Access to Green Public Spaces in Warsaw. Spatial and Statistical Analysis.

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Key words: urban greenery, geoinformation, spatial distribution, smart city, sustainable development goals, urban planning.

SUMMARY

Green spaces within cities are recognized as an essential component of the urban environment. In general, they are composed of street plantation, lawns, parks, gardens, forests, green roofs, and so called semi-natural vegetation. Urban greenery provides valuable ecosystem services, plays an irreplaceable role in the enhancement of the urban environment, and is perceived as an indicator of the relative wealth of a neighborhood.
The purpose of paper is to show a spatially comprehensive view of greenness in Warsaw, the capital of Poland following a consistent approach aligned with the requirements of the 2030 Agenda for Sustainable Development. Based on topographic data we show that green areas in Warsaw comprise parks, gardens and other green leisure areas as well as forests and a nature reserve. In total, green areas occupied 25 % of the city area. By the means of spatial statistics, i.e.; Global Moran's I, the ANN analysis we shown that the spatial distribution of green areas in Warsaw is irregular, clustered, and not spatially autocorrelated. Parks, lush gardens are mainly located in the central districts of the city, whereas forests and bushes dominate in the outskirts. OLS regression shows that the urban greenery area significantly depends on the area of district (R square=0.96). The relationship between the area of urban greenery and the number of inhabitants depends on the location of a district. For districts located close to the central part of Warsaw, Pearson's r amounts to 0.96, while for the fringe – as much as 0.26. The uneven pattern of spatial distribution of urban green space is also highline by the percentage share of green area in the total acreage of the districts, and green urban ration that varies from 2.0 to 63.0%. Green space allocation per capita is 121.7 sq. m, however, varies significantly between the districts, from 3 to 602. The greenery in Warsaw is well-accessible to inhabitants.74% of residential built-up area is located within 1 km from recreation and leisure parks, and 90% within 2 km. More than 7% residential buildings are in the near vicinity (up to 100 m) of parks and gardens, 47% - not farther than 500 m. The study results provide a reference to urban planners as well as local authorities for future urban greening practices, are helpful for people searching for apartment buying or renting.

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1. INTRODUCTION

Green spaces within cities are recognized as an essential component of the urban environment. In general, they are composed of street plantation, lawns, parks, gardens, forests, green roofs, and so called semi-natural vegetation. Urban greenery provides valuable ecosystem services, plays an inimitable role in the enrichment of e urban environment, and is perceived as an indicator of the relative wealth of a neighborhood. Moreover, green space fulfils important ecological, technical and health functions, such as: reducing the heat island effect, infiltration of rainwater, or noise suppression (Czerwieniec and Lewińska, 2000; Dige 2011, Hudeková 2011). The analysis of urban greenery allows for a better understanding of a city structure and functions. An accurate estimation of green space coverage and an assessment of the type of green space system facilitate city planning (Degórska and Degórski 2017). The benefits and functionality of urban green spaces are broadly discussed in the literature with regard to their social, economic, cultural and environmental aspects of sustainable development. Fuller and Gaston (2009) documented, on the basis of 386 European cities, that a city shape and size affect profoundly the proximity to green space outside the city boundaries. They also found that small, densely populated cities show very low per capita green space allocation. Moreover, the analysis of green space coverage shows very high diversity: from 1.9% (Reggio di Calabria, Italy) to 46% (Ferrol, Spain). Poland and Warsaw fall below the average values. It could be partially explained by the rough data used, e.g. Urban Atlas and CORINE Land Cover with a minimum mapping unit of 25 ha (Ciolkosz and Bielecka 2005).

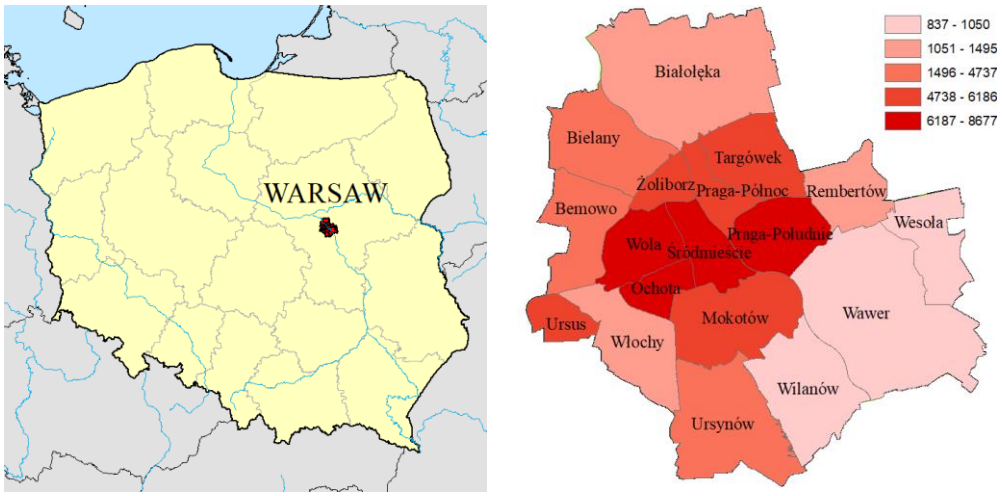
Particularly, urban greenery is an essential component of the Sustainable Development Goal 11 ‘Make cities and human settlements inclusive, safe, resilient and sustainable’, specifically in target 11.7, which aims to achieve the following: ‘By 2030, provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities’ (United Nations 2015). Characterizing and understanding the changes and trends in greenness and its relationship with the development and dynamics of human settlements can help guide sustainable urban development (SDG 11, 2019).

The purpose of paper is to show a spatially comprehensive view of greenness in Warsaw, the capital of Poland, following a consistent approach aligned with the requirements of the 2030 Agenda for Sustainable Development. The paper is structured as follows: section 2 gives in brief characteristics of Warsaw, the overview of data used as well as methods description; section 3 presents and discusses the results, and finally section 4 concludes the findings.

2. DATA AND METHODS

2.1. Warsaw, the study area

Warsaw stands on the Vistula River in the east-central Poland. With population of 1.7 million cover an area of 517.24 km^2 (Fig.1a). The city is diveded in 18 districts which play a major role in defining the character of the city, district names are listed in Fig. 1b.



a b

Fig. 1. a – Warsaw location, b – Warsaw, population density

The population distribution in the study area varies considerably from the densely populated Ochota (8,600 person per km^2) to the sparsely populated district of Wawer (900 person perkm^2) (Fig. 1b). Moreover, the size of the districts is heterogeneous, and varies from 8.5 to 79.9 km^2, in Żoliborz and in Wawer, respectively. Both the city government and the residents perceive Warsaw as a green city. In 2017 Warsaw applied for the European Green Capital Award, and reached the semi-final.

2.2. Data used

Information on the type, area, and location of urban greeneries was deriwed from the BDOT10k - National Database of Topographic Objects. BDOT10k is a seamless vector database with the level of detail corresponding to 1:10,000 civilian topographic maps. Its thematic scope covers nine classes, among which land cover and protected areas contain information on urban greenery (Regulation, 2011). District borders came from the National Register of the Territorial Division of the Country, while the population density - from the Basic Urban Statistics (GUS, 2014).

2.3. Methods applied

Green areas as an element of urban greenery were defined in two legal acts: the Act of April 16, 2004 on Nature Conservation (Journal of Laws 2004 No. 92 entry 880) and the Act of

January 31, 1980 on the Protection and Shaping of the Environment (Journal of Laws, 94.49.196), while the more comprehensive definition, listing various forms of green areas, is in the Nature Conservation Act. In this study the definition given by the Nature Conservation Act. The analyzed urban greenery consists of: city parks and gardens, forests, tree-cover areas, groves, and protected area, including the Natura2000 sites was adopted.

Based on the available data two indices were calculated, namely: (1) green space coverage and (2) green space in capita. Green space coverage, expressed as a percentage, is the quotient of green spaces in a district and the total area of a district. Green space per capita shows the surface area of green spaces (in meters) per one inhabitant in the districts and in the entire city.

Inferential statistics were used to reach conclusions that extend beyond the immediate data alone. The Average Nearest Neighbor (ANN) and Global Moran's I spatial statistics demonstrate the spatial distribution pattern of urban spaces in Warsaw. The ANN measures the distance between each geospatial objects centroid and its nearest neighbor's centroid location and averages all these nearest neighbor distances. If the average distance for a hypothetical random distribution is below average, the distribution of the objects being analyzed is considered clustered. If the average distance is greater, the features are envisaged as dispersed. The average nearest neighbor ratio, calculated as the observed average distance divided by the expected average distance, less than 1 highlight the clustering pattern, greater than 1- dispersion (Mitchell, 2005). The Global Moran's I statistic measures spatial autocorrelation as the similarity between values of an area of urban green features as a function of spatial distance. The Moran's I Index varies between -1.0 and 1.0 for maximum negative and positive autocorrelation, respectively. Non-zero values of Moran's I indicate that richness values in quadrats connected at a given geographical distance are more similar (positive autocorrelation) or less similar (negative autocorrelation) than expected for randomly associated pairs of quadrats. Statistical significance of the Index is expressed as a z-score and p-value (Getis, Ord, 1992).

The accessibility of urban green spaces was computed in a two-step analysis, i.e. (1) 100, 500 1000 and 2000 m buffering recreational green areas (parks, gardens) and natural green areas such as: forest, tree-covers, scrublands and protected areas. (2) All residential buildings within the buffer zones were selected and their percentage share in the district was calculated. The buffers size were justified by Panduro (2013). Moreover, Cvejić et al. (2015) assume that the minimum walking distance should be of 100 m to the nearest green space (door-to-door distance) while the maximum distance - about 2000 m.

3. RESULTS AND DISCUSSION

Public green areas in Warsaw comprise almost 25% of the city surface area. It is one of the few European capital cities where green spaces comprise not only parks, gardens and other green leisure areas but also forests and a nature reserve (Ciołkosz, Bielecka, 2005). Forests occupy 52.39 km^2 and account for a high percentage (42%) of green space in the city. They are located mainly on the fringe of Warsaw and form a green belt around the city (Fig. 2-3). Together with the tree-cover area they constitute 13.6% of the total surface are of Warsaw. The Kampinoski

National Park, located in the near vicinity of Warsaw covers a small part of the Bielany district (the Bielany Wood). It is protected as a UNESCO World Biosphere Reservation. The green bank of Vistula River is the habitat of wildlife, mainly birds, and belongs to the Natura 2000 sites. Other protected areas are small spaces scattered all over the city. Protected green space takes up 14% of urban green space.

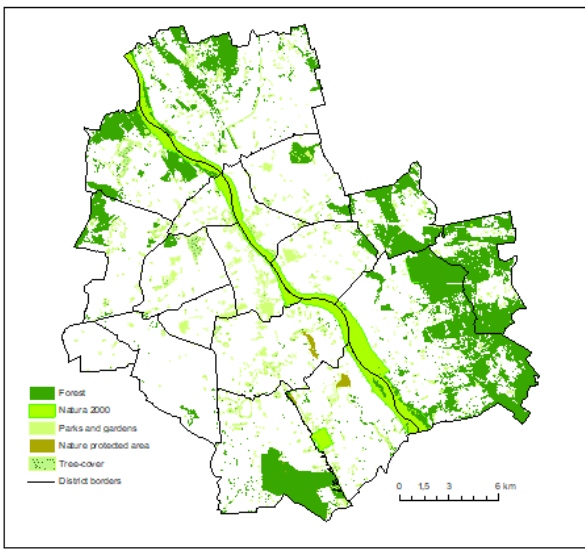


Fig. 2. Public green area in Warsaw

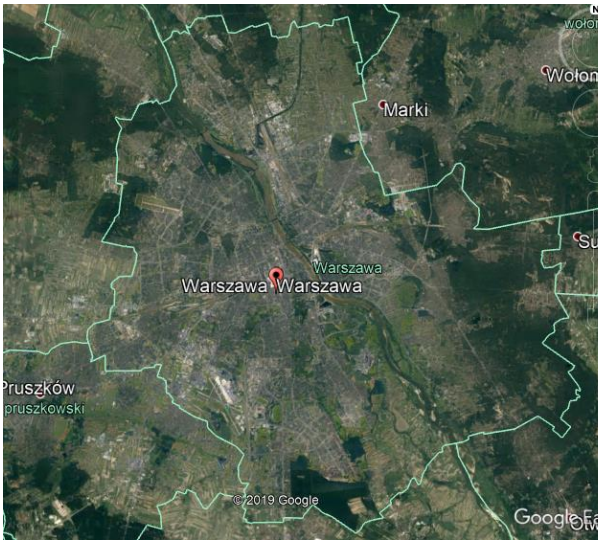
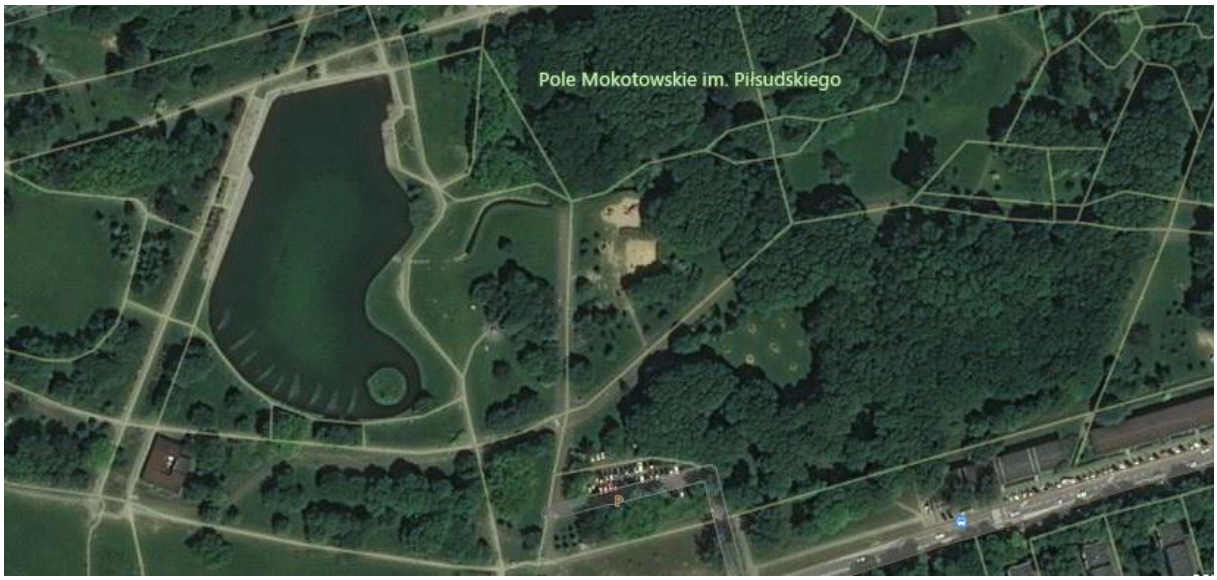


Fig. 3. Google Earth - Warsaw



Source https://www.bing.com/maps?q=pole+mokotowski&FORM=HDRSC4

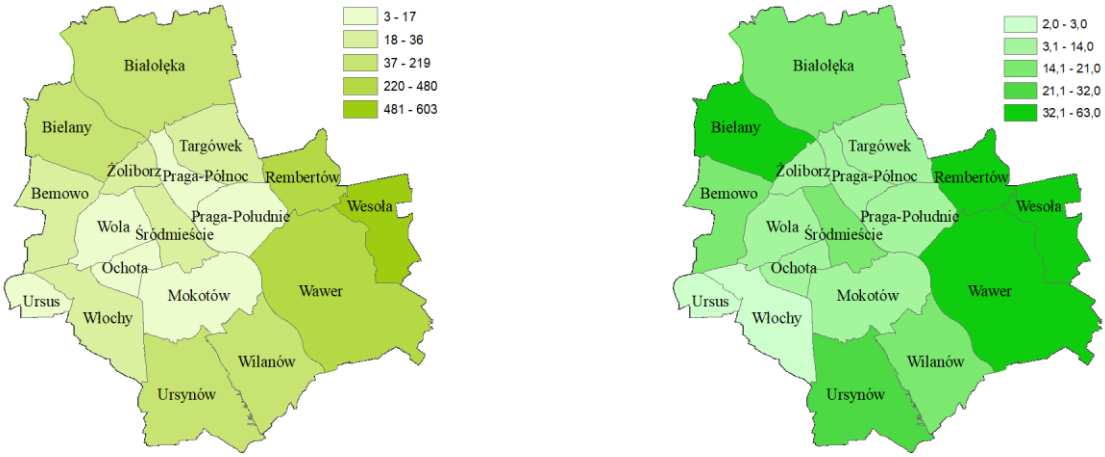
Fig. 4. Mokotowskie Field, the public green leasure area

There are 79 parks and gardens in Warsaw, they cover about 9% of urban green space and 2% of the total surface area of the capital. Some of the city parks are historic objects and are located

near a former royal residence (Wilanów, the Łazienki Park). Many parks are accompanied by sport and leisure areas that make them favorite places of relaxation (Fig. 4).

Parks and gardens are mainly located in the central part of the city, while forests - on the outskirts. The ANN ratio equals 0.75, indicates clusterization, with the level of significance over 99%. Moreover, the analysis of spatial autocorrelation between acreage of urban green space, measured by the Global Moran's Index (equals 0.010) indicates that the null hypothesis of complete spatial randomness cannot be rejected. The pattern created by urban green spaces is not significantly different than random, the value of a z-score is 0.953.

The uneven distribution of urban green space is also underlined by the percentage share of green area in the total acreage of the districts (Figure 5). Green space allocation per capita in Warsaw is 121.7 m^2 but varies substantially between the districts of Warsaw (Fig. 5a). The largest number, as many as 603 m^2 of green space per capita is in Wesoła, a sparsely populated, fringe district. The smallest number, 3 m^2 per person, is in Ursus, which is an industrial and densely populated district of Warsaw. Wesoła is the districts with the highest green space ratio, amounting to 63%. In Bielany and Ursynów, the Bielany Wood and the Kabaty Woods (a common weekend destination for the inhabitants of Warsaw) have the largest influence on the share of green areas. The smallest values of the green space ratio are characteristic for two peripheral districts of Warsaw: Ursus and Włochy, 2 and 3% respectively. The average green space ratio for Warsaw is 20.5%.



(a) (b)

Fig. 5. Greenery indices – (a): green area per capita [in m]; (b): green space ratio

Green spaces in Warsaw are well accessible, with 74% of residential area located within 1 km from green recreation and leisure parks, and 90% within 2 km. More than 7% residential buildings are in the near vicinity (up to 100 m) of parks and gardens, 47% - not farther than 500 m. The residents of Ochota, Śródmieście and Żoliborz have the best access to urban greenery. On average 15% of multi-family buildings are located not farther than 100 m from parks, and for 72-75% buildings distance to parks is not greater than 500 m. The accesibility of parks and forests is the fringe districts. Only 2 to 5% of multi-family housing is located within

a 500 to 1000 m distance to urban greenery. However, it is compensated for by very good access to forests and landscape parks. The percentage of multi-family houses located within a 500 m distance from forests is 72% for Białołeka, 82% for Rembertów and over 95% in Wawer and Wesoła.

4. CONCLUSIONS

Urban greenery is highly diversified both in terms of spatial distribution and the types of green areas. The analysis revealed substantial differences between the central and peripheral districts, especially with respect to the average surface area occupied by green spaces.

The high value of urban green ratio (20.5%), green space allocation per capita equals 121.7 m^2 as well as satisfying green area accessibility prove that Warsaw is perceived as a green city. However, it is important to be aware of some threats linked to rapid urbanization of peripheral districts and densification of sparsely built-up areas that could diminish urban greenery area and cause its highest fragmentation.

The study provides a reference to urban planners as well as local authorities for future urban greening practices. It is also helpful for people searching for apartment buying or renting. Different types of urban greenery have different spatial distributions and diverse associations with districts population and area.

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BIOGRAPHICAL NOTES

Prof. Elzbieta Bielecka is a professor at the Faculty of Civil Engineering and Geodesy at the Military University of Technology, in Warsaw where she heads group on geographic information systems and science. She holds a graduate degree in geodesy and cartography and a PhD in geography form Warsaw University, Poland. She has nearly 40 years of experience in education, research and consulting in the field of GIS and cartography. In her research she focuses on the theoretical issues of GIS, especially data quality and uncertainty, spatial modeling as well as national SDI. She is the author of many research publications, consultant in the implementation of GIS in public administration. Currently, she is editor-in-chief of the Geodesy and Cartography, the journal of Polish Academy of Sciences.

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