Information support for monitoring urban lands to regulate land use in order to improve the quality of the natural environment

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Abstract. This article considers the issues of monitoring urban lands in the general system of state environmental monitoring based on a conceptual model of interaction of the system of monitoring observations of urban lands and their changes to form an information base for monitoring. Under the information base, the article considers a system of measures of financial, economic, and managerial impact that ensure the greening of the land use system, considering the information support for monitoring urban lands to regulate the system and protect the land. Mechanisms for improving information support for monitoring urban lands are beginning to play a key role in the system of greening land use. This allows you to combine the results of terrain modeling with spatial thematic information and nonspatial information (concentration of pollutants at a specific point) to expand the possibility of analyzing environmental problems, and ultimately contributes to increasing the reliability of assessments of the state of multifunctional lands. The article concludes that considering the features of the relief because of information support for monitoring urban lands will increase the objectivity and reliability of the assessment of multifunctionally used lands and contribute to their rational use.

1. Introduction

Currently, the existing mechanisms for managing sustainable land use of urban lands are based on the regulation of existing land relations, considering the economic, social, and legal aspects of the impact on these relations. The issues of greening the land use system are beginning to play a key role, considering information support for monitoring urban lands to regulate the system and protect the land. The problem of improving the quality of the natural environment is acute in urban agglomerations, the reason is the accelerated development of urban areas and, as a result of this impact - an increase in anthropogenic load on natural systems and the deterioration of the ecological state of the environment [1].

Modern methods and approaches to assessing the qualitative state of lands are based on the fixation of quantitative data on the maximum permissible concentrations of pollutants in the places of pinpoint determination of the source of negative impact. However, these approaches do not make it possible to identify and evaluate the effect of pollution spreading processes considering numerous aspects of the
properties of land resources - legal, environmental, engineering and construction, urban planning, and others. A special role in this issue belongs to the relief, or rather its digital model for the expedient improvement of the existing approaches to monitoring urban lands [2].

The relief, as the main factor of influence on the ecological state, determines the directions of the distribution of types of pollution through the migration of substances along the angles of inclination and the exposure of slopes, which determines the morphometric elements of the relief. It should be noted that the regulatory documents assessing the impact of the relief in the structure of land monitoring is not sufficiently developed.

Thus, the aim of our research is to improve information support for monitoring urban lands based on new developments of scientific and methodological provisions for a comprehensive analysis of the relief of urban areas as a fundamental factor in the creation and formation of environmental conditions.

To achieve the goal of the study, it is necessary to solve the following tasks: to analyze the approaches to assessing the qualitative state of lands in settlements; to determine the possibilities of practical use of methods of morphometric analysis of the relief in the information support of monitoring of urban lands; to develop scientific and methodological provisions for the analysis of the relief as a factor in the formation of the ecological situation on land plots by means of GIS technologies.

The works of Vereshchak, T. V., Vladimirov, V. V., Zaikanov, V. G., Kasimov, N. S., Kotlova, F. V., Lappo, G. M., Likhacheva, E. are devoted to studies of urban areas in the aspect of land assessment, Novakovsky, B. A., Prokhorov, B. B., Stroganova, M. N., Tyutyunnik, Y. G. and other authors.

In the works of Lastochkin, A. N., Simonov, Y. G., Spiridonov, A. I., Stepanov, I. N., Timofeeva, D. A., Ufimtsev, G. F., Florensov, N. A., Shary, P. A. methodological approaches to the analysis of the relief of the earth's surface, and aspects of geoinformation modeling of the relief are considered in the works of Zhalkovsky, E.A.

The key issue in the development of a monitoring system for urban lands is the development of an integrated system that will increase the quality and reliability of an objective assessment of the ecological state of multifunctionally used lands, based on the structure of information support for monitoring urban lands, considering the data of morphometric analysis of the relief. Following the ongoing activities Land management and monitoring of the state and use of land resources in the framework of the State program Economic development and innovative economy, an important area of development is a sustainable ecological balance, achieved through the development of measures to prevent and eliminate negative processes on land by their actual use and detection of violations in the complex functioning of their biological properties. [3]

2. Materials and methods
The system of monitoring observations of urban lands is closely related to changes in the administrative-territorial formations of the city and is a conceptual model of interaction, presented in Figure 1 and aimed at rational land use and protection of urban lands in the context of the city's land policy.

Monitoring of urban lands as an information base of quantitative and qualitative data on urban lands should be carried out and carried out according to a unified methodology, considering the principles of compatibility of various kinds of updated and reliable information from state and municipal sources, including information interaction between the state land supervision and the Unified State Register of Real Estate (Figure 2).

Morphometric analysis, which includes characteristics of landforms, horizontal and vertical curvature flows, determination of dispersion, and depression zones is a key stage in the general system of digital elevation model formation [4]. When considering the relief as a factor in the formation of the ecological situation, taking into account the scientific and methodological provisions, particular importance is given to software products and means of geographic information systems from the
standpoint of the possibilities of implementing the provisions for the analysis of the relief. The technological scheme for the use of software for performing morphometric analysis of the relief is shown in Figure 3.

**Figure 1.** Conceptual model of interaction of the system of monitoring observations of urban lands and their changes

In addition, it should be noted the need to expand the use of the capabilities of modern special programs - geographic information systems (hereinafter referred to as GIS) for monitoring urban lands and processing data collected in the process of such monitoring. A generalized monitoring algorithm using GIS technologies is shown in Figure 4.

For the formation of a digital elevation model (hereinafter - DEM) of the area, after choosing the area subject to monitoring surveys, at the initial stage, it is necessary to identify the sources of obtaining the initial data on the relief [5]. These can be cartographic maps or thematic maps of morphometric relief indicators.
Figure 2. The structure of interdepartmental information interaction of bodies and organizations participating in the monitoring of urban lands

To comply with the metricity and plasticity of the image of the earth's surface, the collection of initial data must be carried out not only by the method of digitizing contours, predominantly for areas with a complex relief and with large changes in heights but also along the distinguished structural lines of thalweg, maximum and zero curvature of slopes, watershed lines [6].

The next step after data collection is the detailed and comprehensive reconstruction of the earth model. This process can be carried out in the corresponding software products that allow the method of weighted average interpolation to restore the model of the relief surface closest to the real picture.

As a result of building a digital elevation model, it is necessary to assess the quality of the resulting model, which is often carried out by a comparative method by combining the constructed model with a 3D elevation model, which makes it possible to identify the places of the earth's surface display where terrain elements are ambiguously traced and to fix additional unremoved ones in the shortest possible time, points for correcting the model [7].

At the next stage, several technological operations are carried out to form derived geoinformation layers that reveal the morphometric features of the territory.

The final stage is the discretization of the earth's surface according to the data on its curvature, the differentiation of the surface shapes that emphasize the changes in the direction and velocity of matter flows. The obtained result makes it possible to determine the index of the ecological significance of the relief and display the results in the form of a separate thematic layer. Created and scientifically developed foundations for the analysis of relief and technological solutions for their implementation using GIS make it possible to assess the influence of relief on the formation of environmental conditions [8].
Figure 3. Technological scheme for the use of software for performing morphometric analysis of the relief

Figure 4. Algorithm for monitoring urban land
3. **Results and Discussion**

Aerial photography from an unmanned aerial vehicle is an effective method for monitoring urban lands. The essence of the survey consists in obtaining not only the coordinates of the characteristic points of the boundaries of the investigated land plot or other immovable property, but also an overview view of the plot itself or the object with the astro-landmarks defining it.

As a specific object of research, we selected a land plot of irregular shape with an area of 1.3 hectares, located in the Moscow region. The landform is characterized by a complex relief, which includes elevation differences of more than 2 meters. The configuration diagram of the land plot in the coordinate system is shown in Figure 5.

![Conditional parcel contour with contour turning points](image)

**Figure 5.** Conditional parcel contour with contour turning points

To substantiate the economic feasibility of the aerial survey method from an unmanned aerial vehicle when monitoring a real estate object located in an urban environment, we will calculate the working time spent on fieldwork with three options for surveying the object (Figure 6).

![Three types of survey method for independent comparative assessment for monitoring urban land](image)

**Figure 6.** Three types of survey method for independent comparative assessment for monitoring urban land

Data on calculating the budget of labor costs (labor intensity) for carrying out land surveying in various ways are presented in Table 1. Based on the table, we can conclude that the most labor-intensive method of surveying a land plot for further monitoring is the method of land surveying by aerial photography (method No. 3). The least labor-intensive is method number 1.

Survey of terrain using manned aerial vehicles has been an effective mechanism for carrying out a set of work on terrain mapping for many decades. As a result of this type of work, a shorter period is spent both on the shooting process itself and further processing of the results.

The main advantage of the aerial photography method is the prompt receipt of accurate and systematized information about the objects being shot, and the key one is the state of the earth's surface, taking into account the features of the relief, with an accuracy of 0.1-0.3 m.

However, this entails an increase in the cost of the final product, due to an increase in the economic costs of servicing this type of survey, which is confirmed by the data in Table 1.
Table 1. Calculation of the budget of labor costs (labor intensity) for carrying out land surveying in various ways

| Indicator name                                      | Data source for calculation                                                                 | Value  |
|-----------------------------------------------------|---------------------------------------------------------------------------------------------|--------|
| estimated number of preparatory operations, units   | based on the methodology of work (preparation of equipment, inventory, preparation of reference signs, setting up navigation) | No. 1  | No. 2  | No. 3  |
| estimated number of basic operations, units         | depending on the survey method, the number of turning points, the profile of the site, the distances between the characteristic points, etc. | 25     | 25     | 30     |
| estimated time for one preparatory operation, hour. | accept 0.25                                                                               | 0.25   | 0.25   | 0.25   |
| estimated time for one main operation, hour.        | accept 0.10                                                                               | 0.10   | 0.10   | 0.10   |
| coefficient of time spent on basic operations       | depending on the specifics of each method                                                  | 1.2    | 1.05   | 1.4    |
| time budget for preparatory operations, hours.      | number of preparatory operations * Estimated operation time                                | 1.25   | 1.75   | 2.25   |
| time budget for basic operations, hour.             | number of preparatory operations * Estimated operation time * K                             | 3.12   | 4.60   | 4.20   |
| cumulative time budget, hours.                      | ∑T = T_{prep} + T_{base}                                                                   | 4.37   | 6.35   | 6.45   |
| number of employees (specialists), people           | set equal to 2: cadastral engineer and his assistant                                        | 2      | 2      | 2      |
| concurrent factor                                   | since some of the processes are carried out in parallel by two workers, we take, K_{par} in the range from 0.60 to 0.75 | 0.60   | 0.65   | 0.75   |
| indicator of labor costs for surveying a conventional site, person / hour. | T3 = ∑T (hour.) * N (person) / K_{par}                                                    | 5.24   | 8.26   | 9.03   |

For further analysis, let us assume that the technical devices used for surveying land plots have their definite operational margin, that is, an indicator that decreases with each next hour of its use. We are talking about the depreciation policy of a single enterprise. A similar method is applicable in our calculation (Table 2).

For a visual display of the results obtained, let us draw up a diagram of the costs of shooting by the methods used above (Figure 7).

After analyzing the quantitative data, it can be revealed that when using the aerial photography method, the amount of depreciation costs is 13.4 times higher than when conducting land-based land surveying.
Table 2. Calculation of depreciation costs in the production of cadastral works

| Indicator name                                                                 | Data source for calculation                                                                 | Value       |
|-------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------|-------------|
| estimated number of complex technical devices in the implementation of the method, pcs. | based on the methodology of work (number of theodolites, rangefinders, satellite receivers, UAVs for work) | № 1     № 2     № 3 |
| equipment resource, thousand hours                                            | depending on the specific type, type and manufacturer - in the presence of several different types of devices (for example, a total station, UAV, camera), we take the average value of the resource based on the prices of sellers | 3,00       1,50       1,00 |
| cost of expenses for the purchase of devices, thousand rubles (average calculated) | purchase cost / resource deck on the prices of sellers | 500,00       700,00       1300,00 |
| depreciation for 1 hour of equipment use, rub.                               | we take the factor of capital expenditure equal to 0.5, that is, we assume that 50% of the working time is used by the appropriate equipment | 167,70       466,7        1300,00 |
| indicator of actual capital expenditures for one survey, hour.               | Zₘ = Depreciation (p.)*FZ (hardware hours)                                                  | 2,62        4,13        4,52 |
| the cost of equipment wears when surveying a conventional section, rubles.    | Zₘ = Depreciation (p.)*FZ (hardware hours)                                                  | 439,40       1927,50       5876,00 |

4. Conclusion
The essence of the spatial distribution of objects and their interaction serves as a mechanism for an objective assessment of the state of the land, considering the influence of the relief of the surveyed area. The movement of the amount of matter and energy is controlled by the relief and considering the direction of distribution of pollution and the path of migration of substances, there are morphological elements of the relief. The studies carried out to assess the impact of relief features on the spread of...
pollutants allow us to recommend supplementing the structure of information support for monitoring with the results of morphometric analysis (Figure 8) [9].

Figure 8. The structure of information support for monitoring urban lands, considering the features of the relief

Based on the research carried out, the following conclusions and suggestions can be drawn. The use of the results of morphometric analysis of the relief makes it possible to carry out a detailed and comprehensive presentation of the entire structure of the geocological space of the city territory. This idea can serve as a basis for dividing the urban area into separate sections, differing from each other in different insolation exposure, the direction of streams by levels, different illumination, and more. A set of information on the spatial distribution of pollutants over the territory of land plots, the rate of their spread, allows one to give an independent comprehensive assessment of the nature of the impact of certain elements of urban infrastructure on the elements of the natural complex [10]. This serves to select the key assessed sites in different territorial and functional zones of the city for monitoring observations.

Improving monitoring methods makes it possible to extensively predict changes in the components of the natural complex. With the use of modern geoinformation technologies, it is possible to combine
results of relief modeling with spatial thematic information and nonspatial information (concentration of pollutants at a specific point), which expands the possibilities of analyzing environmental problems, and, ultimately, contribute to an increase in the reliability of assessments of the state of multifunctionally used lands.

Considering the features of the relief when organizing and conducting land monitoring will increase the objectivity and reliability of the assessment of multifunctionally used lands and contribute to their rational use.

References
[1] Trubina L K, Lisitsky D V, Panov D V 2013 Spatial differentiation of urban lands based on geoinformation analysis of the relief University Bulletin. Geodesy and aerial photography 4 149-152
[2] Kudinova A V 2016 Methods of using a single geoinformation space in the tasks of monitoring objects of the state cadastre of real estate (Moscow) 153 p
[3] Varlamov A A, Galchenko S A, Gvozdeva O V, Chuksin I V 2020 The process of digitalization of agriculture on the basis of a conceptually new system of smart land use International agricultural journal 63, 5(377) 69-72
[4] Panov D V, Chernovsky L A 2015 Analysis of spatial air pollution by transport using a 3D model of the urban area Interexpo GEO-Siberia-2015. 8th Int. scientific. Congr.: International scientific conference. Remote sensing methods of the Earth and photogrammetry, environmental monitoring, geocology: collection of articles. materials in 2 volumes (April 10-20, 2015, Novosibirsk: SGGA) vol 2, pp 107-112
[5] Gileva L N 2018 Monitoring of lands as an information basis for the management of the use of land resources and real estate objects: a tutorial (Tyumen: TIU) 128 p
[6] Varlamov, A, Gvozdeva, O, Zhdanova R 2019 Environmental requirements in land management of land use facilities IOP Conference Series: Earth and Environmental Science 012059
[7] Panova A Y, Ershov A V, Trotsenko E S 2018 Application of GIS technologies for monitoring land use Regulation of land and property relations in Russia: legal and geospatial support, real estate appraisal, ecology, technological solutions, vol 2, pp 126-129
[8] Zelepugin A, Zhdanova R 2010 Methodological features of land monitoring as a basis for land management International Agricultural Journal 2 54-58
[9] Diaz-Pacheco Gutiérrez 2015 Exploring the limitations of CORINE Land Cover for monitoring urban land-use dynamics in metropolitan area Journal of Land Use Science 243-259
[10] Sizov A P 2016 Monitoring and protection of urban areas (Moscow: Academy) 224 p