Assessment of comfort potential and prospects for environmental development of cities in steppe Russia using the index method

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Abstract. The paper describes the results of comfort potential assessment and prospects for development of urbanized geosystems in steppe Russia on the basis of constructed geoinformation index assessing potential for development of environmental comfort (CDPI). The index was calculated on various areas for technogenic geosystems, and the total area was represented by individual functional structures. The index was constructed as the ratio of existing and planned natural-anthropogenic components to the areas suitable for the expansion of green zones. For the first time, cartographic models were built, showing the spatial differentiation of urbanized geosystems. Index values, obtained for the studied objects (Simferopol and Rostov-on-Don), differ depending on planning structure development and topography of anthropogenic landscape. The index comfort indicators for the studied cities of Simferopol and Rostov-on-Don were characterized mainly by negative values. The highest index values were associated with urban areas in redevelopments of floodplain and terrace complexes, and also with small areas dispersed across local draw terraces.

1. Introduction

In the geographical community, at the center of anthropogenic landscape studies, a question is raised about the essence of urban landscapes, in which, according to F. M. Milkov (1973) [1], we could see a restructuring of individual components of the landscape. Residential landscapes are a special class of anthropogenic landscapes, represented by “a set of complexes associated with human activity in any one branch of the national economy” [2]. Human transformation of the natural landscape for performing new socio-economic functions is usually accompanied by the appearance of new elements that radically change its natural component. F. V. Tarasov (1977) [3] defines the urban landscape as an anthropogenic geosystem with the features of technogenic cover. G. I. Martsinkevich and I. I. Schastnoy (2017) [4] use the term “urban landscape” as a natural and anthropogenic complex having a homogeneous natural basis and a certain type of urban-planning use. The authors emphasize the heterogeneity and fragmentation of urbanized space by functional zones, resulting in revealing smaller urban-planning complexes, where unique microclimatic features and geodynamic processes can be formed. The human being can only direct the natural component by changing the nature of development, types of cover, social and economic features of the urban environment development. The issues of comfort and prospects of urban development are in the focus of modern scientific research [5, 6, 7, 8, 9, 10, 11, 12, 13, 14]. Problems of urban spatial organization are directly related to the planning constraints and the correct environmental and functional zoning of area, which should be
based on the landscape-environmental principle. The main environmental requirement in urban planning design is the maximum preservation of natural landscape in conditions of intense anthropogenic load: reducing proclaimed areas by increasing the number of floors, creating underground parking spaces, additional roofs refit to accommodate sports and recreation areas, etc. [15].

In 2018, the urban population totaled about 55% of the global population, and this estimate is supposed to grow to about 68% by 2050 [16]. The city is a combination of artificial environment with elements of nature [17]. In world literature, numerous concepts are used to optimize urban planning, and also sustainable and integrated development using a landscape-geographical approach [18; 19; 20; 21; 22]. The city is a non-equilibrium system [23], and its state will depend on the degree of anthropogenic impact on the urban environment. Urbanized spaces are far from ecological balance of natural environment (i.e., balanced state and preservation of the area’s biodiversity). The densely built-up urban environment made of glass, concrete and asphalt has lost the ability to reproduce biological component and neutralize chemical pollutants. Anthropogenic load must be reduced through green suburban areas and recreational resource of the urban environment. It is possible to bring the urban environment closer to the state of ecological balance only by increasing the area of natural landscapes that, in steppe biome, should be planted with tree and shrub groups, as much as possible selected for local climate.

Green infrastructure [6] forms environmental framework of the city. Vegetation improves air quality, reduces noise, stabilizes the wind regime, increases humidity of urban air, and reduces erosion processes [15; 23]. Regulation of the urbanized environment quality and degree of anthropogenic impact depends on the population. Development of the green zone system in every city is determined by its planning project, which is designing for a certain period (in Russia, this period is 20-25 years). Then, a set of vegetation is selected and principle of its localization in the urban structure is being formed in accordance with geographical and climatic features. Distribution of plantings in urban areas should be uniform and mission-oriented (provision of residential areas, that differ in density, should be directly proportional to the number of people in these residential areas). The system of green spaces for general, limited and special purposes is an important element of city's infrastructure, a component of spatial planning and a factor in optimizing its ecological environment [24].

Complex geographical research is based on geoinformation methods for analyzing spatial and temporal information about geosystem and digital data of objects. Among existing classifications in geoinformatics, the top level is the conceptual model of reality representation [25]. Research into geoinformation mapping uses heterogeneous sources of digital data obtained from diversified sources and with different accuracy. Integrated digital data on the urban geosystem enabled to create a cartographic model describing the urban environment comfort potential. Assessment of population living comfort, both environmental and environmental-geographical (geo-environmental), focuses on the natural and landscape conditions that are important for residing the person (population) and its economic activity [26]. When considering environmental comfort, we analyzed cumulative conditions and their parameters (geomorphometric, landscape, and environmental). In the scientific world, attempts are being made to calculate integral indices based on environmental parameters [27, 28, 29].

2. Material and Methods
The objective of the work was to assess urban environment comfort development potential, based on the geoinformation index measuring the potential for development of urban environment comfort (CDPI), given the existing and future anthropogenic situation of cities (Rostov-on-Don and Simferopol). To solve this problem, the following task was implemented – we built integrated cartographic models based on calculation of CDPI index for urban areas in the Black Sea region. Main phases of assessing comfort potential and prospects for the environmental development of our studied objects included: calculation of landscape characteristics (geomorphometric parameters processed using automated classification by the nonparametric neural network algorithm (artificial neural networks, or ANN) based on T. Kohonen’s self-organizing maps [30] in the software package ScanEx
An algorithm for estimating urban environment comfort development potential, subject to current and prospective anthropogenic situation in Simferopol and Rostov-on-Don, is based on the general area of studied technogenic objects:

\[ S_{gs} = S_{ra} + S_{pb} + S_{ind} + S_{tr} + S_{sp} + S_{pd}, \]

where \( S \) – area of: \( S_{ra} \) – residential zones; \( S_{pb} \) – public and business development; \( S_{ind} \) – zones for industrial use; \( S_{tr} \) – transport infrastructure; \( S_{sp} \) – special purpose land; \( S_{pd} \) – potential development neighborhoods, including those listed in the renovation program.

The geoinformation index for measuring urban environment comfort development potential (CDPI) is calculated using the following formula:

\[ CDPI = \frac{S_{ls} - S_{gs}}{S_{ls} + S_{gs}}, \]

where \( S_{ls} \) – area of a landscape structure unit.

The calculated CDPI index values are aimed at identifying areas where it is possible to implement environmental activities for increasing green infrastructure area in urban space. Index values take both positive and negative values and, therefore, enable to define the potential for environmental development within a single type of landscape. Positive values, close to one, indicate a high potential for development of recreational areas and a low degree of anthropogenic load on the total technogenic landscapes. An important value in calculating the CDPI is the green space area (\( S_g \)), since its function under conditions of anthropogenic pressure is among the leading ones in the urban landscape. Suburban and inner-city green landscaping systems contribute to comfortable living conditions for the population, environment improvement and health of natural components to enhance the appearance of urbanized space. The results obtained on the basis of different types of geoinformation data allow us to identify and differentiate landscape units where it is necessary to implement complex measures and improve architectural and planning situation. These measures are required when CDPI is +0.5 or more. Calculation algorithm identifies areas of urban space where it is impossible (or minimally possible) to plan landscaping works due to high level of anthropogenic load within the selected landscape unit. Values that fall into low positive values from 0 to -0.5 are relatively suitable for urban landscape improvement. These include built-up neighborhoods with natural elements (parks, squares, botanical gardens) and suburban and urban garden plots owned by city residents.

3. Results and Discussion

The obtained index results, subject to regional characteristics of the area, reflect the nature of prospective environmental development of cities in steppe biome of Russia. The first object of our study is Simferopol, which is characterized mainly by negative CDPI values (figure 1). The city topography features pronounced deep extended gullies in combination with valleys and high points. The model of spatial structure is polycentric. Simferopol is located in the central part of the Crimean Peninsula, at the junction of the Mountainous and Outer Crimea. The main landforms of the urban district are the Inner and Outer ridges of the Foothills, the longitudinal depression between them and the transverse valley of the Salgir River. According to the physical and geographical zoning, Simferopol belongs to the Crimean-Caucasian karst country, Simferopol karst district, Foothill-Crimean karst area. The Salgir River Valley divides the urban area into the eastern (low) and western (high) sections. The maximum height within city limits is 325 m, so called Petrovskaya height. The south-east portion is characterized by a complex terrain (elevation difference up to 150 m), and the north-east one is a relatively flat surface with minor elevations in the west direction. Terrain features are thalwegs in areas of the Salgir river valley and steep slopes. The river itself is a linear object and component of the environmental framework of the city. There are four karst sections, corresponding to the key landforms of the area, and 12 karst caves. According to Simferopol General Plan technical and
economic parameters, the recreational zone area is 869 hectares, or 25.04 m² per one resident. The main area of green space in the city falls on the area adjacent to the Salgir River.

The main potential for expanding and improving the state of green areas relates to the objects found in accumulative complex of the Salgir River floodplain (CDPI= +0.2). The highest index values are associated with eastern exposure slope of Kurtsy gully and with the Salgir River valley slope heavily affected by mineral development activity (Lozovoe building-stone quarry), near the Simferopol reservoir (CDPI between +0.5 and +0.6). The remaining urban landscapes are characterized by a low potential for comfort development (CDPI<0) as a result of a high level of urban development activity. Location of Simferopol in the intermountain basin makes it impossible for watercourses to shape wide river valleys, and therefore makes significant restrictions for providing green spaces in future. These areas are subject to a high risk of natural emergencies, which prevents them from urban development activities and using as recreational zones.

The second object of our study is Rostov-on-Don, which is characterized mainly by negative CDPI values (figure 2). The city relief formation occur within floodplain of the Don River (the municipality southern boundary) and its right tributaries Temernik and Kiziterinka. The model of the spatial structure is ring-radial or rectangular. Intensive differentiation of the area can be found in the Temernik River valley, with five gullies located here. In the city limits of the Don River valley, a

\[ \text{Figure 1. Schematic map showing CDPI index calculation results in Simferopol urban system.} \]

\[ \text{Numbers on map indicate terrain types: 1 – accumulative (above-floodplain complex of the Salgir river), 2 – accumulative (terrace complex of the Salgir river), 3 – erosive and denudative (subhorizontal near-watershed slopes of river valleys), 4 – erosive and denudative (subhorizontal gully slopes), 5 – watershed (flat surface of the Outer ridge in the Crimean Mountains).} \]
number of gullies also stand out. As a result of anthropogenic impact, valleys of the city gullies have been significantly changed: they were filled in, built up, sewers, ponds and dams were constructed here, terracing was made, and they were occupied by garden plots. The main landforms according to geomorphometric data are the Pontic plateau (height 80-110 m), the Pliocene (Khaprovskaya) terrace (elevations between 25-55 m and 60-80 m, width between 3 and 6.7 km), three above-floodplain terraces and floodplain of the Temernik River, left-bank floodplain section of the Lower Don. According to approved Rostov-on-Don General Plan for 2007-2025, provision with green inner-city plantings for recreational purposes is 26.3 m² per 1 resident.  

Modern compact planning structure and the use of landscape structures in the city of Rostov-on-Don are influenced by historically formed diverse settlement system. Floodplain landscapes located in the western part of the city are quite complementary to creating green spaces. The low-sloping flat territory of Rostov-on-Don creates favorable conditions to form floodplain and terrace complexes. Accumulative type of the Don River topography (CDPI between 0 and +0.5) and the Dead Donets River topography (CDPI between +0.3 and +0.4) are promising areas for additional green landscaping. They also include sections of the first and second terraces of the above-floodplain complex on the right bank of the Don River (CDPI between +0.2 and +0.3). The Temernik River floodplain, designated in the General Plan as a transformation zone for multifunctional housing development with a high degree of green landscaping through replanning (at the confluence of the Temernik and Kamyshchevaka rivers), has CDPI values ranging between +0.1 and +0.2. A portion of the Don River left-bank floodplain, between the main riverbed and irrigation canal, and an area between the Don
River and the Dead Donets River are difficult to access for city residents due to low transport accessibility and high density of land reclamation hydraulic structures. All areas that are promising for landscaping are already included in development projects, with the exception of landscapes most distant from the centers of agglomerations. Local gully terrace and gully slope of the north-eastern exposure of the Shchepkin gully have high index values (CDPI between +0.5 and +0.6) compared to the entire city territory. Index values for a portion of the flat watershed surface of the Pontic plateau range between +0.4 and +0.5.

4. Conclusion
A tool for assessing quality of the urban environment and conditions for its formation in Russia is the Urban Environment Quality Index. This index uses assessment of six types of urban spaces (six criteria based on 36 indicators). According to this index assessing 1,115 cities with possible 360 points, our study cities had the following points in 2019: Simferopol (160 points, including 22 points for green spaces) and Rostov-on-Don (193 points, including 36 points for green spaces).

Urban landscapes of Rostov-on-Don and Simferopol are characterized by extremely low values of the index assessing potential for development of environmental comfort. This is due to extremely high degree of command-and-control functions in relation to territorial planning and fully historically formed settlement system. Among other reasons for negative values of the geo-information index assessing potential for development of environmental comfort may be high density and compactness of the planning structure. Because they define the necessity of the rational use of urban landscapes in modern urban development and rational approach to reshaping of functional features of urban objects in favor of green space.

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References
[1] Milkov F N 1973 Man and landscapes: Essays of anthropogenic landscape studies (Moscow: Mysl publ.) p 224
[2] Gorbunov R V and Tabunschik V A 2020 On defining urban landscapes Geopolitics and Ecogeodynamics of Regions vol 6(16) Issue 2 pp 97-126
[3] Tarasov F V 1977 Urban landscapes Issues of Geography vol 106 pp 58-64
[4] Martsinkevich G I and Schastnaya I I 2017 Patterns and trends in formation of multifunctional structure of urban landscapes in Belarus Journal. Belarusian State University. Geography. Geology 1 pp 99-108
[5] Vladimirov V V 1986 City and landscape (Moscow: Mysl publ.) p 238
[6] Podoyntisyna D S 2016 Critical analysis of the concept “Green infrastructure” Architecture and Modern Information Technologies 1(34) pp 1-8
[7] Morozova G Yu and Debelaya I D 2018 Analysis of green landscaping problems of a modern city (a case study of Khabarovsk) Vestnic of the Far Eastern Branch of the Russian Academy of Sciences 4 pp 38-48 doi: 10.17059/2018-2-18
[8] Abass K et al 2020 Urban sprawl and green space depletion: Implications for flood incidence in Kumasi, Ghana International Journal of Disaster Risk Reduction vol 51 101915 doi: 10.1016/j.ijdrr.2020.101915
[9] Bakar N I A, Mansor M and Harun N Z 2014 Vertical Greenery System as Public Art? Possibilities and challenges in Malaysian urban context Procedia - Social and Behavioral Sciences vol 153 pp 230-241 doi: 10.1016/j.sbspro.2014.10.057
[10] Cameron R W F, Blanuša T, Taylor J E, Salisbury A, Halstead A J, Henricot B, Thompson K 2012 The domestic garden – Its contribution to urban green infrastructure Urban Forestry & Urban Greening vol 11 pp 129-137 doi:10.1016/j.ufug.2012.01.002
[11] Nasir R A, Ahmad S Sh, Zain-Ahmed A and Norhati I 2015 Adapting Human Comfort in an
Urban Area: The role of tree shades towards urban regeneration Procedia - Social and Behavioral Sciences vol 170 pp 369-380 doi: 10.1016/j.sbspro.2015.01.047

[12] Grimmond C S B et al 2010 Climate and More Sustainable Cities: Climate Information for Improved Planning and Management of Cities (Producers/Capabilities Perspective) Procedia Environmental Sciences vol 1 pp 247-274 doi:10.1016/j.proenv.2010.09.016

[13] Tian Yu, Jim C Y and Wang H 2014 Assessing the landscape and ecological quality of urban green spaces in a compact city Landscape and Urban Planning vol 121 pp 97-108 doi: 10.1016/j.landurbplan.2013.10.001

[14] El Din H S, Shalaby A, Farouh H E and Elariane S A 2013 Principles of urban quality of life for a neighborhood HBRC Journal vol 9(1) pp 86-92 doi:10.1016/j.hbrcj.2013.02.007

[15] Khomich V A 2002 Ecology of the urban environment: educational aid for universities (Omsk: SibADI Publishing House) p 267

[16] World Urbanization Prospects 2018 (New York: United Nations) https://population.un.org/wup/

[17] Lunz L B 1974 Urban green construction: a study guide (Moscow: Stroyizdat publ.) p 275

[18] Barmin A N and Nikulina E M 2011 The role of landscape-geographical approach in construction of environmental framework of cities Geology, geography and global energy 4 pp 168-174

[19] Neirotti P, De Marco A, Cagliano A C, Mangano G, and Scorrano F 2014 Current trends in Smart City initiatives: Some stylised facts Cities vol 38 pp 25-36 doi: 10.1016/j.cities.2013.12.010

[20] Leźnicki M and Lewandowska A 2014 Implementation of sustainable development on the example of the concept of eco-city Ecological Questions 19 pp 91-96. doi: 10.2478/ecoq-2014-0010

[21] Egger S 2006 Determining a sustainable city model Environmental Modelling & Software 21(9) pp 1235-1246. doi: 10.1016/j.envsoft.2005.04.012

[22] Mouratidis K 2019 Compact city, urban sprawl, and subjective well-being Cities 92 pp 261-272 doi: 10.1016/j.cities.2019.04.013

[23] Armand D L 1975 The science of landscape (Fundamentals and Logical-mathematical methods ed Leonov V V (Moscow: Mysl publ.) p 288

[24] Klimanova O A, Kolbowski E Yu and Kurbanovsky A V 2016 Geo-environmental functional assessment of green infrastructure in Canada Geography and natural resources 2 pp 191-200

[25] Lurie I K 2008 Geoinformational mapping. Methods of geoinformatics and digital processing of satellite images: tutorial (Moscow: KDU publ.) p 423

[26] Antipova A V and Kochurov B I 1999 Scientific school with focus on assessment and mapping of environmental situations Issues of Regional Ecology 3 pp 60-75

[27] Living planet report 2002 (ed. Jonathan L World Wild Fund: Gland) p 35

[28] Tikunov V S and Chereshnya O Yu 2017 Indices of pollution and environmental stress in regions of the Russian Federation Theoretical and Applied Ecology 3 pp 34-38

[29] Jia Y, Tang L, Xu M and Yang X 2019 Landscape pattern indices for evaluating urban spatial morphology – A case study of Chinese cities Ecological Indicators vol 99 pp 27-37 doi: 10.1016/j.ecolind.2018.12.007

[30] Kohonen T Essentials of the self-organizing map Neural networks 2013 vol 37 pp 52-65 doi: 10.1016/j.neunet.2012.09.018