Multidimensional Relation of Urban Dwellers and Green Spaces

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Abstract: Green spaces have a positive impact on the daily life of urban communities; however numerous aspects of the relation between humans and urban green spaces are not widely understood. This PhD thesis is concerned with this ambiguous relationship and focuses on three of its aspects. First, the thesis explores the relationship between humans' subjective evaluations on urban green spaces and objective, spatially explicit indicators of the same green spaces. Secondly, the work complements green space users' perception of services supplied by green spaces, with crowd-sourced data on actual community usage. Finally, the spatial relation between the geographic distribution of demographic groups of urban population with high green space demand and the distribution of urban biomass with the highest societal use value is identified. The expected outcome of the thesis is an improved knowledge on the multidimensional relation between urban dwellers and green spaces.

1 INTRODUCTION

Urban green spaces (UGS) are essential contributors to city dwellers' quality of life (QoL). Their positive impact on visitors' physical and mental health is a well-known fact (Irvine et al., 2013; Lee and Maheswaran, 2011). Urban green spaces stimulate social cohesion and provide a place for recreational activities (Germann-Chiari and Seeland, 2004; Kaźmierczak, 2013). Other essential services supplied by UGS are air purification (Tallis et al., 2011) and microclimate regulation (Bowler et al., 2010). Shelter and habitat services that they provide for biodiversity indirectly contribute to QoL (Fontana et al., 2011). Unambiguously UGS have a positive impact on the daily life of urban communities; however numerous aspects of the relation between humans and urban green spaces are not widely understood.

This PhD thesis is concerned with the aforementioned ambiguous relationship of humans and urban green spaces and focuses on three of its aspects. The associated research is tackled by the author of this paper in an article based PhD thesis. The results will be reported in three ISI ranked journal articles with first authorship. Each article is dedicated to one of the three studied aspects of the human–urban green space relationship and provides solution for each research problem.

Beyond contributing only to science, another main concern of the thesis is to strongly support the work of urban planners and managers with practical solutions for informed decisions regarding UGS and QoL. To ensure the fulfilment of this goal, prior to starting the work, expert interviews were conducted with urban developers, architects, and urban environment managers in the City of Szeged, Hungary, to learn their needs and demands on perceptual information of urban green spaces. This initial step eventuated in an active working collaboration and dialogue with the Szeged Architect Office and the Szeged Environment Management Non-profit Ltd. This cooperation ensures continuous feedback and provides suggestions from the target user groups to secure the practical relevance of the research.

2 RESEARCH PROBLEMS

The fragmented knowledge on the relation between humans and UGS is a multicomponent phenomenon of which three aspects will be investigated within this PhD thesis. Accordingly to the aforementioned

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ambiguities, this thesis is concerned to fill the subsequent three research gaps.

2.1 The Relation between Human Perception of Urban Green Spaces and Their Objective Attributes

The first investigated component is arising from the human perception of the ambient environment which differs by individuals. In contrary, objective environmental indicators foster a relatively straightforward characterisation of the studied areas. Therefore the two inherently different data domains may depict different information on the ambient environment without featuring any knowledge on the encompassed discrepancies. An extensive literature research for evidences of the investigation of the relation between subjective and spatially describable objective attributes of UGS resulted in the definition of the first research problem. Accordingly, the first research gap which this thesis is going to fill is articulated as follows. The degree of relationship between visitors' subjective evaluations on urban green spaces and objective, spatially explicit indicators of the same public green spaces is unknown.

2.2 Information Gap on Actual Green Space Use

The second concern of the thesis is described as follows. The community use and appreciation of services supplied by UGS can incorporate essential information to urban planning and development, although it is not readily measurable. Therefore current assessments of services derived from UGS often solely rely on subjective data input, such as societal benefits perceived and reported by visitors of UGS. The application of this purely subjective information for planning and management of UGS encumbers the objective decision support. Accordingly the second research gap is identified and explained here. Easily quantifiable data on real usage and appreciation of services provided by UGS is not present to decision support processes to complement perceptual information, such as data obtained from questionnaire surveys.

2.3 Relation between the Spatial Distribution of Urban Biomass and Demographic Groups with High Green Space Demand

The third studied aspect of the ambiguous human-UGS relationship is that the distribution of biomass heterogeneity varies in the urban space as well as does the distribution of various demographic groups of urban communities. This eventuates in the third research gap that this thesis is going to fill: The degree of relation between the spatial distribution of urban biomass and spatial locality of those members of urban communities who most desperately need easily accessible green space is unknown.

3 OUTLINE OF OBJECTIVES

Concerning the interests explained in Section 2, this PhD thesis has three main objectives.

3.1 Objective 1

According to Research gap 1, the objective of the first tier of the thesis is to investigate the degree of relationship between human perceptions of urban green spaces and spatial environmental indicators of these studied green spaces by matching perceived and reported features of the parks to their spatial environmental indicators.

3.2 Objective 2

To fill the second research gap the work outlines the following aim as the second objective of the thesis. The research aims to complement subjective information, explicitly green space users' perception of services supplied by UGS, with crowd-sourced data on actual community usage and appreciation of UGS.

3.3 Objective 3

The third objective of the work is explained here. The thesis aims to reveal the spatial relation between the geographic distribution of demographic groups of urban population with high green space demand and the distribution of urban biomass with the highest societal use value to reveal inequalities in urban green space availability.

4 STATE OF THE ART

To achieve the objectives described in Section 3 the research introduces the following novelties.

4.1 Novelty 1

The thesis delivers the first study that explores the degree of relationship between perceived, subjective, properties of UGS and spatially explicit, objective attributes of the same green spaces.

4.2 Novelty 2

The novelty of the second tier is twofold and explained here.

The research introduces a methodology that uses easily quantifiable crowd-sourced, voluntary information on actual community consumption of recreational and aesthetic services of UGS. This will complement questionnaire records on park visitors' perceptions of services supplied by the study areas.

4.3 Novelty 3

The state of the art of Tier 3 is threefold.

- Spatial location of demographic groups with high green space demand will be identified.
- The work will apply digital surface model (DSM) to identify vegetation with the highest societal usability value.
- Distances between demographic groups with high green space demand and high societal value urban vegetation will be identified on the road network, which allows calculating real distances instead of following recent practices which use Euclidean distance to assess green space availability.

5 METHODOLOGY

This PhD research applies a multi-method approach to study the composite relationship between urban green spaces and humans. Firstly, this section introduces the study areas, then it explains the applied methodologies that are conducted to solve the three research problems.

5.1 Study Areas

The research was conducted in the city of Szeged, Hungary. Arching across the River Tisza, Szeged is situated in south-east Hungary and serves home for 160,000 urban dwellers. Numerous green spaces of the city contribute to the improvement of the citizens' QoL. The diversity of the studied parks was a main concern of the research to ensure the objective and subjective environmental heterogeneity. Five green spaces have been chosen accordingly for study areas of the thesis.

Erzsébet liget (ER) located in the vicinity of the city centre is a relatively large, 21 ha, area with a high proportion of vegetated surfaces including mainly lawn and wooded areas. The park is visited by recreational users of all age groups, from all over the city. The recently renovated Dugonics tér (DU) is situated in the city centre, and nearly half of its size is vegetated. Széchenyi tér (SZ) is the attractive main square of the city. More than half its size is covered with lawn, flower beds, and a number of trees. Both DU and SZ are located in neighbourhoods consisting of pleasant late-19th and early-20th century architecture. Whilst SZ mostly serves as refuge and aesthetic enjoyment for locals and tourists, DU functions as an important pedestrian transit area. At the edge of the city, Vér tó (VE) boasts a large lake and houses a hill at its eastern edge. VE is surrounded by 5-10 storey residential housing and suffers from serious noise pollution due to nearby traffic. Similar to VE, Zápor tó (ZA) is surrounded by residential blocks and has a pond located in its centre. An important aspect in which ZA is rather different from VE is that its quiet environment serves as a tranquil resting area for its visitors. Figure 1 pictures the location of the study areas within Szeged.

Figure 1: Study areas.

5.2 Methodology 1

As described in Section 3.1, this study seeks for the relationship between human perception of urban green spaces and their spatially explicit environmental indicators. To achieve this aim the following study was conducted.

5.2.1 Used Datasets

Perceptual (subjective, qualitative) data:

- Records of a questionnaire survey campaign in the study areas.

Spatial (objective, quantitative) data:

- Raster data: 2 m ground resolution Multispectral bands of Pléiades satellite imagery of Szeged (Astrium et al., 2014) to derive Normalized Difference Vegetation Index (NDVI); 10 cm ground resolution colour aerial image of Szeged (DPGG, 2011) to delineate vegetated areas and water surfaces of the green spaces.
- Vector data: Building height layer of Szeged (Sümeghy et al., 2011); Cadastral layer of Szeged.

5.2.2 Description of Methodology

A questionnaire survey campaign was conducted in the five UGS of Szeged, in April and May 2014, to explore visitors' subjective evaluations on objective, spatially describable attributes of the studied areas. The topics of the survey were the "Personal judgement of the area"; the "Perceived greenness of the UGS"; the "Accessibility"; and finally the "Functions of the area". Two hundred and fifty five questionnaires were collected. After validation 227 answers supplied the subjective, perceptual data for the research.

Area of the park grounds, water surfaces and vegetated areas of the green spaces were digitised from the aerial image to vector layers. An NDVI image was generated form the multispectral bands of the Pléiades satellite scene.

Applying geographical information systems (GIS) and remote sensing technology (RS) the following spatial indicators were calculated for each green space based on the available objective data: Area of the parks (ha); Area of vegetated surfaces (ha); Percentage of vegetated surfaces (%); Area weighted NDVI for the parks; Percentage of water surfaces (%); Number of building units in a 50 m buffer zone around the parks; Percentage of built up area in a 50 m buffer zone around the parks (%); Average building height in a 50 m buffer zone around the parks; Standard deviation of building heights in a 50 m buffer zone around the parks.

During a principal component analysis (PCA), performed on the questionnaire data, three subjective assessment dimensions were identified: Impression of green, healthy and recreational environment; Impression of the state of the park and Assessment of accessibility of the park by private or public transport. The subjective assessment dimensions, representing visitor's perception on the studied UGS, and the objective data were tested against each other with multiple regression analysis to seek for a correlation and the degree of the relation between the two inherently different information domains. Figure 2 demonstrates the workflow of the first tier.

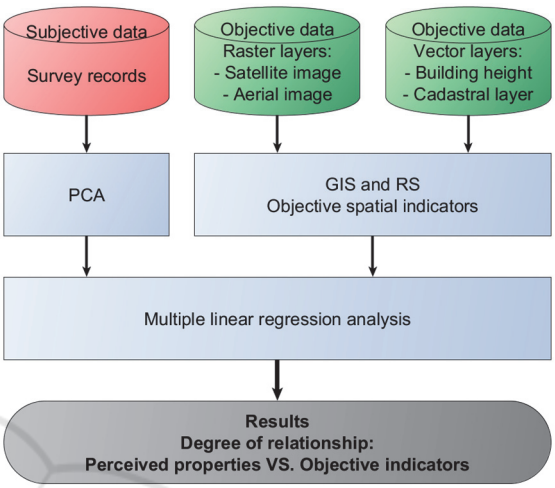

Figure 2: The workflow of Tier 1.

The results of the analysis are explained in Section 6.1.

5.3 Methodology 2

5.3.1 Used Datasets

Perceptual (subjective, qualitative) data:

- Questionnaire survey on perceived services of the studied five urban green spaces of Szeged.

Crowd-sourced voluntary information on actual usage and aesthetic appreciation of the study areas:

- Crossing and tangential running paths uploaded to online recreational applications, Futótérkép and Runtastic (www.futoterkep.hu; www.runtastic.com);
- Photos from Panoramio, 360cities, Flickr and Instagram picturing aesthetic appreciation and recreational use of the five green spaces (www.panoramio.com, www.360cities.net, www.flickr.com and www.instagram.com).

5.3.2 Description of Methodology

The questionnaire data, described in Section 5.2.1 and Section 5.2.2, also incorporated information on the perceived services provided by the five studied parks. The answers for the questionnaires were

collected through a 1 to 5 Likert scale. The scores reflect on green space users' assessment of the quality of recreational and infrastructural services of the parks, as well as the subjective (perceived) capacity of the five urban green spaces to mitigate natural and human generated environmental nuisances. As this information reveals individually different opinions of survey participants it is rather subjective. Therefore it reflects perceived, though still crucially important, properties of the study areas. Since the actual park usage and aesthetic appreciation cannot be revealed by questionnaire surveys the addition of this information is crucial for urban planning and public space management.

To complement perceived information with data on real park usage, the running paths crossing or touching the park grounds were collected from the Futótérkép and the Runtastic recreational crowd services. For the assessment of recreational and aesthetic use of the parks geo-located photos taken and uploaded by users of the five public spaces were downloaded from Panoramio, 360cities, Flickr and Instagram photo sharing services.

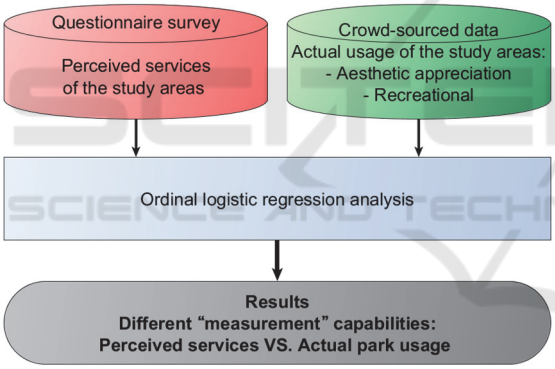

Figure 3: The workflow of Tier 2.

The downloaded photos were individually studied and classified into seventeen categories each representing different aspects of the aesthetic appreciation and recreational use of the green spaces. The number of running paths will be summed for each park in the next phase of the second tier. The number of running paths and the number of images per classes will provide real park usage information and demonstrates the popularity and suitability of the studied urban green spaces for recreational and aesthetic purposes.

The survey records, the number of running paths and the number of images per classes will be input for an ordinal logistic regression analysis. The analysis is expected to reveal the different "measurement" capabilities of the perceived services of the parks collected through the survey, and the green space visitor generated actual usage of aesthetic and recreational benefits from the study areas. Figure 3 demonstrates the workflow of the second tier of the thesis.

5.4 Methodology 3

5.4.1 Used Datasets

- Stereo scene of the panchromatic band of the Pléiades satellite imagery;
- Normalized Difference Vegetation Index derived from the multispectral product of the Pléiades satellite imagery;
- Enumeration district level, tabular format census data of Szeged sourced from the 2011 Census of Hungary;
- Vector layer of census enumeration districts of Szeged;
- OpenStreetMap road network of Szeged.

5.4.2 Description of Methodology

Digital surface model (DSM) of the city of Szeged will be generated from the stereo scene of the Pléiades satellite imagery. The DSM will be used to detect object heights within the satellite scene. The vegetation within the scene will be indicated by the NDVI product.

Using object heights and NDVI values, the vegetation will be identified and classified into three levels of vegetation height classes using object based image analysis (OBIA) methods:

- Low vegetation (e.g. lawn);
- Middle height vegetation (e.g. bushes);
- High vegetation (tree canopy).

The High vegetation class will indicate tree cover. As green spaces with tree canopies have the highest societal value, this class will be used for the further analysis. Families with children and elderly citizens have an increased demand on green space availability. The method, being elaborated in Tier 3, will provide a solution for calculating green space deprivation based on demographic data and real distances measured on the road network.

Records of the tabular format census data will be joined to the corresponding enumeration polygons of the Szeged enumeration district vector layer. Number of children, their family members and elderly citizens in each enumeration district will be calculated based on the demography sensitive variables of the census records (e.g. "Households by

household composition and by the age composition of household members, 2011"; "Families by family composition and by the number of children living in the family, 2011"; etc.). By applying this method census blocks with high proportion of children and/or elderly citizens will be geographically identified.

In the next step, routable road network of Szeged will be generated from the OpenStreetMap data. Using the road network, walking distances to the closest vegetation patch with "high societal value" will be calculated for polygons of each enumeration district. By using the walking distances to high societal value vegetation patches, and the number of people with high green space demand within the enumeration districts, hot spots of spatial inequalities in personal availability of urban green spaces of Szeged will be identified. Figure 4 demonstrates the workflow of the second tier of the thesis.

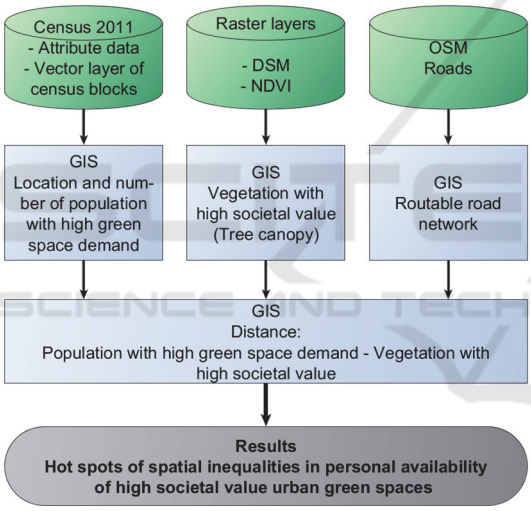

Figure 4: The workflow of Tier 3.

6 EXPECTED OUTCOME

The general expected outcome of the thesis is an improved knowledge on the multidimensional relation between urban dwellers and green spaces. This outcome is expected to be achieved through the results from the three tiers of the work. The expected outcomes of the three studies are described in this section.

6.1 Outcome 1

The multiple regression analysis, applied in the first tier, found two minor and two mediocre correlations between the perceived properties and the ten objective spatial attributes of the studied green spaces. The study concluded that there is a weak relation between subjective and objective, spatially explicit, attributes of urban green spaces. Therefore the work proposes a combined use of perceptual information and spatially explicit data for green space planning and management.

6.2 Outcome 2

First, the results from Tier 2 are expected to unveil the potentials of park visitor generated crowd-sourced information to provide quantifiable input data on actual use of aesthetic and recreational services of urban green spaces. Secondly, the statistical test is supposed to prove that questionnaire surveys, as the most common sources of perceptual information, and actual park usage reveal different aspects of societal benefits visitors derive from urban parks. Therefore, the tier will propose the addition of crowd-sourced park usage information to the results of questionnaire surveys to provide a more comprehensive input for decision making processes. The research warns: only the application of both information domains can ensure thorough and informed urban development and management practices.

As questionnaire surveys are often conducted by urban governments and crowd-sourced data is readily available online, the introduced methodology has a high transferability to further study areas regardless of environmental settings.

6.3 Outcome 3

The methodology, applied in Tier 3, will identify the spatial location of demographic groups of urban population with high green space demand. More importantly, the tier reveals real distances between the identified groups of Szeged's population and urban green spaces with high societal value. By achieving this, hot spots of spatial inequalities in personal availability of high societal value urban green spaces of Szeged will be identified.

Although the method introduced in this research is highly transferable to other cities, the demographic development of the society is constant in time and space. To overcome this difficulty, the more frequently available micro-censuses or mid-year population estimates can also be used for the described analysis rather than relying solely on less frequent census data. Thereby, the adaptability of the

methodology to other urban environments can be ensured.

7 STAGE OF THE RESEARCH

This PhD research is planned to last for four years. The work was started in October 2013 and is planned to be finished by September 2017.

The first tier of the work has been fully elaborated and written up for publication in an ISI ranked journal, Urban Forestry & Urban Greening. The manuscript was accepted with major revisions. The revisions have already been carried out. The revised draft will be read by co-authors and proof-readers, and then it will be resubmitted by April 2016.

Research associated to the second tier of the thesis is being conducted at the moment. Green space user generated, voluntary information on aesthetic and recreational use of services generated by the study areas have been collected from crowd-sourced recreational and content sharing applications. At the moment, February 2016, images picturing aesthetics of the five green spaces are being evaluated. The analysis of running paths will be carried out in March and April 2016. The statistical analysis will take place in May, then the course of the work and the results will be written up for an ISI ranked journal article. The draft is expected to be submitted in the third quarter of 2016.

The work related to the third tier has already been planned. Practical work accomplished so far is that point cloud data has been retrieved from the stereo pair of Pléiades satellite imagery for DSM extraction. Secondly, routable road network of Szeged has been generated form OpenStreetMap data. At the moment, access to census data is being negotiated with the Szeged Branch of the Hungarian Central Statistical Office. The research is expected to being accomplished in the third and the fourth quarters of 2016. The work and its results will be written up for an ISI ranked journal article parallel to the research. The manuscript will be submitted in the first quarter of 2017.

The recent state of the entire PhD thesis is approximately thirty percent of completeness.

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