

GIS MODELING OF WASTE CONTAINERS' PLACEMENT IN URBAN AREAS

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Abstract. As a result of this research, a methodical approach to the geoinformational analysis of the waste containers' placement for the collection of municipal solid waste in urban areas according to current standards and rules for the improvement of settlements was developed. According to the current Rules of maintenance of residential buildings and adjacent territories, waste containers of all types should be installed on a concrete or asphalted site, usually with fencing made of standard reinforced concrete products or other materials with planted shrubs around the site. Moreover, container platforms on wheels should be equipped with a ramp from the roadway and a fence (curb) which is 7–10 cm high, to keep the containers from rolling off to the sides. In the process of determining the optimal locations of waste containers a database of container park was created including the register of containers, the register of platforms, and the register of trash cans was created a list of influencing factors at the data collection stage, was made a proximity analysis and data reclassification to move to a unified scale for calculations of different types and/or heterogeneous source data, and weighted overlay as the main instrument of aggregated analysis. The analysis of the results is based on comparing the location of existing waste container sites with the resulting overlapping areas.

Keywords: geospatial analysis, waste containers, municipal solid waste, urban areas, placement modeling, GIS technology.

Introduction

Disposal of municipal solid waste (MSW) and construction debris is an important part of modern city life, as is a water supply, sewerage, and heating. Disposal of solid waste is handled by the special services that help maintain cleanliness and order on the streets. Containers of different volume, purpose and structure are used for garbage collection and removal to landfill and recycling places.

Since January 1, 2018, according to Article 32 of the Ukrainian Law "About Waste" Ukrainians were officially obliged to sort garbage. In October of the same year, a change in the National Building Regulation and Construction Standards for the design of residential buildings came into force, which abolished the mandatory design of garbage chutes in multi-storey buildings during construction or reconstruction. The National Waste Management Strategy indicates that the volume of solid domestic waste disposal in dumps should be reduced from 95% in 2016 to 50% in 2023 and 30% in 2030.

Starting from May 1, 2019, according to the new regulations on the provision of services for domestic waste management, approved by the Cabinet of Ministers of

Ukraine No. 318 of March 27, 2019, Ukrainians must sort their garbage.

The purpose of the work is to develop a methodical approach to the geoinformational analysis of the waste containers' placement for the MSW collection in urban areas according to current standards and rules for the improvement of the settlement.

1. Analysis of the current state

A significant amount of research is devoted to GIS monitoring of waste accumulation location and condition based on using satellite imagery, which is due to the availability of technology and high accuracy of the results (Dmytriv & Dudko, 2017; Domanska & Bodnar, 2013; Vambol' et al., 2015; Kokhan & Moskalenko, 2009; Timofeeva et al., 2012; Abrosimov et al., 2014; Aristov, 2009; Batrakova et al., 2017; Gusev & Molochko, 2015).

The Ministry of Ecology and Natural Resources of Ukraine ensures the functioning of interactive landfill maps on the territory of the country and provides citizens with the opportunity to send a message with georeferencing and photo materials about identified sites of

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unauthorized dumps. The Ministry of Natural Resources ensures the prompt receipt of such information by the local authorities responsible for their timely elimination. Separate layers on the map represent data from the register of waste disposal sites and places of unauthorized dumps (Ministry of Environmental Protection and Natural Resources of Ukraine, 2016).

The question of waste sorting in order to reduce the overall anthropogenic load on the environment is the subject of numerous studies, by both Ukrainian (Grabowsky et al., 2014; Shchuryk & Nadraha, 2017; Bashutska, 2018) and foreign scientists (Murray, 2002; Gallardo et al., 2012; Mahmood et al., 2016; Farahbakhsh & Forghani, 2018; Kallel et al., 2016; Hammer, 2003). A number of public organizations with the assistance of local governments are engaged in information support of separate collection processes of individual components of solid waste ("No Waste Ukraine", "Clean City", "Zelene Misto", "ZERO WASTE", etc.).

A number of initiatives in different regions are also devoted to the renewal of the container parks in populated areas, in particular in Kyiv city (Ukrinform, 2017). The installation of modern deep type (underground) containers continues in Kyiv, the volume of which are 5 cubic meters, and they replace 5 conventional recycling bins. But the analysis of information sources demonstrates a lack of systematic research on monitoring of observance of operating sanitary norms and rules of maintenance of territory settlements on accommodation of waste containers.

2. Presentation of the main research material

Spatial analysis of waste disposal locations formally can be presented as a function of finding the optimal object location, which is a classic task of geospatial analysis, for which there are several built-in algorithms of GIS tool:

$$SAWCP = SOLO = FGIS(KF, BZ, SF, SP), \quad (1)$$

where: *SAWCP* – spatial analysis of waste containers' placement; *SOLO* – search for optimal location of objects; *FGIS* – GIS functions for the aggregated analysis of heterogeneous data depending on the set of the key factors *KF*, which determine the restrictions on the location of the container sites in the urban areas, and are usually set as buffer zones *BZ* around the objects of urban infrastructure in accordance

with the current regulations on the maintenance of territories; *SF* – a subset of additional geospatial analysis functions that can be applied in the process of adding the values of weighting factors to a unified scale, for example, data reclassification tools; *SP* – functions of aggregation of influence factors taking into account the weight of each, for example, the spatial weighted overlay function.

According to the current Rules of residential buildings and adjacent territory maintenance, all types of waste containers should be installed on a concrete or asphalted site, usually with fencing made of standard reinforced concrete products or other materials with planted shrubs around the site. Containers platform on wheels should be equipped with a ramp from the roadway and a fence (curb) which is 7–10 cm high, to keep the containers from rolling off to the sides. The analysis of an arrangement of existing waste platforms in urban areas for compliance to standard norms and rules of an improvement of public services provides the creation of a database of container parks as a part of the register of containers, the register of platforms, and the register of trash cans (Figure 1).

The container register should include information on a type, material, actual size and disposal volumes. The waste container sites are located at a defined address and have regulated sizes depending on the numbers. As the load increases (e.g., in the case of construction of new facilities), the size of the site may remain unchanged, but the recycling capacity increases through re-equipment (e.g., larger or additional containers). Urns are also classified by type and are assigned to certain public infrastructure objects and therefore to service organizations.

The following tasks can be highlighted for the implementation of the operating function in the instrumental GIS environment:

- formation of the knowledge base on the key factors of restriction of waste container sites on the basis of regulatory documents and technical regulations for the maintenance of urban areas;
- development of a general assessment scale of the suitability of the landfill territories for the collection of municipal solid waste in urban areas;
- determination of weighting coefficients of key factors' influence.

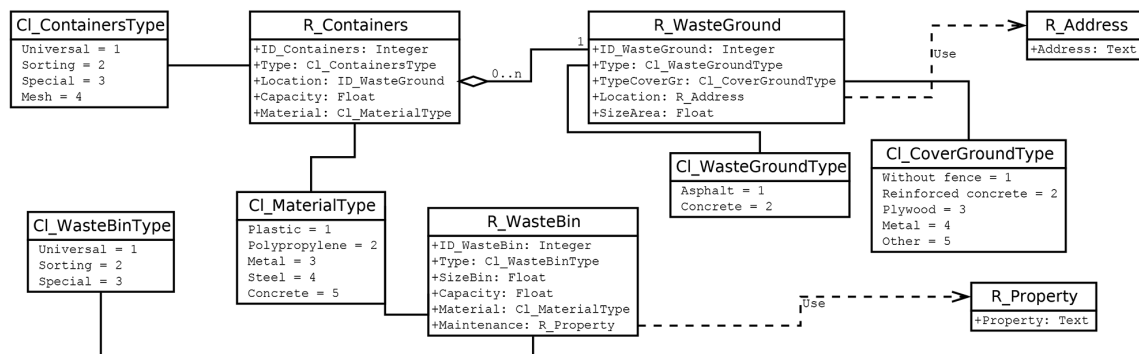


Figure 1. UML-diagram of the conceptual model of the container park database

The research area of urban infrastructure is located in the Solomenskyi district of Kyiv. The total area includes four urban quarters and is equal to 52 hectares. The main impact factors include residential buildings, educational and medical institutions (educational buildings of KNUCA, hospital of Kyivmiskbud), public places (N. Ostrovsky Park) and street a network consisting of Osvity, Vuzivcka and M. Kryvonosa streets, V. Lobanovskyi and Povitroflots'kyi Avenues (Figure 3).

Modeling of the influence factors starts with the proximity analysis using the Euclidean Distance tool, which

calculates, for each cell of the input raster, the distance to the source – object, which limits the location of the waste containers according to Table 1. The Reclassification Tool has been used to create the unified scale of assessment of the territory suitability from 1 to 5 (Figures 4–6).

The Weighted Overlay tool allows performing a spatial overlay of several rasters depending on the weight of each raster to control the influence of different criteria in the suitability model (Figure 7). The analysis of existing waste container sites located on the research territory indicates the violation of conditions in 9 cases out of 38, which is more than 23%.

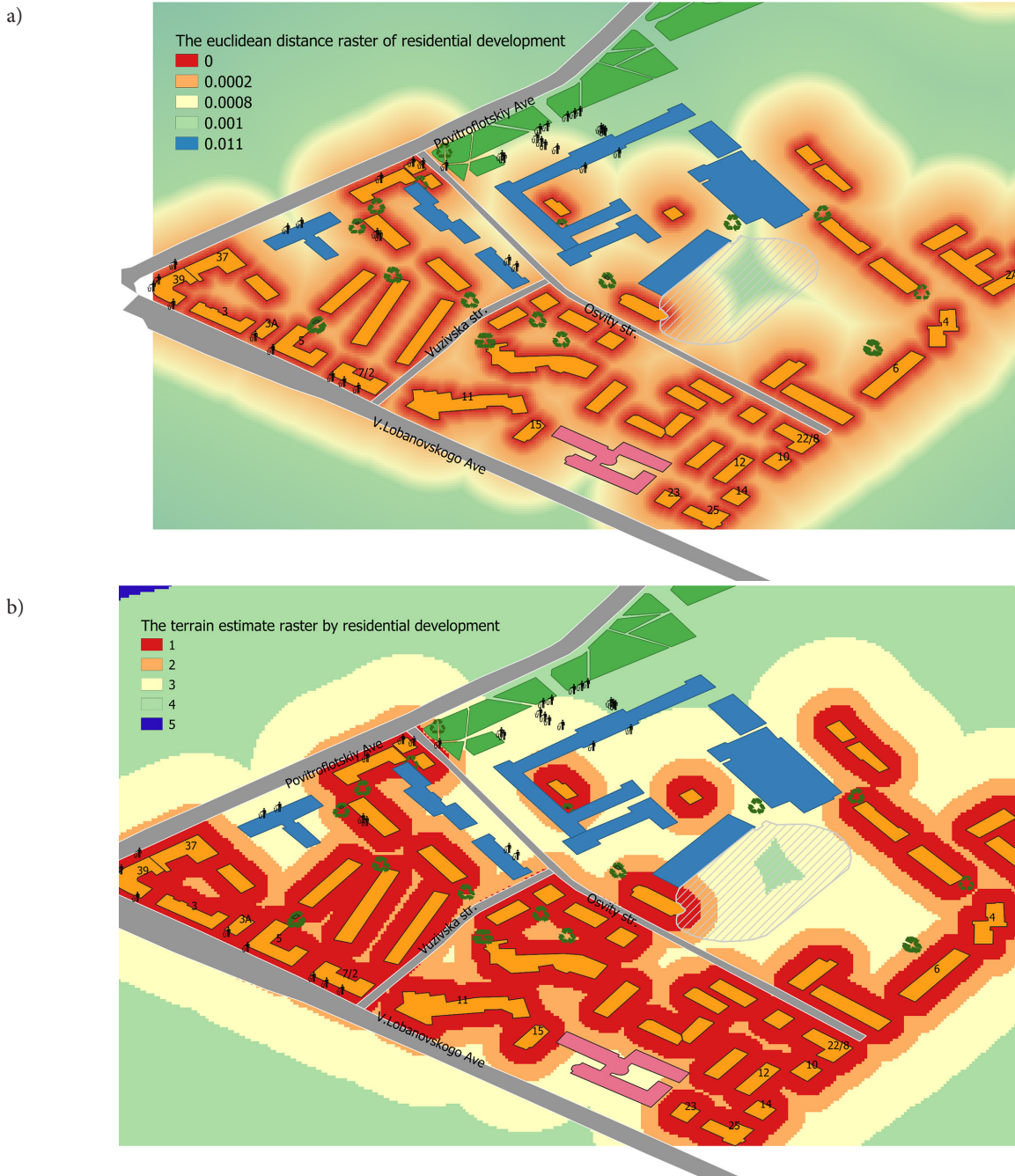


Figure 4. Territory assessment by the proximity factor to residential and public buildings and structures: a) the result of the proximity analysis by the Euclidean distance tool; b) the reclassify result to a unified scale of assessment of the suitability of the territory from 1 to 5

The result of the weighted overlay contains a raster only from four classes of the suitability of the territory from the second to fifth, that is, there are no places in the urban quarter, which are categorically unsuitable for the location of waste container sites. But it is worth noting the significant simplifications in the experimental study, which did not allow us to take into account such factors as the location of playgrounds. Further researches will be aimed at taking into account all influence factors according to the regulatory rules of improvement of settlements. Also, to work with significant data sets in real urban area

modeling projects, the algorithm of proximity analysis, reclassification, and spatial overlay requires implementation into the ModelBuilder environment.

Conclusions

Summarizing the work carried out would like to make the following conclusions. The proposed algorithm is a classic example of GIS technology application to determine the optimal location of objects, in particular, proved effective enough to analyze the location of waste container

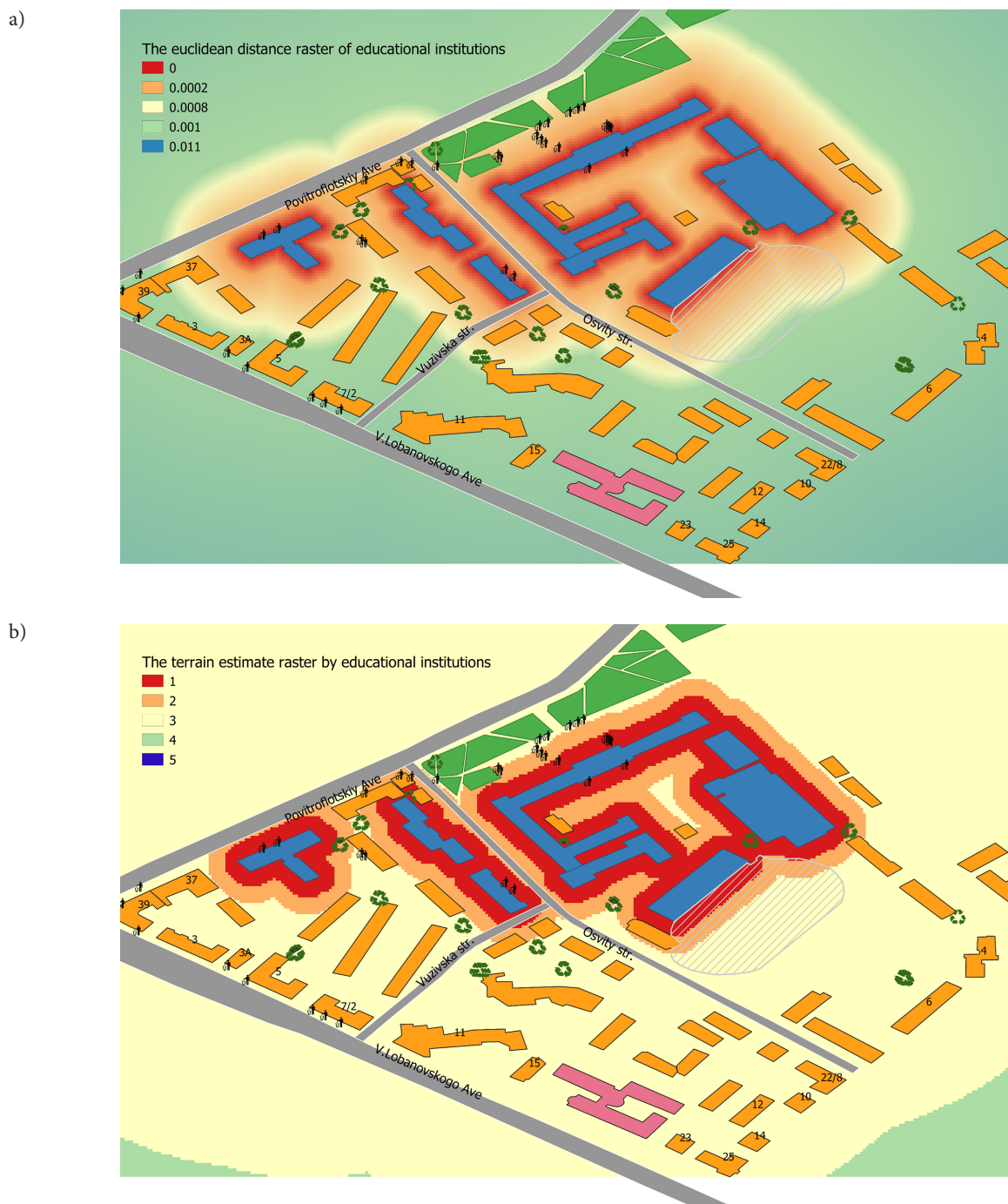


Figure 5. Territory assessment by the proximity factor to educational institutions: a) the result of the proximity analysis by the Euclidean distance tool; b) the reclassify result to a unified scale of assessment of the suitability of the territory from 1 to 5

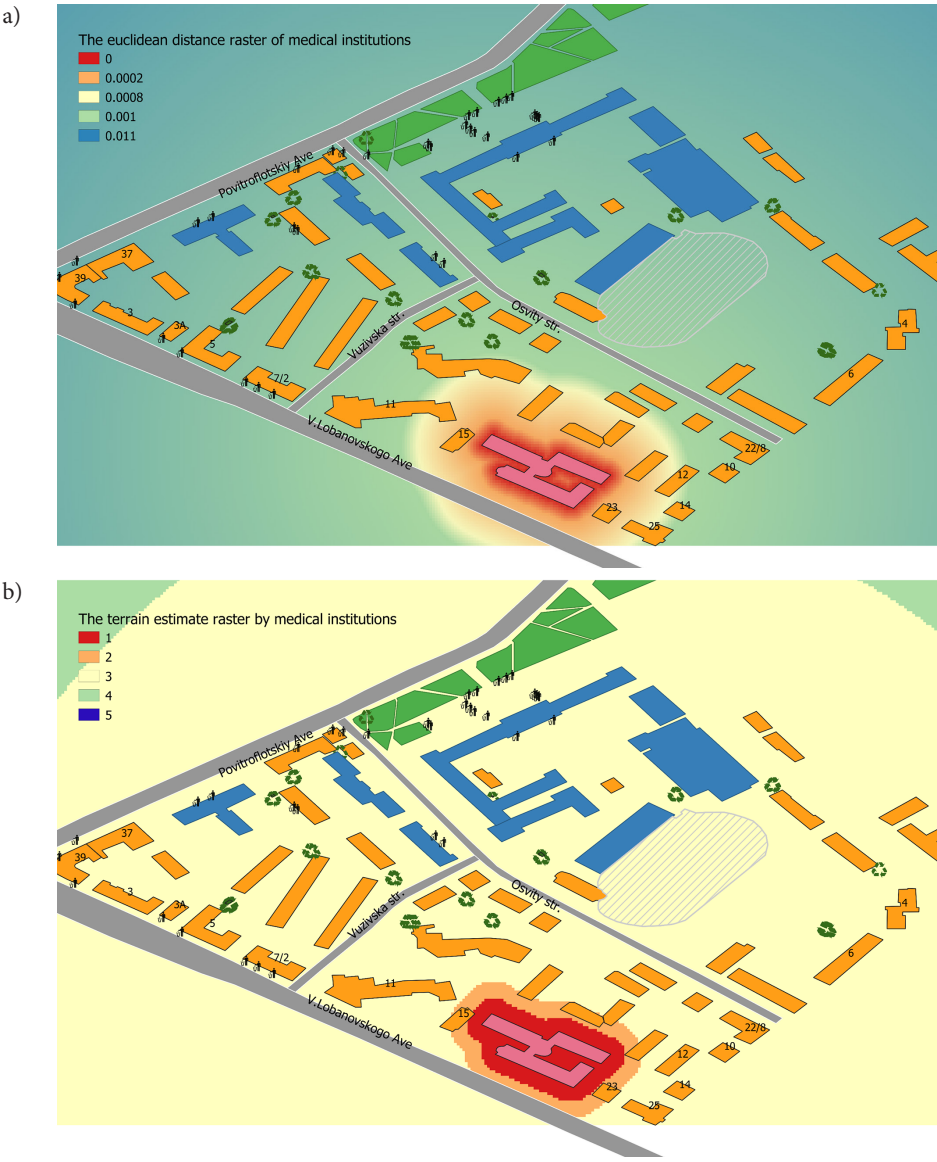


Figure 6. Territory assessment by the proximity factor to medical institutions: a) the result of the proximity analysis by the Euclidean distance tool; b) the reclassify result to a unified scale of assessment of the suitability of the territory from 1 to 5



Figure 7. Aggregated assessment of the suitability of the area for waste container sites

sites. The obtained results of territory modeling according to the classes of suitability for placement of solid waste containers are a sufficient justification for landscaping measures on the local level within a quarter or a separate residential area. But thorough researches on the violation of regulatory standards of urban planning should take into account the volume of solid waste production depending on the population density and the type and size of existing containers and trash cans. An important stage in the implementation of the methodology is the creation and filling of a Geospatial database of the container fleet, as a basis for calculating the load on garbage containers and sites according to their types and sizes.

The conducted experimental research on the territory of Kyiv city quarters testifies to the high efficiency of the proposed tools, even with the accepted significant simplifications. Landfills in Class 1 and Class 2 areas need immediate relocation and retrofitting. Visual analysis of the research area shows, that 90% of the existing waste container sites need to be retrofitted, in particular by adding fencing and ramps or curbs. Modeling of waste containers' placement in urban areas will allow justifying the order of installation of a newer type of containers to improve the situation of collection and disposal of solid waste in urban landscaping. Considered technology is very promising. On the one hand, this approach provides a rationale for the decision to improve the quality of life on the basis of landscaping, on the other – modern instrumental GIS allows you to apply the proposed technique quickly and with minimal costs.

Further research, in addition to taking into account a wide range of influencing factors, should focus on the use of automated information collection tools, such as large-scale UAV surveys as one of the most common tools for monitoring urban areas.

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