Multiscale GIS based Analysis of Urban Green Spaces (UGS) Accessibility: Case Study of Sisak (Croatia)

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Keywords: Urban Green Spaces (UGS), ANGst, Accessibility, Sisak.

Abstract: By the year 2050, two-thirds of the world population will live in urban areas. Therefore the quality of life in cities has become the object of numerous research papers. One of the basic elements of satisfying the quality of life is the accessibility of urban green spaces (UGS). In this paper accessibility of UGS for the city of Sisak (Croatia) has been analysed. Based on the fact that Sisak is traditionally an industrial type of town, the optimal distribution of UGS has the potential to ease the negative effects of urbanization and industrialization. Accessibility analysis was performed according to guidelines of ANGst (Accessible Natural Greenspace Standard) methodology. The research is conducted at a multiscale level (based on GIS analysis). The primary spatial database of UGS for the city of Sisak was created using the supervised classification method of Sentinel-2A images and vectorization of high-resolution digital orthophoto (DOP). Accessibility zones were generated using the Network Analyst extension. Results show that the basic ANGst standard of UGS accessibility is not satisfactory throughout the city. To get more detailed results we suggest using the very high-resolution satellite imagery or aerial photogrammetry.

1 INTRODUCTION

Urbanization can be considered as a rapid converter of natural environments to impervious surfaces (Frick and Tervooren, 2019). City population constantly grows and according to the United Nations' population projections, by the year 2050, approximately two-thirds of the world population will live in urban areas (UN, 2018).

As a consequence of urbanization, the quality of life in cities has become the object of research to numerous authors (Franklin, 2001, Amao, 2012, Balestra et al., 2013, Pacione, 1986).

Accessibility of urban green spaces (UGS) is an integral element of satisfying the quality of life (Šiljeg et al., 2018). Accessibility can be defined as "relative ease" of approach to a specific location, in this case, UGS (Mak et al., 2017). It usually represents the non-linear distance traveled without using the means of transportation. According to the European Urban Green Belt project, urban green space is any public or private open property covered with vegetation, directly or indirectly accessible to users (Šiljeg et al., 2018).

Access to green areas provides the potential to reduce health inequalities, improve well-being, and aid in the treatment of mental illness (WHO, 2019). WHO (World Health Organization) quotes that physical inactivity, linked to the lack of access to recreational zones accounts for 3,3% of global deaths. From the environmental aspect, besides producing oxygen, green spaces are a sufficient filter for air pollution and have an impact on moderating temperatures.

At the Rio+20 conference on sustainable development (2012) is concluded that the square meter per capita of urban green space is one of the health indicators of sustainable cities. Studies conducted in several cities confirmed that green spaces are more accessible to high-income residents (Hoffimann et al. 2017). Therefore, the lack of green spaces in cities can be an indicator of inequality and marginalization among the population.

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Šiljeg, S., Milošević, R. and Vilić, E.
Multiscale GIS based Analysis of Urban Green Spaces (UGS) Accessibility: Case Study of Sisak (Croatia).
DOI: 10.5220/0009470802400245
In *Proceedings of the 6th International Conference on Geographical Information Systems Theory, Applications and Management (GISTAM 2020)*, pages 240-245
ISBN: 978-989-758-425-1

All of the abovementioned contribute that studies about UGS are becoming one of the key elements in urban planning. Green volume data can be used as an input for modeling (urban climate, water balance) as well as for evaluation processes (Frick and Tervooren, 2019).

In this research, the case study is the city of Sisak. Sisak is a traditionally industrial city and there are two industrial zones within the boundaries of the settlement. The optimal spatial distribution of UGS in the city of Sisak is important to keep the environmental balance of the urban landscape and to mitigate negative industrial effects.

The aim of this research is to analyse the coverage and accessibility of green spaces according to European standards (ANGst, WHO) at the multiscale level. The research questions are:

- Are the green spaces equally accessible to all residents?
- Are there enough green spaces unto the population?

2 STUDY AREA

Sisak (32 km²) is the administrative center of the Sisak-Moslavina county (Fig. 1.). Development of Sisak as an industrial center started in the second part of 20 century and it became one of the most developed industrial cities in Croatia (Slukan - Altić, 2003). At the latest census (2011), the total population of Sisak was 33,322 (DZS). The city of Sisak consists of 28 statistical circles – the smallest official statistical unit in Croatia. They were created in 1959 and have been revised for each population census. They represent a permanent network of spatial units, which covers the entire mainland area of Croatia (Šiljeg et al., 2018).

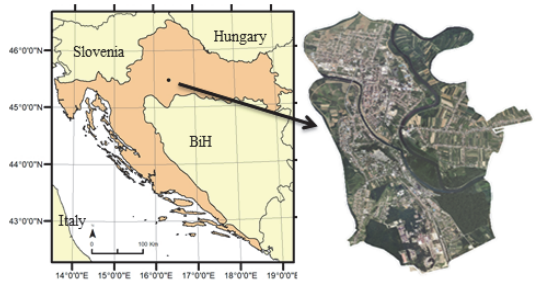

Figure 1: Study area - City of Sisak.

3 MATERIALS AND METHODS

The database of UGS was created based on the analysis of multispectral satellite images (Earth Explorer, 2019) and high-resolution (0,5 meters) digital orthophoto (DOP). Analysis has been conducted in Erdas Imagine (2018) and ESRI Arc GIS 10.1.

3.1 Satellite Remote Sensing Data

The land cover model of Sisak is generated in Erdas Imagine by supervised classification using the *Maximum Likelihood* algorithm (pixel-based approach). Classes of the UGS were initially derived from Sentinel 2A satellite imageries analyses. They were modified and corrected using the data acquired by the manual vectorization method of high-resolution DOP. The spatial resolution of Sentinel 2A varies from 10m to 60m depending on the spectral band (Drusch et al., 2012).

Classification is made according to the methodology of the *Urban Green Belt* project (URL urban green belts (UB) project wpt 1 activity) and following the ANGst standards.

3.2 ANGst Methodology and Accessibility

Accessibility was analysed following the ANGst methodology (English Nature, 2003), which recommends that everyone should have access to the natural greenspace. The main criteria followed in this paper were:

- Minimum 2 hectares in size, no more than 300 meters (5 minutes walk) from home

Accessibility model was generated based on UGS, which are publicly accessible (with or without entry fee) and bigger than 2 hectares. That eight classes of UGS encompass; urban forest, public green spaces (parks, promenades, lawns, city gardens, greenery by the buildings and institutions, playgrounds), green spaces by the river, abandoned areas, sport green surfaces, green spaces by the train rails and cemetery.

UGS accessibility zones were determinate using the Network Analyst extension, specifically the New Service area tool in which the following parameters were used;

a) Default breaks 5 minutes
b) Restriction – disabled
c) Polygon type – Detailed, trim polygons 50 meters

d) Multiple facilities options – overlapping
e) Overlap type – discs

3.3 Data Quality Assessment

Topology correction was performed on the traffic data following the rules: must not overlap, must not intersect, must not self-overlap, must not self-intersect, must be a single part. As a cost attributes walking time (minutes) was calculated. Assumed walking speed is 5 km/hour. After the topology correction Network dataset has been created.

The classification was based on satellite imagery with a spatial resolution of 10 meters. Accuracy of the classification is evaluated based on the field validation. On the public green spaces bigger than 2 hectares, 30 control points were selected.

3.4 Indicators of Green Space Accessibility

Indicators of green space accessibility, in general, takes into account the distribution of the population (statistical circle, settlement) in terms of their proximity to green space (WHO, 2019). The most widely used indicator to assess green spaces is their total area with respect to the total population (m^2/inhabitant) (Taylor et al., 2011; Van Herzele and Wiedemann, 2003; Caspersen et al., 2006; Kabisch and Haase, 2013; ISO, 2014). But this indicator is too general and does not give us information about the actual distribution of UGS and population throughout the city. That is why this research is conducted at three levels; macro, meso and micro:

- At the macro level of the research, UGS accessibility is expressed as a percentage of the total settlement area, which has accessible UGS.
- At the meso level of the research, UGS accessibility is expressed as a percentage of the total statistical circle area that has accessible UGS.
- At the micro-level of the research, UGS accessibility is expressed as a percentage of the total housing units within the UGS service area.

In this paper, the presented results are only for representative statistical circles, those with the highest percentage and with the lowest percentage. Total housing units data are the result of fusing the data downloaded from Geofabrik and data from the State Geodetic Administration. Missing units were manually vectorized using the high-resolution DOP. The results of these indicators are relevant for comparison with other European cities (Zadar, Leicester, Scheffiled).

4 RESULTS AND DISCUSSION

4.1 UGS Database of Sisak City

In the city of Sisak 11 distinctive classes (public and private) of UGS were identified (Fig. 2). Excluding the private green spaces, UGS encompasses slightly less than 31%. Forest is the most widespread class of UGS (bigger than 2h) with 12% in the urban area. The second is public green spaces with 9%.

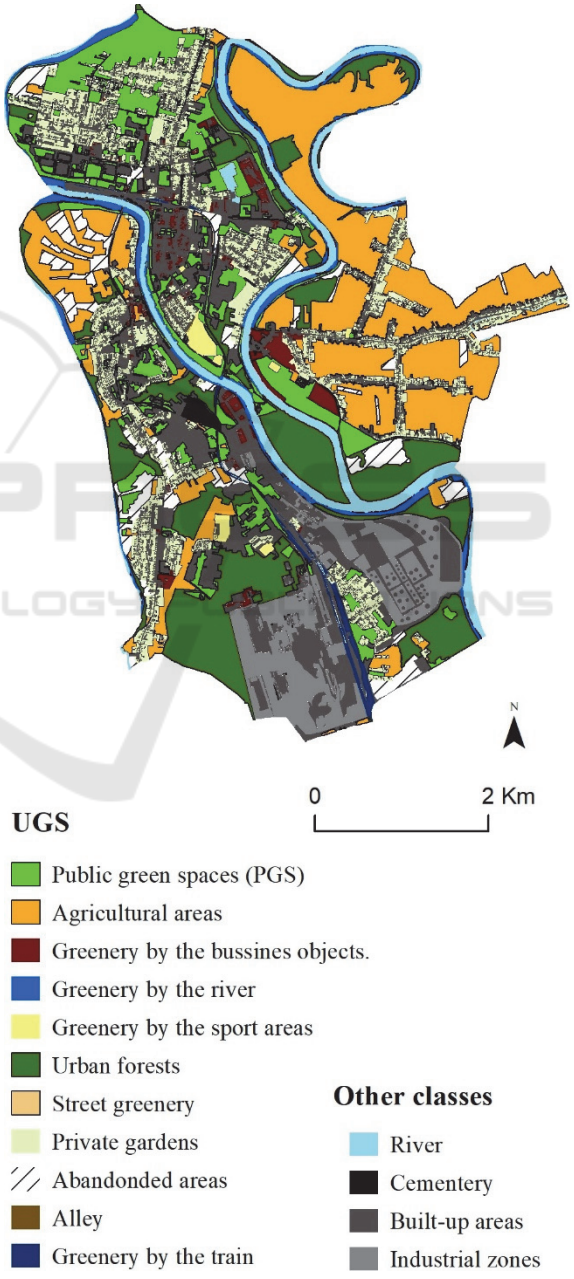

Figure 2: UGS classes (private and public) and other classes in the city of Sisak.

4.2 Macro Level

Within 5 minutes UGS is accessible to nearly 30% of the city area. On average there is 297m² of UGS per capita. The optimum value suggested by the WHO is 10 to 15 m² of UGS per capita, while the minimum is 9 m² (Karayannis, 2014, Šiljeg et al., 2018). Sisak with 297 UGS per m² is far beyond the optimal distribution.

On the other hand, ANGst states that the entire population of the city should have access to UGS. Considering that, Sisak does not meet the standard (Fig. 3). If we compare UGS per capita in other towns (Zadar, Leicester), Sisak has much better results. Each resident in the settlement of Zadar has around 114 m² per capita of green space (Šiljeg et al., 2018). Leicester has 30 m² per capita of UGS (Comber et al 2008).

Figure 3: UGS accessibility map.

4.3 Meso Level

The results at meso level highlight the diversity among statistical circles. This was expected and corresponds with the results of other authors.

Circles located near the city centrum have mostly more percentage of UGS accessible within five minutes than those closer to the outskirts of town. In the city centrum, there are a lot of green areas intended for recreation and rest. On the outskirt of the town, green areas are predominantly transferred into private gardens and agricultural land which are excluded from the analysis. Three out of 28 statistical circles do not have access to UGS. (Fig. 4). Following the WHO suggestion (10 to 15 m² per capita), all statistical circle meets the standard.

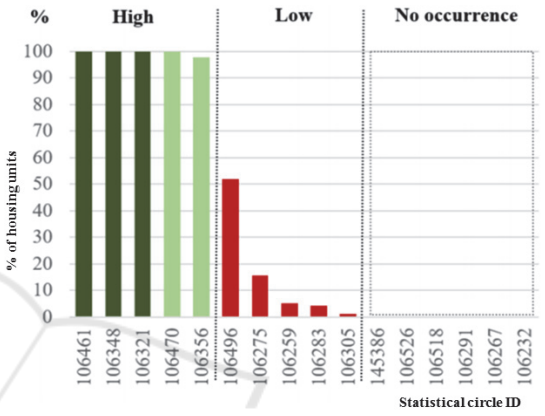

Figure 4: Percentage of statistical circle areas with accessible UGS (bigger than 2 ha) within 5 minutes.

4.4 Micro Level

The result at the micro-level has shown the unequal distribution of access to UGS. UGS is accessible within 5 minutes to 79,9% of the housing area. There are three statistical circles with 100% accessibility to UGS. These circles are closer to the city center. The six from 28 circles (20%) don't have access to UGS but there is not a lot of residential buildings in these circles. For comparison, in the Leicester city, UGS was accessible to 10,3% (Kuta et al., 2014) of the population, in the Sheffield 36,5% (Barbosa et al., 2007) and in Zadar 38,9% (Šiljeg et al., 2018). Therefore, Sisak with 79,9% of housing units with accessible UGS is above average.

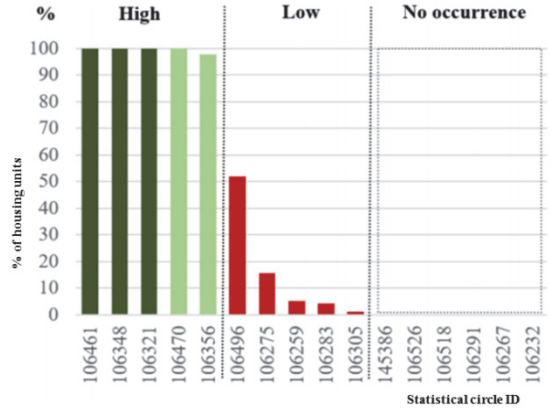

Figure 5: Percentage of housing units with accessible UGS (bigger than 2 ha) within 5 minutes.

4.5 Data Accuracy

Data quality assessment was performed by field validation on 30 control points. Data accuracy is 96,66%. Maximal accuracy was expected because the object of research was areas bigger than 2 hectares.

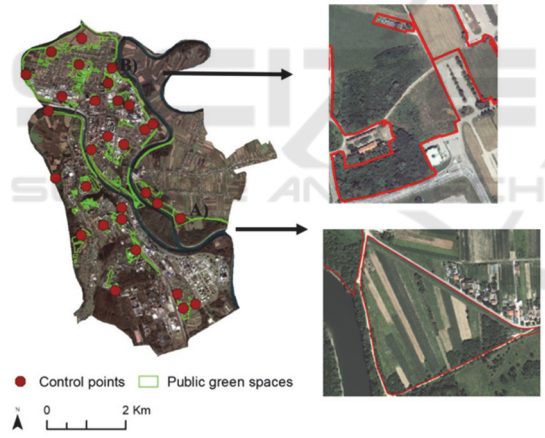

Figure 6: Field validation of data.

5 CONCLUSION

Multiscale GIS analysis of UGS accessibility reflected differences among results depending on the level of research. At the macro-level (297 m² per capita) Sisak meets the WHO standards of UGS accessibility. On the other hand, only 30% of the urban area meets the ANGst standard. So answers to research questions are; there are enough m² UGS per capita, but they are not equally accessible to all residents. In comparison with other cities (Zadar, Sheffield, Leicester) in which the same methodology has been applied, Sisak has average results.

At the meso level, there are differences among statistical areas, depending on their location in the city. Few statistical circles are completely (100%) within the UGS access area. However, these statistical units are not only encompassing the housing area but are also referring to unpopulated areas.

Therefore, analysis of the micro-level of research is performed. It takes into account the spatial distribution of the housing units within statistical circles. At the Micro level, 79,9% of the population have five-minute access to UGS bigger than 2 hectares. The result is above average in comparison with other towns. Possibly, there are plenty of UGS in the city center because of industrial zones, to make a balance in the ecology system. Still, considering UGS benefits, every resident should have standardized access to green spaces. As long as some important measures don't get applied to certain city areas, residents may feel marginalized or discriminated. In Sisak, a big part of UGS is abandoned and is not reaching its full potential. Taking care of these areas may bring equality to certain areas in the city. Using high-resolution multispectral images is suggested to generate a better quality model of UGS.

ACKNOWLEDGEMENTS

This work has been supported in part by Croatian Science Foundation under the project UIP-2017-05-2694 and National Park „Krka".

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