

Green spaces system analysis and assessment of plantings' ecological state in Minsk city applying geoinformation technologies

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Abstract. The article presents the results of public green spaces system of Minsk city exploration and assessment of their plantings' ecological state, implemented with applying geoinformation technologies. To conduct the study, the information about spatial distribution features of green spaces system parameters, urban planning indicators and the ecological state of atmospheric air was selected and ranked (groups 1-9). Using this data set, in ArcGIS program with its additional Spatial Analyst module territory modeling was implemented and an original assessment map of Minsk city, which shows various favorability degrees areas (6-1) for green spaces system organization, was created. It was revealed that the sites of the lowest favorability degree (1) are concentrated in the southwestern part of the city (Oktyabrsky, Moskovsky, Frunzensky administrative districts). On their territory the ecological condition monitoring of public green spaces was carried out. Within green areas boundaries 74 field areas were laid on which 2220 trees were examined. The assessment of plantings was conducted in stages: an individual assessment of trees based on a set of dendrometric indicators, calculation of tree stands condition indexes, identification of public green spaces ecological state category. The completed assessment became the basis for measures proposal to optimize the green spaces system.

1 Introduction

In the 20th and 21st centuries, urbanization became one of the most significant trends creating for the majority of the planet's population their residence areas. Currently, urban residents account for about 55% of the global population, while urbanized spaces occupy only 3% of the total land surface area [1]. Meanwhile, 60% of citizens, or a third of the world's population, live in the largest settlements – megapolises. It becomes obvious that such a high concentration of people within such small area cannot but lead to various environmental transformations and the emergence of a completely new complex, combining both natural and anthropogenic features. The high concentration of industrial facilities and transport in cities, along with artificial surfaces abundance, not only create an unfavorable environmental situation, but also decrease the recreational and aesthetic

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potential of the territory. All these factors have a noticeable negative impact on the quality of the urban population life, especially on residents' physical and even mental health.

The most available and effective approach that can be used to fix the current situation is the creation of an optimal urban green spaces system. Moreover, the advantage of using green areas consists in their complex impact on the urban environment, i.e. the ability to optimize its condition indicators through many different functions: from sanitary-hygienic to decorative and recreational [2]. Such vegetation cover multifunctionality leads to the need for a detailed study of the existing green spaces system located in a large city in order to identify their distribution problems and further careful assessment of their ecological condition, necessary to create an appropriate living place for the population.

2 Materials and methods

In order to identify areas in acute need of optimizing the current green spaces system, the territory of Minsk, the largest urbanized area within the Republic of Belarus, serves as the main research object. The city with an area of 348.85 km² and a population of about 2 million people is divided into 9 administrative districts [3]. Such settlement size has led to a high concentration of industrial facilities, mainly located in the western, southwestern and southeastern parts of the city. The green spaces are also unevenly distributed: their main areas are concentrated in other parts of the city – north-eastern and eastern. Among them public green spaces are represented as the most valuable for the city and their residents due to their recreational assignment. They include forest parks, parks, squares and boulevards, and exactly their location and plantings characteristics play an important role in maintaining the appropriate population life quality.

The identification of territories requiring green spaces system optimization was implemented by processing a large amount of diverse spatial information that comprehensively characterizes not only the planting system, but also the city in general. The analysis of Minsk city's territory was executed in the ArcGIS program using the additional Spatial Analyst module. Firstly, spatial information about green spaces system (their spread, accessibility, population provision) was used as input data, for which necessary maps were compiled. In cases when such indicators don't reach required normative values, an important city development strategy will include not only bringing them to normal, but also creation of circumstances for maintaining existing plantings in proper condition. Information about building density [3] and the ecological state of atmospheric air [4-6] was also involved to analyze the territory of Minsk. All cartographic information was ranked with the allocation of 6-9 favorability degrees (from minimum to maximum).

The processing of the collected data in order to complete the task was conducted by modeling method. The final model is represented by a sequence of connections between tools and geodata in the ModelBuilder window. Also, during this step, the data sets were reclassified in order to establish a single measurement scale for further spatial information combination. The final analysis step consisted of weighing the input data, expressing in percentage their influence on the formation of the analysis final result: a higher percentage means a higher influence. It was revealed that the dominant indicators are: building density, provision of green spaces and their accessibility.

Modeling allowed to identify territories within the borders of Minsk city that urgently require optimization of the green spaces system. Exactly in these areas the monitoring and the ecological state of green spaces assessment were exercised. Data collection was carried out through field inspections of public green spaces, within the boundaries of which stand sites were allocated. The analysis and assessment were conducted based on the obtained set of dendrometric characteristics (crown tracery; drying and color of needles; drying of branches; the presence of mechanical damage; bark abscission) with further calculation of

the tree stand condition index within the bounds of field sites. The received quantitative parameters allowed to relate plantings to various categories of living conditions, in accordance with the modified classification scale of V. A. Alekseev [7].

According to the conducted research results, the implementation of a vertical gardening system, tested on one of the administrative buildings of Minsk, was proposed as a solution of the identified problems. Before the practical realization of the project, its visualization was performed, which required several stages. The initial building frame was created in a 3D modeling program – SketchUp Pro. The final 3D visualization of the vertical phytomodule layout was made in the Lumion 12 program.

3 Results

The realized spatial analysis of the city territory and further modeling process revealed that the lowest favorability degree for green spaces system organization according to a set of indicators (1) is inherent to the southern and southwestern city parts. In case of considering urban space at the level of administrative units, it was determined that the most difficult situation with green spaces system organization is peculiar to the Moskovsky, Oktyabrsky and Frunzensky districts. Within their borders, territories requiring green spaces system optimization (the first favorability degree) occupy 33.5%, 30.5%, and 25.5% of district area respectively. These administrative districts have been selected as key areas for monitoring and assessing the ecological state of green spaces (Figure 1).

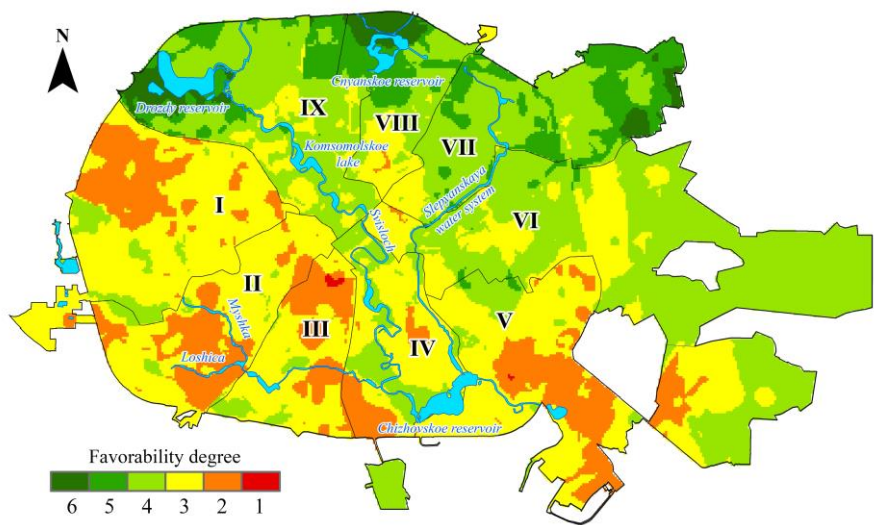


Fig. 1. Spatial analysis of the territory to assess green spaces system organization in Minsk city. I – IX – administrative districts; key areas (districts): I – Frunzensky, II – Moskovsky, III – Oktyabrsky.

In this part of the city 74 field sites, covering territories of 1 forest park, 12 parks, 63 squares and 6 boulevards with a total area of 459.2 hectares, were laid [3]. 2220 trees were examined. The assessment of their ecological state was conducted by analyzing such dendrometric characteristics as crown tracery, drying and color of needles, drying of branches, the presence of cracks, bark abscission and the presence of other mechanical damages [8].

It was revealed that the majority of trees are characterized by a light green shade of foliage or needles with a drying degree of about half. Also, most of the examined plants

have separately drying branches, and the predominant crown tracery ranges from 10 to 40%. Bark abscission is observed in less than 30% of inspected trees, while the predominant abscission degree is only 5%. Among other trunk mechanical damages, cracks and growths are more common.

Further processing of dendrometric characteristics set made it possible to calculate tree stand condition indexes and determine the category (1-5) of plantations vital state. Thus, in assessing key areas of Minsk by stand sites, it was revealed that among the five categories of plantings – healthy, healthy with signs of weakening, weakened, damaged and highly damaged, weakened (64.9%) and damaged (20.3%) predominate. It’s also important to notice the minimal spread of healthy (2.7%) or, conversely, highly damaged plantations (Figure 2).

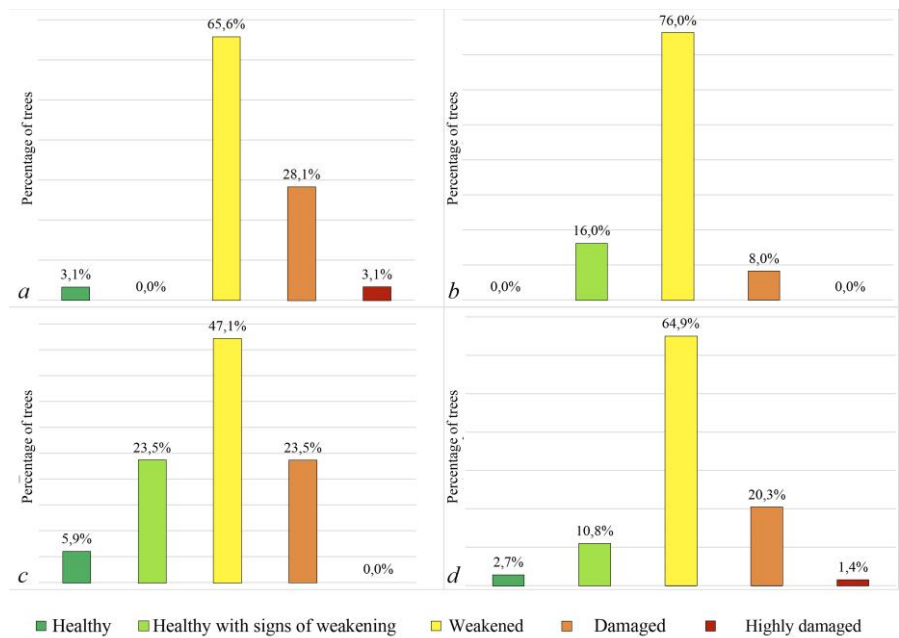


Fig. 2. Tree stands condition index of public green spaces within: a – Frunzensky district; b – Moskovsky district; c – Oktyabrsky district; d – key areas of Minsk city territory.

In general, the ecological condition of public green spaces within the borders of Minsk’s key areas, according to the ratio of their living condition categories, was assessed as acceptable with a preponderance of unsatisfactory, because the majority of the examined trees belong to the weakened category with a low proportion of healthy ones, and among the tree stands dominate weakened and damaged ones (85.2%).

4 Discussion

In terms of administrative districts, the worst condition of green spaces is inherent to the Frunzensky district. Exactly here the highest proportion of damaged stands (28.1%) is located, and only here a significant proportion of stands with the worst category within selection sample – severely damaged (3.1%) – was identified. The most favorable ecological condition of plantations among key areas’ territory is peculiar to the Oktyabrsky district. Within its borders, among examined stands, there’s a significant proportion of plantings in the healthy with signs of weakening category (23.5%), whiledamaged ones are

completely absent. Such distribution may be related to several factors: ecological situation peculiarities of the territory, likewise species and age diversity of the plantings. The green areas of the Frunzensky district are distinguished by older plantings, as well as an extensive distribution of tree species that are less resistant to pollution and high temperatures. Among the examined trees of the Frunzensky district, the lightened color of leaves or needles and unnatural yellow spots are more common. At the same time, unlike in the Oktyabrsky district, leaves or needles with varying drying degrees are observed on all trees. Parameters of crown density are also significantly lower, and the degree of trunk damage is higher.

In reviewing different planting categories, the following pattern was revealed. The worst condition of stands is inherent to forest parks, mostly due to the monotonous species composition (the predominance of conifers). A more favorable, but still not the best, condition is typical for plants of squares and boulevards. These green areas are usually located near highways, suffering by active diverse pollution, as well as large anthropogenic loads due to frequent public visits.

The best condition is typical for park stands, where the greatest age and species diversity of trees is observed, which prevents massive deterioration of green spaces condition. In addition, such large green spaces allow visitors to be dispersed throughout the territory, which lowers the overall level of anthropogenic load.

5 Conclusion

Green spaces system is an essential part of every city due to the ability of implementation a wide range of different functions. At the same time, the development of this system often lags behind the speed of urban development which leads to a disparity in its distribution within different parts of the city.

To identify such situation in Minsk city, a spatial analysis of the territory was conducted, within which the spatial distribution of city ecological state indicators, urban planning features and characteristics of green spaces systems were studied. The final result is modeled in the form of a map with the allocation of sites with varying degrees of optimization necessity for green areas system.

It's been revealed that green spaces system of Frunzensky, Oktyabrsky and Moskovsky administrative districts need correction first of all, that's why they, as key areas, have been examined more detail. The research and assessment of the ecological condition of green spaces in this part of the city has been carried out. The assessment of the ecological condition required several stages: inspection and assessment of individual trees, then assessment of stands state. According to the study results, it was revealed that the ecological condition of the public green spaces within the boundaries of Minsk's key areas is assessed as acceptable with a preponderance of unsatisfactory and needs optimization measures.

First of all, it's the expansion of the green areas as much as possible. Timely emerging problems liquidation, proper care of plants, and a diverse species and age plantings composition introduction will also prevent the deterioration of city's green areas ecological state. In addition, the optimization of current system can be produced by the introduction of one modern practice of green construction – vertical gardening. This urban planning practice uses vertical surfaces of buildings and structures as a basis, which makes it possible to expand the green spaces system without allocating additional territory [9]. At the same time, vegetation retains its numerous functions capable of optimizing urban environment state [10]. This idea has been tested, and based on the results both spatial analysis and the ecological state of green spaces assessment, a vertical phytomodule layout for the wall of an administrative building within one of Minsk's key areas (in Oktyabrsky district) has been developed. The project of a green installation includes: selection of a

suitable building and a specific wall, features analysis of chosen structure, developing phytomodule size calculation, frame and irrigation system description, selection of plant reservoirs and their required quantity, choice of proper substrates, formation of plant assortment and provision of additional maintenance elements information.

It's proposed to use such vertical gardening systems, together with other measures, as a universal tool for optimizing the green spaces system both in Minsk and other cities of Belarus.

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