi.org/10.1016/j.ufug.2015.01.006

Grahn, P., & Stigsdotter, U. K. (2010). The relation between perceived sensory dimensions of urban green space and stress restoration. Landscape and urban planning, 94(3-4), 264-275. http://dx.doi.org/10.1016/j.landurbplan.2009.10.012

Haines-Young, R., & Potschin, M. (2010). The links between biodiversity, ecosystem services and human well-being'. In D., Raffaelli, & Frid, C. (Eds.), Ecosystem Ecology: a new synthesis. Cambridge: Cambridge University Press.

Kaczynski, A. T., & Henderson, K. A. (2008). Parks and recreation settings and active living: a review of associations with physical activity function and intensity. Journal of Physical Activity and Health, 5(4), 619-32.

Kaplan, R., & Kaplan, S. (1989). The experience of nature. A psychological perspective. Cambridge: Cambridge University Press.

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. Landscape and Urban Planning, 79, 240–252. http://dx.doi.org/10.1016/j.landurbplan.2006.02.013

Kopomaa, T. (1995). The use of urban parks. Helsinki: Helsingin tietokeskuksen julkaisuja.

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La Rosa, D., Spyra, M., & Inostroza, L. (2016). Indicators of cultural ecosystem services for urban planning: a review. Ecological Indicators, 61(1), 74-89. http://dx.doi.org/10.1016/j.ecolind.2015.04.028

Larondelle, N., & Haase, D. (2013). Urban ecosystem services assessment along a rural–urban gradient: a cross-analysis of European cities. Ecological Indicators, 29, 179-190. http://dx.doi.org/10.1016/j.ecolind.2012.12.022

Larson, L. R., Jennings, V., & Cloutier, S. A. (2016). Public parks and wellbeing in urban areas of the United States. PLoS ONE, 11(4), e0153211. doi:10.1371/journal.pone.0153211

Manning, R., Valliere, W., Anderson, L., McCown, R. S., Pettengill, P., Reigner, N., Lawson, S., Newman, P., Budruk, M., Laven, D., Hallo, J., Park, L., Bacon, J., Abbe, D., & van Riper, C. (2011). Defining, Measuring, Monitoring, and Managing the Sustainability of Parks for Outdoor Recreation. Journal of Park and Recreation Administration, suppl. Special Issue on Sustainability, 29(3), 24-37.

Martín-López, B., Gómez-Baggethun, E., Lomas, P. L., & Montes, C. (2009). Effects of spatial and temporal scales on cultural services valuation. Journal of Environmental Management, 90(2), 1050-1059. http://dx.doi.org/10.1016/j.jenvman.2008.03.013

Norwegian Environment Agency. (2014). Kartlegging og verdsetting av friluftslivsområder. Mapping and valuation of recreation areas. (Rapport M98-2013). Trondheim: Norwegian Environment Agency.

Mjaaland, B., & Andresen, J. W. (1986). Amenity and service functions of Oslo`s municipal forest. Arboricultural Journal, 10(2), 101-112. http://dx.doi.org/10.1080/03071375.1986.9746741

Nordh, H. (2010). Park characterisitcs, a tool for classg ‘ying and designing urban green areas. Aas: VDM.

Nordh, H., Alalouch, C., & Hartig, T. (2011). Assessing restorative components of small urban parks using conjoint methodology. Urban forestry & urban greening, 10(2), 95-103. http://dx.doi.org/10.1016/j.ufug.2010.12.003

Nordh, H., & Østby, K. (2013). Pocket parks for people–A study of park design and use. Urban Forestry & Urban Greening, 12(1), 12-17. http://dx.doi.org/10.1016/j.ufug.2012.11.003

Odden, A., 2008. Hva skjer med norsk friluftsliv? En studie av utviklingstrekk i norsk friluftsliv 1970-2000. What is happening to Norwegian Outdoor recreation? A study of developments in Norwegian outdoor recreation 1970-2000. (PhD Thesis). Trondheim: Norwegian University of Science and Technology (NTNU).

Oslo Municipality, 2009. Metode for dekningsanalyse. Grøntplan for Oslo. Methods for vegetation cover. Green plan for Oslo. Oslo: Plan og Bygningsetaten, Avdeling for Byutvikling.

Oslo Municipality, 2015. Oslo mot 2030 Kommuneplan for Oslo. Municipal Plan for 2030. DEL 1. Oslo: Plan og Bygningsetaten, Avdeling for Byutvikling.

CC-BY-NC-ND

Schwab, J. (1993). Planning for the urban forest. In Proceedings (pp. 254-256) of the Sixth National Urban Forestry Conference. Washington, DC: American Forests.

Sheate, W. R., Eales, R. P., Daly, E., Baker, J., Murdoch, A., Hill, C., Ojike, U., & Karpouzoglou, T. (2012). Spatial representation and specification of ecosystem services: a methodology using land use/land cover data and stakeholder engagement. Journal of Environmental Assessment Policy and Management, 14(1), 1250001. http://dx.doi.org/10.1142/S1464333212500019

Shoard, M. (2003). The edgelands: The time has come to give the expanses of no-man's-land which have sprung up on the margins of our towns and cities their due and recognise them as landscapes in their own right. Town and country planning association, 72(4), 122-125.

Shores, K. A., & West, S. T. (2008). The relationship between built park environments and physical activity in four park locations. Journal of Public Health Management and Practice, 14(3), 9-16. doi: 10.1097/01.PHH.0000316495.01153.b0

Skår, M. (2010). Forest dear and forest fear: Dwellers' relationships to their neighbourhood forest. Landscape and Urban Planning, 98(2), 110-116. http://dx.doi.org/10.1016/j.landurbplan.2010.07.017

Ståhle, A. (2006). Sociotope mapping: Exploring public open space and its multiple use values in urban and landscape planning practice. Nordic journal of architectural research, 19(4), 59-71.

Stamps, A. E. (1999). Demographic effects in environmental aesthetics: A meta-analysis. Journal of Planning Literature, 14(2), 155-175. doi: 10.1177/08854129922092630

Swensen, G, H. Nordh, J. Brendalsmo (2016) A green space between life and death – a case study of activities in Gamlebyen Cemetery in Oslo, Norway. Norsk Geografisk Tidsskrift - Norwegian Journal of Geography , Volume 70, 2016 - Issue 1 pp. 41-53

Ter Braak, C. J., & Smilauer, P. (2012). Canoco reference manual and user's guide: software for ordination, version 5.0.

The Noise Action Plan, 2008-2013. A new plan is in the making: The Noise Action Plan 2013-2016. Oslo: Oslo Municipality.

Tveit, M., Ode, Å., & Fry, G. (2006). Key concepts in a framework for analysing visual landscape character. Landscape research, 31(3), 229-255. http://dx.doi.org/10.1080/01426390600783269

Tyrväinen, L., Pauleit, S., Seeland, K., & de Vries, S. (2005). Benefits and uses of urban forests and trees. In C. Konijnendijk, Nilsson, K., Randrup, T., & Schipperijn, J. (Eds.). Urban forests and trees. Berlin Heidelberg: Springer. DOI:10.1007/3-540-27684-X_5

Tyrväinen, L., Mäkinen, K., & Schipperijn, J. (2007). Tools for mapping social values of urban woodlands and other green areas. Landscape and Urban Planning, 79(1), 5-19. http://dx.doi.org/10.1016/j.landurbplan.2006.03.003

United Nations. (2001). World Urbanization Prospects. Department of Economics and Social Affairs. New York: United Nations Publications.

CC-BY-NC-ND

Van Herzele, A., & Wiedemann, T. (2003). A monitoring tool for the provision of accessible and attractive urban green spaces. Landscape and Urban Planning, 63(2), 109-126. http://dx.doi.org/10.1016/S0169-2046(02)00192-5

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. DOI: 10.1007/s13280-014-0508-9

Yli-Pelkonen, V., Pispa, K., & Helle, I. (2006). The role of stream ecosystems in urban planning: a case study from the stream Rekolanoja in Finland. Management of Environmental Quality: An International Journal, 17(6), 673–688. http://dx.doi.org/10.1108/14777830610702511

Zulian, G., Paracchini, M. L., Maes, J., & Liquete, C. (2013). ESTIMAP ecosystem services mapping at European scale. (EUR, Scientific and technical research series, 1831-9424 ; 26474). Luxembourg : Publications Office of the European Union.

Zulian, G., Polce, C., & Maes, J. (2014). ESTIMAP: a GIS-based model to map ecosystem services in the European union. Annali di Botanica, 4, 1-7. http://dx.doi.org/10.4462/annbotrm-11807

Soy Massoni, E.; Barton, D.N.; Rusch, G.; Gundersen, V. Bigger, more diverse and better? Mapping structural diversity and its recreational value in urban green spaces. Ecosyst Serv 2018 10.1016/j.ecoser.2018.02.013
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