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RESEARCH ARTICLE

Green spaces in Sofia – analyses of spatial distribution

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Abstract

Green spaces in urban ecosystems is the main provider of a variety of ecosystem services. It is important for a city that undergoes dynamic changes in size, structure and number of inhabitants to manage balanced urban green spaces. Using the geographical information systems, this research investigates the green spaces within the building boundary of Sofia by administrative regions and confirms and demonstrates the spatial deficiencies in their distribution. The proportion of parks and gardens and open green spaces by region is taken into consideration and supplemented with analysis of the density of the tree coverage in the park. The green area per capita is calculated to demonstrate how the coverage with green spaces relates to the population. The results outline some main issues that urban development is facing towards sustainability. If considered by the planning and management of the city this could help respond to the contemporary challenges and adopt policies for a vital, healthy, and attractive environment for the capital's residents.

Keywords

ecosystem services, GIS, green areas management, urban ecosystem, urban greenspace

Introduction

The growing role of cities as concentrators of people makes them crucial focal points of both potential benefits and problems. The problems related to the urban environment are becoming even harder to tackle, considering the fragile balance of the environmental components and the growing anthropogenic pressure on them. As rates of urbanization and climatic change soar, decision-makers are increasingly challenged to provide innovative solutions that simultaneously address

climate change impacts and risks and inclusively ensure quality of life for urban residents. Cities have turned to nature-based solutions to help address these challenges. Nature-based solutions, through the provision of ecosystem services, can yield numerous benefits for people and address multiple challenges simultaneously (McPhearson et al., 2022).

Ecosystem services can address many of the challenges that cities increasingly face, and the false dichotomy between environment and development is nowhere as easy to disprove as in cities (Elmqvist et al., 2013). The concept of ecosystem goods and services is inherently anthropocentric: it is the presence of human beings as valuing agents that enables the translation of basic ecological structures and processes into value-laden entities (deGroot et al., 2002). According to conventional economic theory, the value of environmental assets can be estimated by reference to the preferences for or against conservation of those assets by quantifying both use and non-use values. (Owen and Unwin, 1997). Urban ecosystems are especially important in providing services with direct impact on human health and security. The classification and description of important ecosystem services provided in urban areas using the Millennium Ecosystem Assessment and the TEEB initiative include 4 major classes – provisioning, regulating, cultural, supporting and habitat. (Gómez-Baggethun et al., 2013). The green spaces in the city could provide all these as they are the main connection between urban and nature. Green infrastructure presents diverse opportunities to mediate adverse effects, while simultaneously delivering human health, well-being, environmental, economic, and social benefits to contemporary urban dwellers (Parker and Baro, 2019). A green city means a way to increase the sustainability of urbanized areas. It is a concept of urban planning relying on the ecosystem services that green infrastructure can supply. (Tirla et al., 2014). Therefore, contemporary urban politics become more and more intricate and are challenged with complex issues that need balance between urban and green. These contemporary tendencies are also reflected by Sustainable Development Goal 11, which is about making cities and human settlements inclusive, safe, resilient, and sustainable (United Nations, 2015).

Sofia is the capital of Bulgaria and is the fastest growing city in recent years, both in size and population. The dynamics of anthropogenic pressure needs to be governed in order to mitigate the negative consequences on the urban environment and quality of life. With this regard, green infrastructure is acknowledged from planners and city managers as an instrument for regulating the city environment and so it becomes the focus of many research and public policies - the Green city action plan from 2020 (EBRD, 2020) and the Green system analysis, part of the Programme for Sofia (Sofiaplan 2021) are such examples. Gehl Report (2017) concludes the green network of Sofia needs to be protected and strengthened and that a better distribution of existing trees is required. The main conclusion is that Sofia has a large relative share of green spaces, but the problem remains with their quality and distribution. Some large parks are well maintained while other areas, such

as inter-block spaces in residential quarters, need improvement. The green system is developing in a disproportionate territorial manner; it is underdeveloped in the northern part of the city and new neighborhoods. Appropriate measures should be introduced to protect and enhance green space in new built-up areas (Green city Action plan, 2020). An example of neglecting green spaces in newly built residential areas is the southern Lozenets region - deficiencies of social and green infrastructure have already been established in the analysis of the southern part of Lozenets region (Sofiaplan, 2021). Another specific example of rebuilding, hence green territories of ecological importance, is presented by Todorov and Kirov (2022), who studied the case of a wetland with important environmental functions in a newly formed residential area.

This article is focused on analyzing the distribution of green spaces within the building boundary of Sofia city by administrative regions. The main objective is to establish whether there is a disproportion in the spatial arrangement of green spaces by inspecting the density of the parks and garden areas throughout the city. The study also inspects the density and distribution of all the green areas, including inter-block and open green spaces, the tree coverage of the parks as well as distribution of green spaces per capita. Open access data from Sofiaplan, Stolichna municipality is processed, explored, and interpreted using various techniques in GIS to obtain and visualize the results. The dynamics in the development, growing and building in Sofia pose the risk of creating an urban environment with low quality because of disturbed balance between urban and green. Healthy urban planning requires good knowledge of the current state-of-the-art, urgent issues and their location. Therefore, this research aims at outlining the territories with deficiency in green infrastructure of different nature that have the most tangible effect on urban environment.

Methods

The area of interest for this research is the city of Sofia – the capital of Bulgaria, a growing and developing urban area with high dynamics and significant changes in the urban texture and morphological structure. The main unit of the present research study is the administrative regions of Sofia, within the building boundary of the city. The building boundary was last determined in the Sofia land use plan in 2009 (Sofia municipality, 2009). Only the territory of the regions (or parts of them) that fall within this boundary, was taken into consideration, since the periphery regions encompass large areas of peri-urban territories are not included. All the input data is tailored to that coverage.

Sofia is situated in the western part of Bulgaria, at the foot of the Vitosha Mountain.

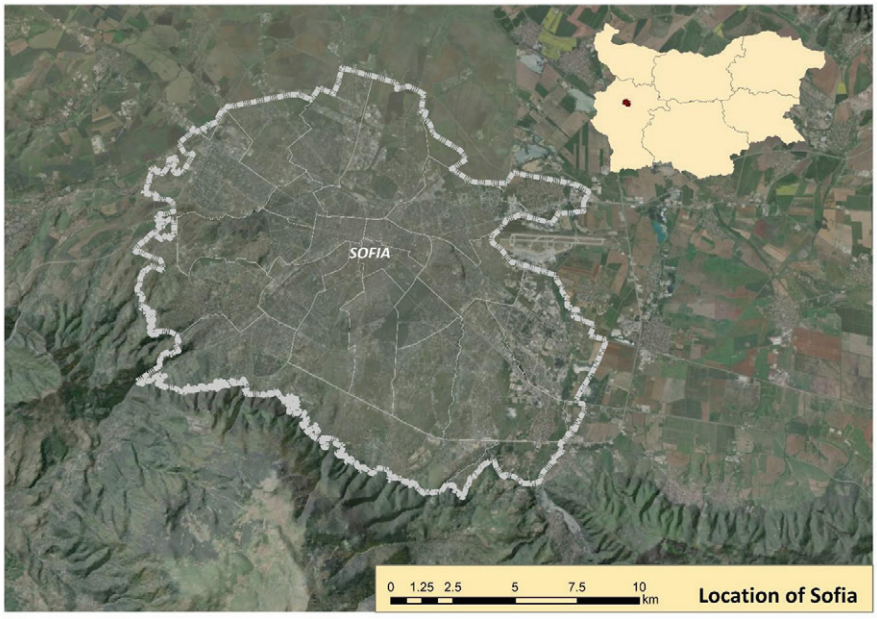

Figure 1. Location of Sofia city, Source of basemap: Google maps, Source of data: Sofiaplan

As the capital of Bulgaria, the city concentrates 19.5% (1 274 290 people) from the population of the country in 2021 (National Statistical Institute). Sofia has the natural prerequisites to be a green city, considering the contiguity of Vitosha Mountain and the river network passing through its territory. Historically, it was planned to be a green city, back in 1934 when Adolf Musman developed the idea of a green belt that makes the connection with Vitosha Mountain and a transport system that contributes to developing Sofia as a garden city (Stoycheva, 2017)

Among other, newly elaborated methodologies, urban green infrastructure is analyzed by reporting the extent of urban green, measured with reference to the city area (% of urban green) or as m^2 per inhabitant (Zulian et al., 2022). According to the European Environmental Agency, the percentage of the total green system in Sofia is 46% of the territory, the urban tree cover is 37% and the urban green space – 4% as a percentage of the respective surface area, which ranks Sofia 14th out of 38 European cities (EEA, 2022).

The definition of urban green spaces which is agreed on by ecologists, economists, social scientists and planners is public and private open spaces in urban areas, primarily covered by vegetation, which are directly (e.g. active or passive recreation) or indirectly (e.g. positive influence on the urban environment) available to the users (Estingoff, 2015). Green spaces and green areas are perceived as concepts with the same meaning that include parks and gardens. Green infrastructure is the network of open space, woodlands, wildlife habitat, parks and other natural areas, which sustain clean air, water, and natural resources and enrich their citizens (McMahon and Benedict, 2000).

The analysis of the coverage and distribution of the green spaces requires input data that is up-to-date, reliable, with appropriate scope and quality. Therefore, data for the green system with open access, generated and distributed by the municipal enterprise Sofiaplan were used. The distribution in the spatial and functional classification of urban green areas Sofiaplan presents is based on Sentinel-2A multispectral satellite images, freely available within the framework of the European Earth observation program „Copernicus". A 100% cloud-free S2A satellite image downloaded from the Copernicus Center for Free Access to Scientific Data from Sentinel from 2015-08-28 was used. Data verification was performed based on visual interpretation of available S2B 2017 satellite image data and expert evaluation (Sofiaplan, 2015). The data includes the following: administrative border of the regions in Sofia; Polygons of the parks and gardens in Sofia that includes the percentage of the tree coverage; Polygons of the green areas in Sofia (Fig. 2).

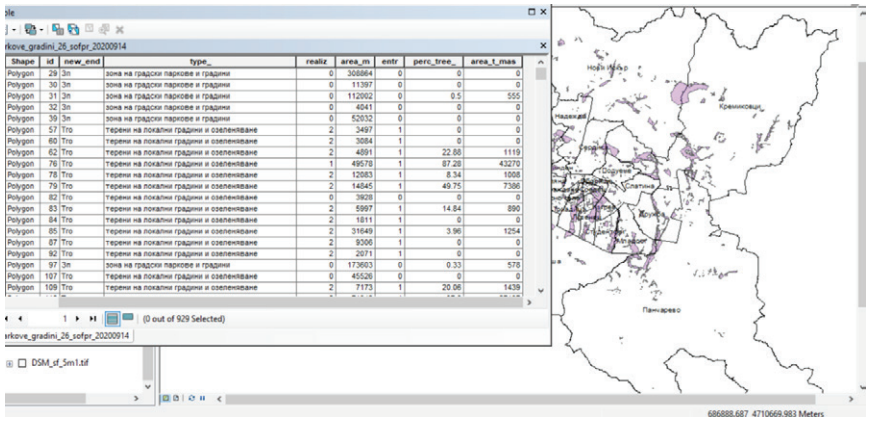

Figure 2. Content of the database. Source: Sofiaplan

What is important to differentiate is the concept and meaning of parks and gardens and green areas that are used in this spatial analysis (Fig.3). The parks and gardens layer includes two types of terrains: zones with city parks and gardens and terrains of local garden and landscaping. They include the regulated terrains for green space.

Figure 3. Parks and gardens layer vs. Green areas. Database provided by Sofiaplan

The green areas on other hand include all the open spaces that are non-paved, and they cover the parks and gardens as well.

To calculate the coverage of green spaces and parks and gardens per each region, an analysis in ArcMap was done. The "Intersect" analysis was used to identify the overlapping green zones within the regions. Their area was calculated using the function "Calculate Geometry" and then processed further via pivot tables in excel.

The results from the coverage of green spaces are classified in 5 classes using the Jenks natural breaks classification method that clusters data into groups with least variance within the group and maximum variance between the groups (North, 2009).

The statistical data for the population within the regions from the last census (2011) was available from Sofiaplan.

Results

The spatial pattern of gardens and park distribution shows intensity of the green coverage in some regions from 25-41% - Sredets, Triaditsa, Izgrev, Lozenets and Krasna polyana (41.38%) and regions with parks that make up less than 10% of the territory (Fig. 4).

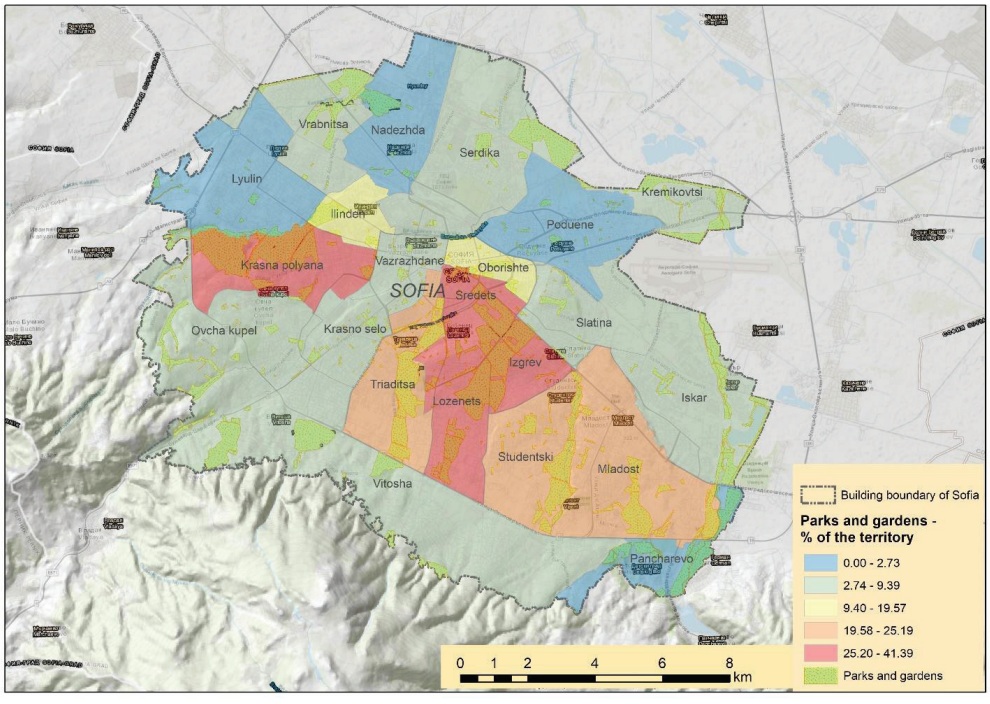

Figure 4. Share of gardens and parks from the total area by regions in Sofia, Source of basemap: Google maps, source of data: Sofiaplan

The analysis of the proportion of the green areas that cover the parks, gardens and all the open green spaces outline the southern part of central Sofia as greener than northern Sofia. Most of the green areas in the urban core are parks and gardens, the open green spaces are a very low percentage, which is explained by the densely built-up center of the city (Fig. 5, Tabl. 1).

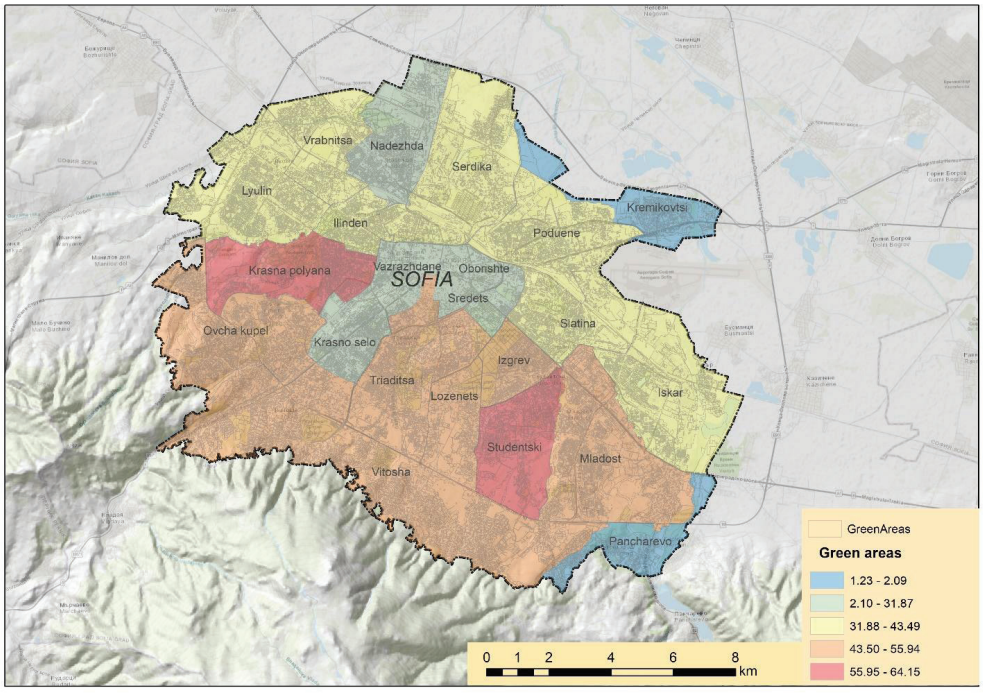

Figure 5. Share of green areas from the total area by regions in Sofia
Source of basemap: Google maps, source of data: Sofiaplan

Krasna polyana, Izgrev, Triaditsa and Lozenets confirm their green character. The parks and gardens cover 22% of the Studentski region, but when all green open areas are included, Studentski turns out to be 63% green (Table1). There is another group of outliers that show low coverage of parks and gardens, less than 10% but good coverage of green areas - more than 35%. These are regions with preserved open green spaces, like inter-block spaces, pocket parks, houses' gardens or just unused green spaces.

Regions	Parks and gardens	Green areas
Krasna polyana	41.39	64.15
Lozenets	36.77	48.22
Izgrev	34.61	52.95
Sredets	29.41	29.91
Triaditsa	25.19	52.21
Mladost	23.89	53.42
Studentski	22.86	63.09
Ilinden	17.36	43.42
Oborishte	13.61	22.66
Iskar	8.52	38.12
Slatina	6.68	43.49
Vrabnitsa	6.01	38.66
Krasno selo	5.46	31.87
Vitosha	4.47	55.94
Ovcha kupel	4.42	50.47
Vazrazhdane	4.26	21.06
Serdika	2.93	35.66
Poduene	2.26	40.60
Nadezhda	1.41	31.53
Pancharevo	1.22	1.23
Lyulin	1.03	34.87

Table 1. Regions with low coverage of parks and gardens, but good coverage of green areas

For urban inhabitants, urban green space is often the only source of nature-based interaction readily available within any reasonable distance. Research points to at least 9 m^2 of green space per individual with an ideal UGS value of 50 m^2 per capita (Russo and Cirella, 2018). Analysis of the green areas per person was carried out only in the regions that fall completely within the building boundaries of the capital (Fig. 6).

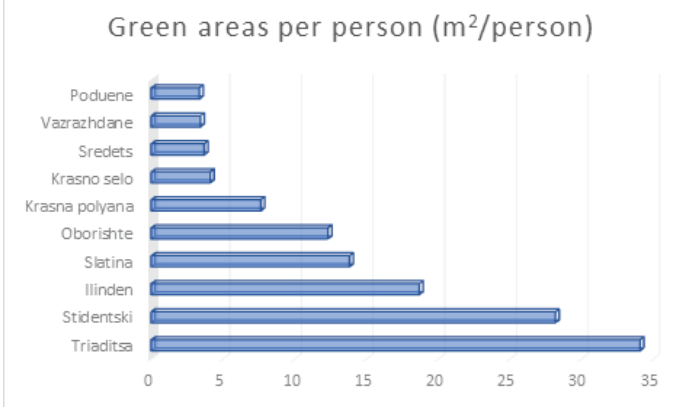

Figure 6. Green areas per person, m^2/person.
Source: population data-2011, Sofiaplan, Green areas data – Sofiaplan, 2015

Some of the regions provide less than 10 m^2 green spaces per person (Poduene, Vazrazhdane, Sredets, Krasno selo, Krasna polyana).

The last parameter that is considered is the percent of trees that cover the park and garden areas within the building boundary of the city of Sofia. The input data involves the area covered by trees in the parks and gardens, digitized by using Sentinel-2A satellite images and calculated as a ratio from the total urban parks and gardens territory. The data is available at Sofiaplan. This comes to show the texture of the green areas and give an idea of the ecosystem services they could provide.

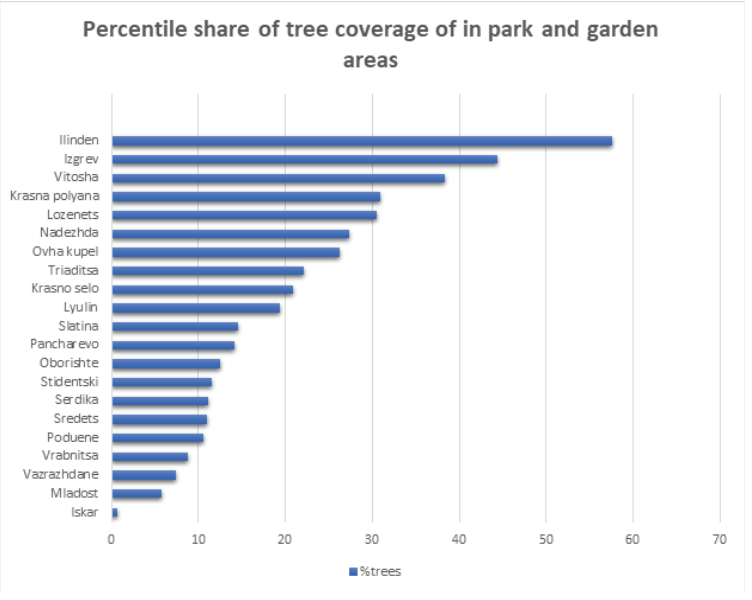

Figure 7. Percentile share of tree coverage in park and garden areas, %.
Source of input data: Sofiaplan, 2015

Mladost, which is one of the regions well-covered with parks, is poor in trees – only 5% coverage. There are regions with low share of parks and low share of trees in them, like Vazrazhdane and Vrabnitsa. The overall trend shows low share of trees in the central urban parts – Slatina, Serdika, Poduene, Oborsihte, Sredets, which is mainly due to the dense construction.

Discussion

Urban parks and open green spaces are of strategic importance for the quality of life of our increasingly urbanized society (Kovachev, 2012). The center of Sofia's has a distinct green identity due to its public parks, gardens and tree-lined streets. (Gehl, 2017). The vision that the Green city action plan (EBRD, 2020) sets before Sofia Municipality is to achieve visible, tangible improvements with opportunities to turn parts

of its urban areas into green oases, integrate green infrastructure throughout the city and create a city with spaces and space for all ages. Analyses are made to determine the accessibility, quality and possibilities for the green areas in the capital (Sofia Program, 2021, The green city Action Plan, 2020). Gehl Report (2017) suggests strengthening that impression through a network linking green pockets and public gardens and additional greening and also better distribution and maintenance of existing trees as well as strengthening the connection between the big parks bordering the center and the city gardens. An initiative for the green ring of Sofia – a linear park that forms a green highway which connects the central and peripheral neighborhoods, large parks, and gardens, as well as many cultural and sports sites has started. Sarafova (2021) uses remote sensing data to analyze the NDVI and calculate the amount of green vegetation per capita. The analysis shows large differences within the study area in terms of the area of green vegetation that is available in different parts of the city.

The present research confirmed and demonstrated the spatial deficiencies in green spaces. The coverage with urban green spaces in some regions is very poor and it does not correspond to national and worldwide standards of green space per individual (Russo and Cirella, 2018). The central urban zones are well-covered with parks and gardens, but the analysis shows these are the only green areas in this territory – there is a lack of inter-block green spaces and open green territories. There is also the opposite example – regions with good coverage of green open spaces that have almost no parks and gardens. Another case that needs attention is the regions with good coverage of parks and green spaces, but the lack of tree coverage. Urban trees provide positive contributions to cities and people in many ways - aesthetical, ecological, psychological, economic, scientific, educational (Tugluer and Mert, 2021). Trees also have their specific role in regulating urban heat islands, as vegetation barriers in urban canyons, air quality and connectivity for nature, providing and linking habitats for plants and animals and thereby increasing biodiversity (Ferranti et al., 2019). There are regions in Sofia city that seem green in proportion to green spaces, but have less than 5% trees, like Mladost, for example. Therefore, this important issue should not be neglected in green infrastructure planning. The research confirmed that the disproportion in the spatial arrangement of green spaces is of different character and needs to be addressed in a different manner. The planning and management of the city needs to respond to new challenges and adopt new policies in order to keep the balance of nature within the city and provide a vital, healthy and attractive environment for the capital's residents. The determined minimums for the urban area per person by the World Health Organization conclude that, at a societal level, urban dwellers are happier and healthier when those minimums are exceeded. (Russo and Cirella, 2018).

Conclusion

The distribution of green spaces within the building boundary of Sofia city by administrative regions is disproportional. There are green regions like Krasna polyana and Lozenets where the parks cover about 40% of the territory and there are also open

green spaces. The urban parks are well incorporated in the regions of the city-center, but there is a lack of other types of green spaces. Nadezhda and Lyulin are outliers with minimal coverage with parks, but plenty of open green spaces. The territory of Mladost includes 24% parks %) but only 5% of them are covered with tree vegetation. Sredets, Vazrazhdane and Poduene provide very low green areas per person - only 4 m^2/person, while the minimum is 9 m^2/person according to the international standards. Krasna polyana is covered with the most gardens and parks but provides only 8 m^2 of green areas per person. These territories are identified with the most outstanding deficiency in terms of quantity of green spaces. The findings could be supplemented with qualitative analysis of green spaces downsized to quarters. Green infrastructure contributes to the quality of life, health and wellbeing of individuals and communities, flood resilient towns and cities, and places where nature can flourish and be more viable as a result of development (Jerome et al., 2019). Knowledge on qualitative and quantitative aspects of the green system and the distribution of deficiencies is a prerequisite for taking the scientific-based decisions in urban planning and for sustainable territorial development of Sofia.

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