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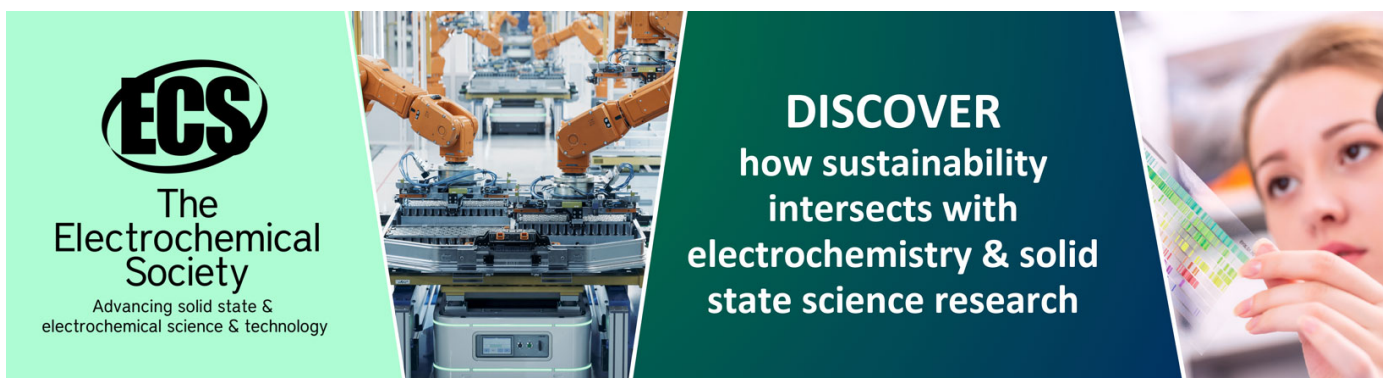
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The environmental monitoring and management of urban greenery using GIS technology

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Abstract. The main provisions of using GIS technologies for the environmental monitoring of urban green spaces (UGS) are described. The main factors of anthropogenic negative impact on the UGS are characterized. The paper considers the necessity of using modern methods of the Earth remote sensing and geospatial mapping for the inventory, assessment, and monitoring of environmental conditions of UGS. The principles of geoinformation modeling of UGS are characterized. The definition of UGS geospatial model is given, the tasks solved with its help are listed, the considered parameters of UGS are provided by the authors. The main stages of UGS geospatial modeling are described. A fragment of digital greening plan of Novosibirsk is presented. The paper concludes about the importance of geospatial modeling and mapping for the effective organization of environmental monitoring of UGS.

1. Introduction

The urban green spaces (UGS) are an important component of the urban environment, ensuring environmental safety and environmental comfort of the population [1]. At the same time, they are subjected to constant anthropogenic pressure, which is expressed in the following phenomena:

- Accumulation of pollutants in plant tissues due to the pollution by industrial plants and road transport of the urban air basin and soil;
- Deterioration of plant nutrition due to the deposition of dust, soot, and other suspended substances on the aboveground parts of plants;
- Degradation of plant root systems as a result of soil compaction under the vibration effect of road transport;
- Violation of the integrity of tree crowns and soil cover as a result of industrial and recreational activities (construction and road works, lawn trampling, illegal parking, etc.).

The optimal state of the UGS is an important factor contributing to the improvement of the ecological condition of the city. Therefore, taking into account the wide range of impacts to which they are exposed, the condition of the UGS should be monitored and regularly assessed from a geoecological point of view. This will provide the city management bodies with relevant and reliable information on the state of the UGS and, making it possible to optimize care activities.

The environmental monitoring of the UGS should include the following actions [2, 3]:



- Country-wide inventory of the UGS, providing for the collection of information on individual landscaping objects (trees, groups of shrubs, flowerbeds and lawns), the totality of which forms the UGS;
- Assessment of the ecological condition of the UGS in general and of individual landscaping objects (especially high-growth vegetation) within their borders;
- Formulation of care recommendations for existing the UGS;
- Planning of the new UGS taking into account their desired location, species composition recommended for this climate, geographical features of the area, regulatory requirements for the territorial planning of cities, financial and aesthetic value of different plant species.

The officially adopted method of inventory of green plantings is marked by methodological and technological obsolescence, since it does not provide for the use of modern capabilities of computer equipment and technology [4].

2. Materials and Methods

The modern technologies of Earth remote sensing (ERS) and geo-information mapping provide all the possibilities for collecting highly detailed information that is spatially referenced on any objects of the earth's surface. These technologies provide opportunities for collecting information including on the boundaries of the UGS and the location and condition of individual trees within their limits. Relying on the modern achievements of photogrammetry and digital cartography allows us to formulate the following principles of inventory, assessment and mapping of the UGS:

- Comprehensive use of freely distributed data of ERS to determine the main spatial, qualitative and quantitative parameters of the UGS and individual landscaping objects (trees, shrubs, flower beds, etc.) within their borders;
- Systematization, analysis, and modeling of the collected data in the GIS environment, taking into account the available geospatial information about other objects of the urban environment (buildings, engineering structures, communications, etc.);
- Assessment of the ecological state of the UGS and landscaping facilities within its borders, carried out on the basis of the results of the inventory of the UGS on materials of ERS and field surveys;
- A visual representation of the results of the inventory and assessment of the ecological status of the UGS in the form of digital cartographic materials that provide usability with the new knowledge of urban greenery, including the implementation of visual analysis that does not require special technical and technological support.

Based on the above principles, the structure and the sequence of creating the geo-information model of the UGS were developed, which lays the informational basis for monitoring and rational management of the state of the UGS.

3. Results

The geo-information model of the UGS is an ordered set of features reflecting the current state of the UGS and individual landscaping objects within its borders. It provides the following tasks [3, 5]:

- An inventory of all individual landscaping objects (to the level of individual trees and shrubs), including the determination of their spatial position;
- Creation, development, and updating of the database, which contains detailed semantic information about the qualitative and quantitative parameters of individual landscaping objects;
- Assessment of the ecological status of individual landscaping objects on the basis of the collected data, documenting the assessment results in the form of reports;
- Making recommendations for the care of each specific object of landscaping and for the green area as a whole, planning the placement of new UGS and adjusting the area and structure of existing spaces.

In the process of geoinformation modeling of the state of the UGS, the collection of information not only about the UGS itself but also about the urban environment containing them is important to ensure. Information on engineering objects can be obtained from digital maps used by municipal urban management bodies. In addition, information on the development and cadastre of urban areas can be specified and verified using the Rosreestr Public Cadastre Map.

For a more complete understanding of the causes of negative environmental changes in the UGS, their condition should be considered in the context of the general environmental situation of the city. However, it should be noted that the data of state monitoring of the state of the environment conducted by the Roshydromet are determined on a limited number of fixed and mobile posts [6]. And the collection of information on the pollution of the atmosphere by emissions from road transport is not provided for by the current governing documentation and can be carried out only with the involvement of non-governmental organizations and funds, which will lead to higher cost of work [7-9]. The current program of state monitoring of soil pollution with heavy metals provides only for sampling in industrial areas [10].

The general structure of the database of the UGS geoinformation model includes the following main blocks:

- Data on the urban environment (buildings, driveways, engineering communications, etc.);
- Data on the ecological status of the territory (air pollution, pollution of soil and snow cover of the UGS);
- Data on UGS and individual landscaping objects within their borders.

The following information is recorded in the last block of the database [3,5]:

- For lawns: a lawn type, an area, dominant grass types, a total projective cover;
- For trees: a type of planting (includes a tree), a registry number of the tree, a breed, the age, diameter, its height, a quality condition;
- For shrubs: a type and number of shrub planting, a type and number of bushes in planting, the age, the height of bushes, their length and width of planting, a quality condition;
- For flower beds: a type of flower bed, the perennial culture, an area, a quality condition.

The general technological sequence of creating a geo-information model of the UGS includes the following steps:

- Receiving freely distributed materials for ERS on the territory within which the inventory and assessment of the UGS is performed;
- Formation and filling of the database of the UGS geo-information model and the creation of vector thematic layers reflecting the UGS and objects of landscaping within their borders.

The main part of the work consists in deciphering the UGS and individual landscaping objects using ERS data. Decoding allows one to set parameters such as the spatial position and height of trees and shrubs, the configuration and area of lawns and flower beds, the degree of disturbance of the projective cover of the lawn. Information about the species of trees and shrubs, the nature and degree of disturbance of their crowns, forest pathological characteristics are established on the materials of panoramic street photography [4]. The UGS geo-information model is supplemented with information on the environmental situation, either by importing digital layers or statistical databases that already contain environmental information, or by creating an appropriate database and digital layers “from scratch” associated with it.

- Assessment of the ecological state of the UGS and individual landscaping objects (especially trees) within its borders. The assessment is performed in several stages using a specially developed mathematical apparatus. [11];
- Displaying the results of the inventory and assessment of the ecological condition of the UGS and individual landscaping objects in the form of digital landscaping schemes, which are the final product provided to specialists in the field of greenery management.

A Fragment of a similar scheme created in Mapinfo GIS on a landscaped area along the street Titova (Novosibirsk), is shown in Figure 1.

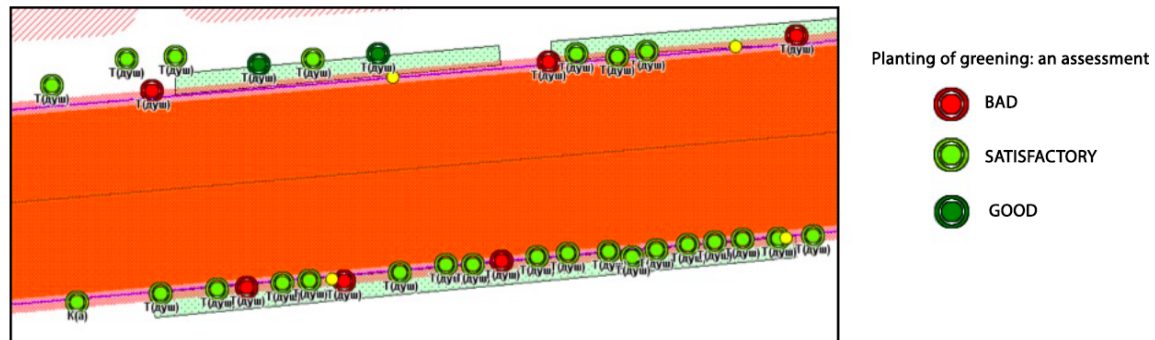


Figure 1. A fragment of a digital landscaping scheme (Titova street, Novosibirsk, Russia).

4. Discussion

The environmentally and economically efficient design of UGS involves a comprehensive analysis of the spatially distributed data on the characteristics of the placement of green spaces and indicators of their structure and condition. However, an analysis of modern processes for managing urban greening [12–15] revealed that the inventory of a state-owned plant is often carried out to a limited extent due to a shortage of man-hours and financial support. As a matter of fact, the urban management authorities identify and control several “hot spots”, which are the largest and most visited greening sites.

The implementation of the proposed UGS geo-information model will ensure the collection and comprehensive analysis of information on the UGS condition throughout the city while reducing the volume of field work. Its content occurs both due to the exchange of information with the existing digital cartographic sources (on-duty cadastral maps, plans, etc.), as well as by obtaining information about UGS with freely distributed ERS data. This ensures the formation of information arrays, sufficient for the effective management of the UGS, by office methods and a visual representation of the information obtained on digital maps. The developed technological sequence of geoinformation modeling and mapping of the UGS ensures the creation of cartographic support of measures for monitoring the condition and caring for the UGS.

5. Conclusion

In the modern era, the effective management of urban greenery is impossible without the use of geo-information and computer technologies. To optimize the process of managing the UGS, a geo-information model has been proposed, which is the main tool for the inventory and monitoring of the UGS. The geo-information models created on street gardening sites and the Monument of Glory Square in Novosibirsk have established themselves as an effective means of systematizing and visualizing information on the state of the UGS. They can serve as a reference tool in the development of measures for the care of greenery in specific areas.

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