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DOI: 10.2478/ahr-2022-0005
Acta hort regiotec, 25, 2022(1): 37–43

Research Article

Green infrastructure in Lviv – example of park zones

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Article Details: Received: 2021-12-09 | Accepted: 2022-01-21 | Available online: 2022-05-31

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The combination of negative effects of urbanization and climate change in large cities poses a real threat to environmental, economic, and social stability in the world. The intensification of climate change and the analysis of its negative effects in cities show that climate change causes special threats in cities that are not specific to other types of human settlements. Assessing the vulnerability of urban ecosystems to climate change and planning measures to adapt cities to climate challenges is an important element of spatial infrastructure planning. The goal was to analyze the green infrastructure spatial arrangements on the example of green zones in Lviv. According to the results of field research and analysis of cadastral data, it was determined that most of the green areas are in the municipal property of the city, the only exceptions are the sites of the nature reserve fund of national importance. The total area of parks and squares of the city is more than 1,069 ha, of which 24% are areas of nature reserve. The provision of the urban population with public green spaces is about 14.82 m^2.$person^{-1}$. The green infrastructure is based mainly on objects – cores (e.g. parks and squares). There is also a reserve in the city to expand the boundaries of green areas. The combination of "cores" with green corridors and the use of point objects of green infrastructure will contribute to the continuity of the green spaces network, which in turn will provide more environmental and socio-economic benefits for the population.

Keywords: green infrastructure, parks, nature reserve fund, greening

1 Introduction

Landscaping is an integral part of sanitation and spatial planning. In large cities (population over 700,000), proper landscaping is a problem due to continuous construction, which occurs with violation of relevant requirements and reduction of urban green areas, due to the expansion of the road network. Other problems are old trees in cities, improper structure of green areas, and outdated approaches to green areas planning and management. The main governing documents for urban green areas management are the Law of Ukraine "On Settlement Improvement" (Verkhovna Rada of Ukraine, 2005), DBN (State Norms for Constructions) B.2.2-12 "Planning and Development of Territories" (Ministry of Regional Development, Construction and Housing of Ukraine, 2019) which replaced DBN 360-92 (State Committee of Ukraine for Urban Planning and Architecture,1992) and also DSTU-N (State Standard of Ukraine) B B.1-1-12 "Guidelines on the structure and content of the zoning plan." (Ministry of Regional Development, Construction and Housing and Communal Economy of Ukraine, 2011). Management of green areas in cities is usually carried out by specialized municipal company working under city councils. In turn, at the legislative level a document "Instructions on technical inventory of green areas in cities and towns of Ukraine" (State Committee of Construction, Architecture and Housing Policy of Ukraine, 2001) was approved for the inventory of green areas, however in most cases the inventory data are no opened for public, i.e. the local population cannot participate and influence on the decision-making process on sanitary felling of trees, landscaping of urban zones, etc. In other cases, the inventory is carried out either according to approved local rules, technical regulations or even not performed at all.

Issues of landscaping in UA cities were studied in (Tsaryk & Poznijak, 2016; Nazaruk & Zhuk, 2013; Stolberh, 2000; Kucheriavyi, 2005). An overview of the development of green infrastructure projects, landscape and environmental planning was performed and results are

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demonstrated in previous works (Klieshch & Maksymenko, 2020; Maksymenko et al., 2021b; Maksymenko et al., 2021c). Some effects of green areas of the city on the natural components of the environment were studied in (Maksymenko et al., 2021a; Maksymenko & Burchenko, 2019; Maksymenko et al., 2021d; Shpakivska, 2001).

Historically, the idea of green infrastructure (GI) planning or an ongoing network of green spaces is not a new one. At the beginning of the 19th century, Frederick Low Olmsted proposed a landscape-architectural concept that combines systems of parks and green corridors, which was more comprehended than isolated greenery and had more benefits. Edward T. McMahon (Benedict & McMahon, 2006) proposed one of the first definitions of green infrastructure as an interconnected network of protected lands and waters that supports local species, natural ecological processes, air and water resources, and promotes human health and quality of life. In 1995, the European Commission provided definition, which is currently the most acceptable in Ukraine, including in view of the Association Agreement between Ukraine and EU (Verkhovna Rada of Ukraine, 2014). According to the EC (European Commission, 2013) "green infrastructure is a strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services. It incorporates green spaces (or blue if aquatic ecosystems are concerned) and other physical features in terrestrial (including coastal) and marine areas. On land, GI is present in rural and urban settings". List of ecosystem services includes water treatment, air quality, recreation and climate change mitigation and adaptation. It should be noted that in our opinion it is advisable to separate approaches to the organization and development of green infrastructure of urban systems and rural areas, as land use has different characteristics – a higher percentage of agricultural land use, nature reserves, recreational areas (sanatoriums, health resorts, etc.). However, urban areas together with rural ones should form a single, mostly continuous ecological network.

2 Material and methods

Lviv has a very long history of green areas traditions. Hundreds of calm green streets, dozens of squares, boulevards; there are about 30 parks in each city district, the total area of green zones is about 1,000 ha, or about 15 m^2.$person^{-1}$, these figures do not include various types of forest-parks and expansion of agglomeration boundaries (Resolution of the Lviv City Council, 2018). The rich, diverse and ancient heritage of gardens and parks is a direct merit of the great gardeners living in the XIX century. The most prominent of them is the inspector of Lviv city plantations Arnold Röhring. He arranged the most of Lviv's parks and squares: Striyskyi Park, Park "Zalizna Voda", Lychakiv Park, boulevards on Shevchenko and Svobody avenues, green area on the St. Yura Square (St. George Square), tree areas on Halytska and Soborna Squares, the park in Kulpark, the lower terrace of the High Castle Park with a gardener's house, arboretum of the National Forestry University located on O. Kobylyanska Street, Resort Park in Bryukhovychi and dozens of gardens.

The researches were carried out through field trips, communication with stakeholders, cartographic study, including open cadastral register data, analysis of historical approaches to green infrastructure management.

3 Results and discussion

A feature of the organization and development of GI in Lviv is the large number of parks, which belong to the nature reserve fund and cover an area of 654.57 he. At the same time, they form a network with other green areas for general use, as well as smaller GI objects with limited and special use, such as linear plantings along roads, green roofs, green walls, and rain gardens.

The area of green spaces is about 15 m^2.$person^{-1}$, which is much higher than existing standards 10 m^2.$person^{-1}$ (Ministry of Regional Development, Construction and Housing of Ukraine, 2019). Also, there is a natural reserve of about 100 ha, which is very promising for landscaping.

An example is the inclusion of a land plot of about 1 hectare to the territory of Park "Zalizna Voda" – the park site of landscape art having local significance (Fig. 1). The restored area will be a community garden, which is one of the types of GI. This was an initiative of NGOs

Figure 1 Park "Zalizna Voda" (area for restoration is marked by black colour)

Figure 2 Landscape of the park «Zalizna Voda»

Permaculture, EkoTerra and PLATO to arrange the public space of the City Gardening "Röhring's Greenhouses" with the consent of the city administration. Previously, a large greenhouse area was located in this area, which is still in an abandoned state. This area is intended for the preservation and use of parks, monuments of landscape art and for the maintenance of the Park "Zalizna Voda".

The territory of Park "Zalizna Voda" has an area of 19.50 ha. There was no re-planning of the natural landscape in the park (Fig. 2); currently works are on-going for the arrangement of pedestrian zones and preservation of forest systems, the formation of a system of surface runoff.

Next to the Park "Zalizna Voda" there is a park-monument of landscape art with local significance named "Snopkivskyi Park". The area is 47.6 ha, the territory of the park is subordinated to the Lviv Municipal Company "Green Lviv" and is in the municipal property of the city. The problem with these two parks is the lack of a natural system of connectivity between them. Park areas are separated with a highway with a tram track, which contradicts the idea of continuity of green infrastructure.

Stryiskyi Park is a central park classified as the city's national landscape art park. It can be considered as an analogue of the Gorky Central Park in Kharkiv. The area of the park is 56 ha and it is a separate legal entity.

Regional Landscape Park "Znesinnya" of local significance is also located in Lviv. The area is 312.1 ha and it is subordinated to the Lviv City Council. It is one of the first parks of this type in Ukraine, established within the city, and one of the few that emerged through a public initiative (as a result of the struggle to preserve the old cemetery). Its territory is divided into the following zones: protected, regulated recreation, stationary recreation, and economic zones. One of the most interesting objects in the park is the historical and cultural open-air museum "Shevchenkivskyi Gai" that is located on the territory of the Klimentyi Sheptytskyi Museum of Folk Architecture and Life. In addition, there is an Information and Education Center on the territory of "Znesinnya".

The park of the Holy Pope John Paul II was called the Forest Park "Zubra" in the past. Park "Zubra" or "Zubrivskyi Forest" was renamed in 2011. Behind the forest in the tract there was Lake "Pioneer", but in 1982 due to industrial pollution the lake was lowered. In 2019, the first eco-trail "Zelena Stezhka Sykhova" (Fig. 3) was opened in Lviv, which runs through the park, and it has many information boards telling about the biota of the park and environmental issues. The Park does not belong to the nature reserve fund; the area is 97.90 ha. One of the features is that the park, namely forest part, is closely located with the site of the Armed Forces of Ukraine.

Ivan Franko Park is a park-monument of landscape art of local significance; it is subordinated to the Lviv Municipal Company "Green Lviv" and its area is 10.6 he. This is the oldest park in Lviv and Ukraine, one of the oldest municipal parks in Europe. Four hundred years ago, the Ivan Franko Park was replaced by urban fields, but later the land passed into private hands. At the end of the 16th century, a rich Lviv burgher, Jan Scholz-Wolfowicz, established a park here. Over time, the park was rebuilt by the owners in the Italian style, redesigned for the entertainment of the local population. In 1855, the park became the property of the city again, thus becoming one of the oldest municipal parks in Europe. The famous Lviv gardener Bauer undertook its arrangement. He reconstructed the park in the English landscape style. At the same time, almost all the old trees were cut down and most of the trees we have today were planted.

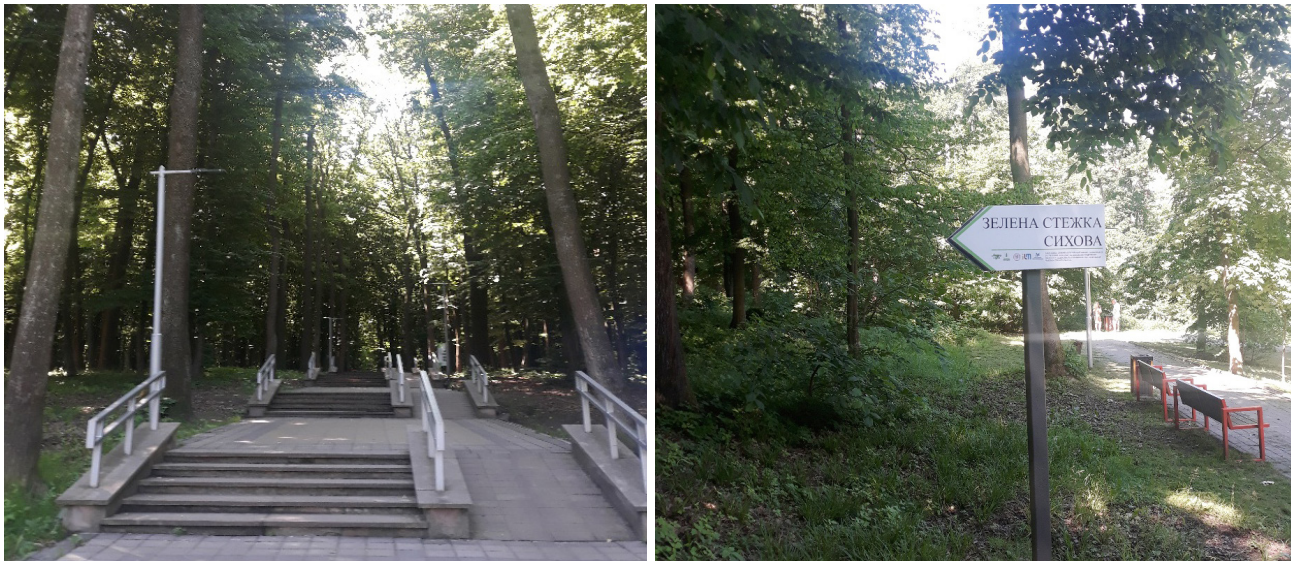

Figure 3 The Park of the Holy Pope John Paul II. Start of the eco-trail "Zelena Stezhka Sykhova"

The High Castle Park was founded in 1835. It got its name from the fortress, the remains of which have been preserved on the territory. The area of the park is 35.38 ha; it is subordinated to the Lviv Municipal Company "Green Lviv". The structure of the park is focused on the landscape park model. It has lower and upper terraces. In the 1950s, the Lviv TV tower was built on the upper terrace and the TV center building was constructed next to it. These objects somewhat disturb the historical and cultural landscape of the area.

Park-monument of landscape art of local significance B. Khmelnytskyi Park of Culture and Recreation is located near Striyskyi Park, from which it is separated by a highway and has an area of 26 ha. It is subordinated to its own directorate. The park was founded in 1951.

"Forest Park Pohulyanka" – botanical monument of local significance – is subordinated to the Lviv Municipal Company "Green Lviv" and its area is 100.33 ha. The park is located in the southeastern part of Lviv, in the valley of the Pasika stream and in the surrounding hills. The Pasika stream merges in an underground collector with the Soroka stream and gives rise to the Poltva river. Pohulyanka hills form a part of the Lviv upland.

City Park "Pohulyanka" was established in 1940. At that time, work began on clearing and arranging the territory of the park area, and reservoirs appeared along the main line. The compositional axis of the forest park is the central alley, along which artificial ponds are arranged. This alley goes through the valley, which divides the park into two parts – northeast and southwest ones. The slopes of the park hills are paved with walking routes, inscribed in relief. Trails can be walked around the perimeter of the park, to the observation decks and several entrances located on different sides of the "Pohulyanka".

Lychakiv Park, a park-monument of landscape art of local significance – is subordinated to the Lviv Municipal Company "Green Lviv" and its area is 8.8 ha. It is a small city park on the heights of the north-eastern district of Lviv. By the nature of the composition it belongs to the landscape parks. It was created in 1892 according to the project of the outstanding master of Lviv garden and park architecture Arnold Röhring. A feature of the stand in Lychakiv Park is the dominance of black pine. There are also maples, lindens, chestnuts, there are several species of shrubs (Zhuk, 2012).

The geological natural monument of local significance "Kortumova Gora" is subordinated to the Lviv Municipal Company "Green Lviv" and has an area of 21.4 ha. The park is located in the northwest of Lviv, on the slopes of the mountain of the same name, which is part of the tract of Roztocze hills. From the highest point of Lviv (Castle Hill), Kortum Mountain is separated by the valley of the Poltva River. Currently, part of the territory is occupied by a penitentiary institution. The territory of the historical park is in an abandoned state, although it continues to attract local people by panoramas of its unique landscapes. Kortumova Mountain is separated from the territory of the Bryukhovytsia Forest Park by railway tracks. The park is a place where scientists finds fossil flora, which are important for the reproduction of the geological history of the Central Europe. The green zone of Kortumivka is formed by plantings of maple, ash, birch, black alder, chestnut, pine and other trees.

Park "Na Valakh" is the second oldest park in Lviv. It is a park-monument of landscape art. The total area is 2.32 ha.

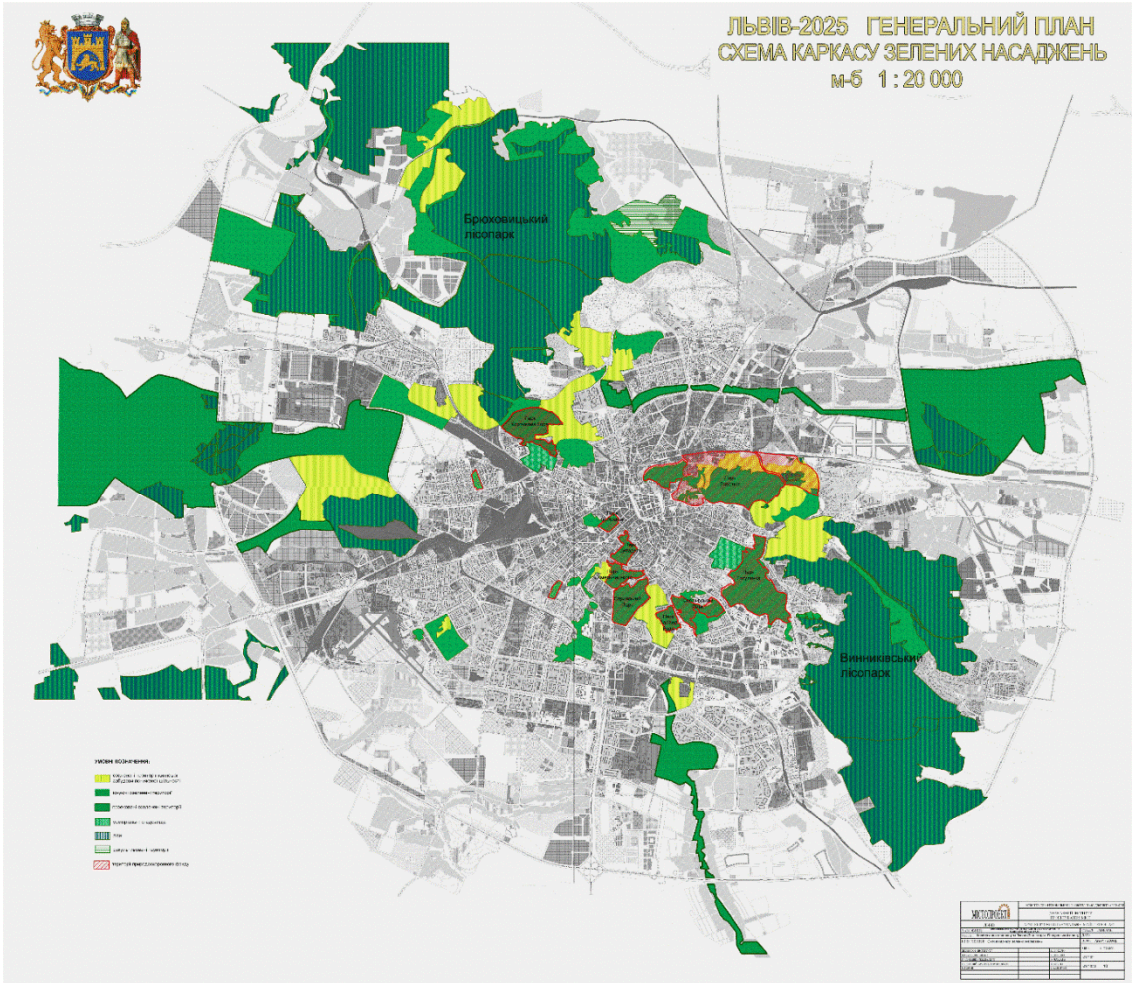

Figure 4 Green areas in Lviv (as from Master Plan for Lviv)

Sknylivskyi Park was established in 1974 and is intended for recreational purposes. The area of the park is 38.46 ha. The park was created in a landscape style on a plain that belongs to the Lviv Plateau and is currently in an abandoned state.

A highway passes through the Ivan Vyhovskyi Park. It was created to preserve and use the lands of the nature reserve fund, as the park is home to botanical monuments of nature. The area of the park is 5.18 ha.

Lewandowski Park is subordinated to the Lviv Municipal Company "Green Lviv" and has a purpose to preserve and use the lands of the nature reserve fund. The area of the park is 5.89 ha.

In addition to the above green areas, in the city under the authority of Lviv Municipal Company "Green Lviv" are (Lviv City Council, 2021):

- the green zone of Mayorivka, which is planned to be included to the geological natural monument of local significance "Medova Pechera", the area of which is currently 1.2 ha;
- Students' Park, area – 6.15 ha;
- Park "Piskovi Ozera", area – 5.9 ha;
- Park "Zamarstynivskyi", area – 32.58 ha;
- Park "The 700th anniversary of Lviv", area – 20.21 ha;
- Park "Gorikhovyi Gai", area – 40.61 ha.

The city's green spaces, which are parts of the nature reserve fund of national importance, are also the territory of botanical gardens – the Botanical garden of Ivan Franko National University of Lviv (area – 18.5 he) and the Botanical garden of National Forestry University of Ukraine (area – 22.7 he).

For each city district there is a position of a gardener, he/she reports to the Department of Ecology and the Natural Resources of the Lviv City Council.

The Master Plan of the Lviv City Council (Lviv City Council, 2006) also contains a scheme of landscaping for Lviv (Fig. 4).

The scheme of green sites of the city also includes green areas (in particular, forests) of the adjacent, suburban areas. Yellow colour indicates green areas of low-density

housing, which also form a network of green areas, but are not public and do not meet the needs of recreation. The objects of the nature reserve fund are highlighted in red. As of 2021, 24 parks, i.e. 70% of city parks, have established and demarcated boundaries that protect them from construction works.

The forest park part of the green zone of the city, which is subordinated to the Lviv Forest Park Company of the State Forestry Association "Lvivlis", occupies 28,867 ha. The area of forests within the city (Vynnykivske, Bryukhovytske, Zavadivske forestry) is 3,447 ha. That is, the area of green spaces in Lviv of various categories is 33,286 ha, including 4,419 ha within the city, or almost 26% of the city area. In total, there are about 54 m^2 of urban green space per person in Lviv.

Generalized data on the park areas of the city of Lviv are presented in Table 1.

Table 1 Park zones in Lviv

No	Name	Area (he)	Nature reserve fund
1.	Park "Zalizna Voda"	19.50	yes
2.	Snopkivskyi Park	47.6	yes
3.	Stryiskyi Park	56.0	yes
4.	Regional Landscape Park "Znesinnya"	312.1	yes
5.	The park of the Holy Pope John Paul II	97.90	no
6.	Ivan Franko Park	10.60	yes
7.	The High Castle Park	35.38	yes
8.	B. Khmelnytskyi Park of Culture and Recreation	26.0	yes
9.	"Forest Park Pohulyanka"	100.33	yes
10.	Lychakiv Park	8.80	yes
11.	Kortumova Gora	21.4	yes
12.	Sknylivskyi Park	38.46	no
13.	Ivan Vyhovskyi Park	5.18	yes
14.	Park "Levandivskyi"	5.89	no
15.	Students' Park	6.15	no
16.	Park "Gorikhovyi Gai"	40.61	no
17.	Park "Na Valakh"	2.32	yes
18.	Park "Piskovi Ozera"	5.90	no
19	Park "Zamarstynivsky"	32.58	no
20.	Park "The 700th anniversary of Lviv"	20.21	no
21.	Park "Bodnarivka"	5.80	no
22.	Park "Levanddivske Ozero"	5.70	no
23.	Park "Mayorivka"	30.60	no
24.	Memorial site "Hill of Honor"	0.76	no
25.	Landscape reserve "Torphovische Biligoscha"	92.00	yes
26.	Botanical garden – Ivan Franko National University of Lviv	18.50	yes
27.	Botanical garden – National Forestry University of Ukraine	22.70	yes
Total		**1,068.97**	

Thus, the total area of the city's parks is 1,068.97 ha, and the largest object is the Regional Landscape Park "Znesinnya". At the same time, 24% of the city's parks belong to the objects of the nature reserve fund of Ukraine.

According to the obtained data, it is possible to calculate the provision of the urban population with public green spaces according to the formula (Kucheriavyi, 2005):

$$P_{pgs} = (S_p + S_{gs} + S_b)/N_p \quad (1)$$

where: P_{pgs} – rate of public plantings (m^2.person^{-1}); S_p – area of parks; S_{gs} – area of green sites; S_b – area of boulevards; N_p – number of population

Thus, norm for landscaping in Lviv is:

$$P_{pgs} = (1{,}068{,}970\ m^2)/721{,}301\ persons = 14.82\ m^2.person^{-1} \quad (2)$$

4 Conclusions

The green infrastructure of the city of Lviv is based mainly on objects – cores, there are city parks and squares – i.e. public facilities. They are mostly owned by the city.

However, for the proper park management, the establishment of dialogue with the local population, the Department of Ecology and Natural Resources has assigned a position of gardeners; each gardener is responsible for a specific administrative district of the city. Having such position give an option to contribute to the more widespread use of nature-oriented practices in city parks.

The volume of parks included in the nature reserve fund is 24%. The calculation of the provision of the urban population with public green spaces is 14.82 m^2.person^{-1}. This figure can be increased, as the city has a reserve for landscaping.

Acknowledgments

The publication was prepared in the framework of the International Visegrad Fund project "Green & blue infrastructure in post-USSR cities: exploring legacies and connecting to V4 experience". Responsibility for the information and views set out in this publication lies entirely with the authors.

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