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CONSTRUCTION OF A DIGITAL RELIEF MODEL OF THE DENDROLOGY PARK USING GIS TECHNOLOGIES

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Geoinformation modeling, including the creation of digital terrain models, is one of the most effective research methods in both environmental and earth sciences. This approach makes it possible to study in detail the natural processes and phenomena occurring in a certain area with high accuracy and detail. Modeling of the nature reserve fund of the State Biotechnological University's arboretum using geographic information systems (GIS) is becoming an indispensable and effective tool for the conservation and rational use of natural resources. It helps to develop optimal territory management strategies and make informed decisions that take into account the environmental, aesthetic, and recreational aspects of the area.

The creation of a digital terrain model of the dendrological park is aimed at identifying and analyzing the main components of the natural environment, assessing their condition and dynamics, taking into account the impact of anthropogenic activities. This approach allows not only to understand the current state of the ecosystem, but also to predict its development in the future. The use of GIS provides the ability to process and analyze a large amount of geospatial data in a complex, which makes it possible to obtain comprehensive and objective information for making decisions on territory management. This, in turn, allows for effective planning of environmental protection measures, preservation of biodiversity and maintenance of ecosystems' sustainability.

Geoinformation technologies open up new prospects for environmental monitoring and research. They allow not only to record the current state of natural systems but also to predict their possible changes under the influence of various factors, including climate change. The use of such methods contributes to the preservation of natural heritage for future generations and ensures the sustainability of ecosystems in response to modern environmental challenges. Thus, geographic information modeling is becoming an important tool for ensuring sustainable development and preserving the natural resources of our planet. *Key words:* dendrological park, GIS technologies, geoinformation modeling, «Surfer» software, digital relief model, 3D model.

Побудова цифрової моделі рельєфу дендрологічного парку з використанням GIS-технологій. Бузіна І.М., Хайнус Д.Д., Сопова Н.В., Сопов Д.С., Чередниченко І.В., Гаврюшенко Г.В.

Геоінформаційне моделювання, зокрема створення цифрових моделей місцевості, є одним із найефективніших методів дослідження як у галузі екології, так і в науках про Землю. Цей підхід надає можливість детально вивчати природні процеси та явища, що відбуваються на певній території, з високою точністю та деталізацією. Моделювання природно-заповідного фонду дендропарку Державного біотехнологічного університету з використанням геоінформаційних систем (ГІС) стає незамінним та ефективним інструментом для збереження та раціонального використання природних ресурсів. Воно сприяє розробці оптимальних стратегій управління територією та прийняттю обґрунтованих рішень, що враховують екологічні, естетичні та рекреаційні аспекти даної місцевості.

Створення цифрової моделі рельєфу дендрологічного парку має на меті виявлення та аналіз основних компонентів природного середовища, оцінку їхнього стану та динаміки з урахуванням впливу антропогенної діяльності. Такий підхід дозволяє не лише зрозуміти поточний стан екосистеми, але й прогнозувати її розвиток у майбутньому. Використання ГІС забезпечує можливість обробки та аналізу великої кількості геопросторових даних у комплексі, що надає можливість отримати всебічну та об'єктивну інформацію для прийняття рішень з управління територією. Це, у свою чергу, дозволяє ефективно планувати заходи з охорони природи, зберігати біорізноманіття та підтримувати стійкість екосистем.

Геоінформаційні технології відкривають нові перспективи для екологічного моніторингу та наукових досліджень. Вони дозволяють не тільки фіксувати поточний стан природних систем, але й передбачати їхні можливі зміни під впливом різних чинників, включаючи зміну клімату. Застосування таких методів сприяє збереженню природної спадщини для майбутніх поколінь, а також забезпечує стійкість екосистем у відповідь на сучасні екологічні виклики. Таким чином, геоінформаційне моделювання стає важливим інструментом для забезпечення сталого розвитку та збереження природних багатств нашої планети. *Ключові слова:* дендрологічний парк, ГІС-технології, геоінформаційне моделювання, програмне забезпечення «Surfer», цифрова модель рельєфу, 3D модель.

Analysis of research and publications. Considering the growing relevance of the topic we have raised, this issue attracts the attention of numerous scientists. Researchers specializing in geographic information systems (GIS), environmental modeling, and natural resource management are actively developing new approaches and techniques to effectively use these technologies in creating highly accurate digital terrain models. These models are important not only for the monitoring and conservation of natural ecosystems, but also for the planning and management of areas such as dendrological parks.

Among the Ukrainian and foreign scientists who made a significant contribution to the research of this topic, the following authors should be noted: *Viktor Voytenko* – a well-known specialist in the field of geoinformation systems and remote sensing. He is engaged in the development of new spatial data processing methods, as well as the integration of GIS in various fields of science and industry; *Olena Kiselyova* – specializes in the use of GIS in urban planning and spatial planning. She researches issues of urban planning and develops tools for analyzing and visualizing data about urban areas; *Serhiy Stogniy* is an expert in the field of geoinformation mapping and landscape analysis. His research focuses on the use of GIS for environmental change monitoring and natural resource management; *Yuriy Panasyuk* – specializes in the application of GIS in agriculture and land resources. He actively works on the development of technologies for monitoring agricultural land and optimizing the use of land resources; *Lyudmila Kucher* – develops geo-information systems for environmental monitoring and assessment of the state of the environment. She actively implements GIS in ecosystem and natural resource management research; *Michael F. Goodchild* is one of the founders in the field of geographic information systems. His research focuses on theoretical and practical aspects of GIS, including terrain modeling and spatial analysis. He made a great contribution to the development of the concept of "spatial thinking" and the application of GIS in various fields of science; *Dan Wright* is known for his research in environmental modeling and landscape analysis using GIS. He is actively involved in the development of digital relief models (Digital Elevation Models, DEM) and their application in watershed studies and water resources management; *Steven Schenkman* – specializes in integrating ecological models with GIS for natural resource management. His work covers the development of methodologies for assessing landscape changes and forecasting ecosystem services critical to sustainable resource management; *Susan Schmidt* is an expert in environmental modeling and the use of GIS for ecosystem and biodiversity analysis. She develops models that help understand the impact of climate change on natural ecosystems and the possibilities of their preservation; *Paul Zipser* – specializes in the development of algorithms for creating high-precision digital terrain models based on remote sensing data. His research is aimed at improving GIS technologies for more accurate forecasting and management of natural resources.

Their scientific works significantly contribute to the development and implementation of GIS technologies in the practice of natural resource management and biodiversity conservation.

Methods and theory. The digital relief model of the dendrological park of the State Biotechnological University (Figure 1) was built with the help of the *«Golden Software-Surfer»* product [1].

When constructing *«Surfer»* surfaces, the following principles are ensured (Figure 2).

With the help of various options for overlaying maps, their different placement on one page, you can get the

Fig. 1. Dendrological park of the State Biotechnological University

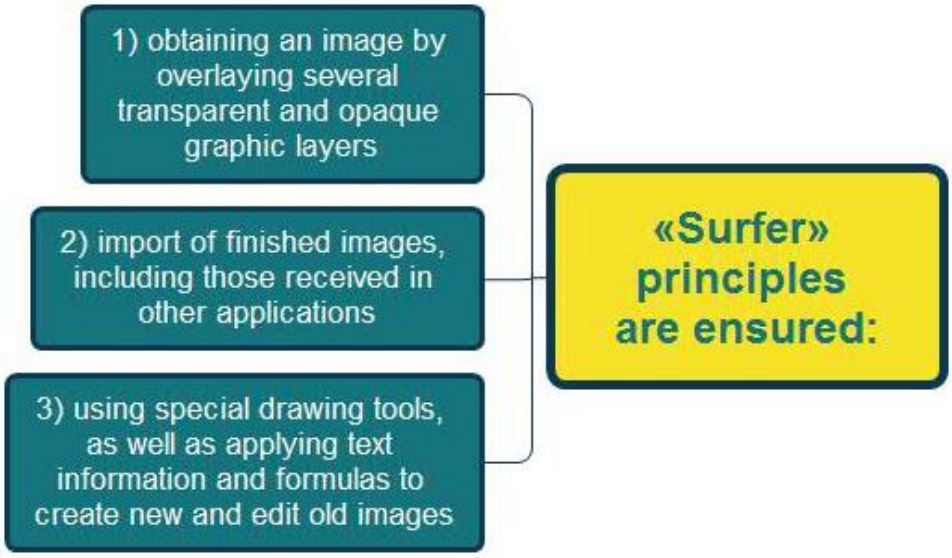

Fig. 2. «Surfer» principles

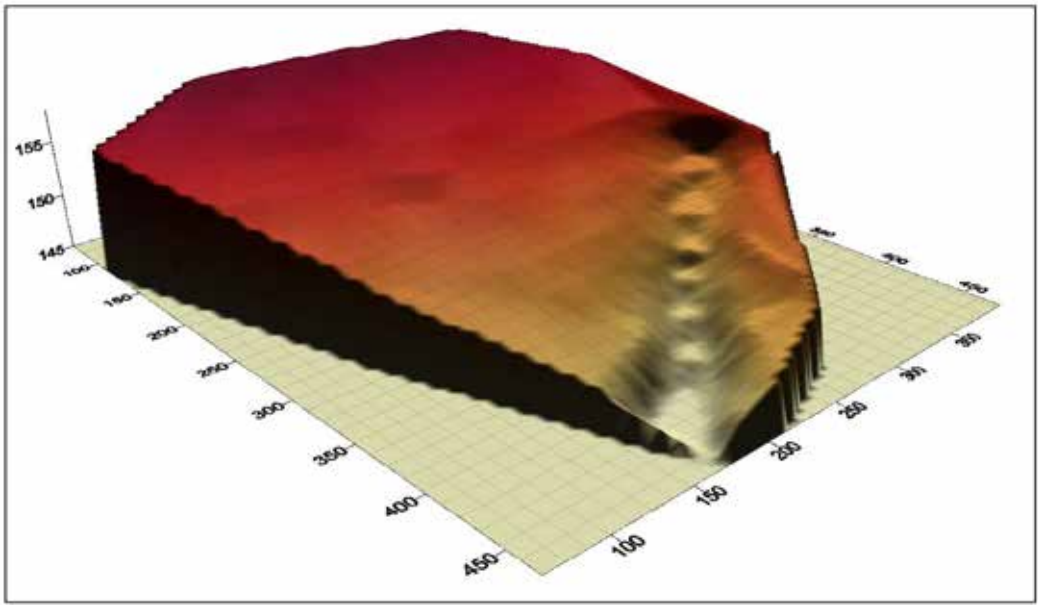

Fig. 3. Digital 3D relief model of a fragment of the territory of the Arboretum of the State Biotechnological University

most diverse options for presenting complex objects and processes. In particular, it is very easy to get various variants of complex maps with a combined image of the distribution of several parameters at once. The user can edit all types of maps using the built-in drawing tools of *«Surfer»* itself.

Results. To study the territory of the arboretum and the manifestations of the processes that take place there, it is necessary to have the widest detail of the topography of the surveyed territory. Figure 3 shows a digital model of the relief (a 3D model of a part of the arboretum was made using the *«Surfer»* program).

The presented mathematical 3D model can display information about the relief of the nature-reserved territory of the arboretum, the processes that occur at the time of research, and in some cases, predictions of behavior, certain phenomena [2].

The information obtained from this model can be used during the anti-erosion organization of the arboretum territory [11], the development of territory zoning projects, the organization of the territory of the nature reserve fund, for the optimal placement of the dendrological composition of plants, depending on the value of the steepness of the slopes.

The digital terrain model is intended for interactive visualization and has the effect of presence on the terrain. Similar models are used to justify measures to optimize land use in order to restore and stabilize the

ecological situation, assess the natural and recreational potential of the territory, monitor environmental components, forecast the development of transformational and degradation processes and phenomena in the environment (Figure 4).

The figure shows a part of the arboretum territory with agricultural groups. The use of the *«Surfer»* software package is a powerful tool for creating a digital model of the terrain. The program is an adapted system for creating three-dimensional maps, models, landscape visualization, grid generation and much more. The product allows you to create realistic 3D maps taking into account lighting and shadows, use terrain images in various formats, export the creation of maps in various graphic formats and print in color up to 50 meters diagonally [3].

The advantages of such modeling are various interpolation methods, means of assessing the accuracy and reliability of the built surface, clarification of the obtained results, provide an opportunity to visualize the spread of erosion and its consequences, and accordingly design a system of anti-erosion measures. Given the relevance of this problem, we see the practical application of 3D maps as promising directions for further scientific research [4].

One of the key aspects of modeling is taking into account the biodiversity of the territory. This includes the analysis of the location and distribution of the species composition of flora and fauna, the study of their interrelationships and ecological needs. GIS allows you to simulate these processes in a virtual environment, taking into account various influencing factors, such as climatic conditions, soil cover, relief, and others [11]. This approach makes it possible to ensure a scientifically based strategy for the conservation and development of the biodiversity of the arboretum [5].

In addition, the modeling of the nature reserve fund by means of GIS includes the analysis of the zoning of the territory taking into account various functional purposes [6]. This may include the allocation of zones for the protection of natural complexes, recreational zones for the relaxation of visitors, as well as zones for scientific and educational purposes. Modeling allows you to optimize the location of these zones taking into account their interaction and minimize conflicts between them [7].

The use of GIS also contributes to effective monitoring and control of the nature reserve fund [8]. This includes the systematic collection of data on changes in the ecosystem, the identification of threats and risks, as well as the evaluation of the effectiveness of measures for their prevention and elimination. GIS allows you to automate this process, which allows you to increase the speed and accuracy of the analysis, and also provides the possibility of prompt response to changes in the natural environment [9].

For conducting research on the territory of the dendrological park, samples were taken (Figure 5) from the upper fertile layer of the soil and the content of mobile forms of heavy metals (iron, manganese, zinc, copper, nickel, lead, chromium and cadmium) was determined by the method of atomic absorption spectrometry.

The obtained results showed the following results, the accumulation of elements occurs in the zones of lowering the relief of the area due to the flow of surface and ground water. The most dangerous of them are lead, cadmium, chromium, nickel, the concentrations of which exceed the maximum permissible concentration by 3-4 times, or are on the verge of exceeding it (Table 1).

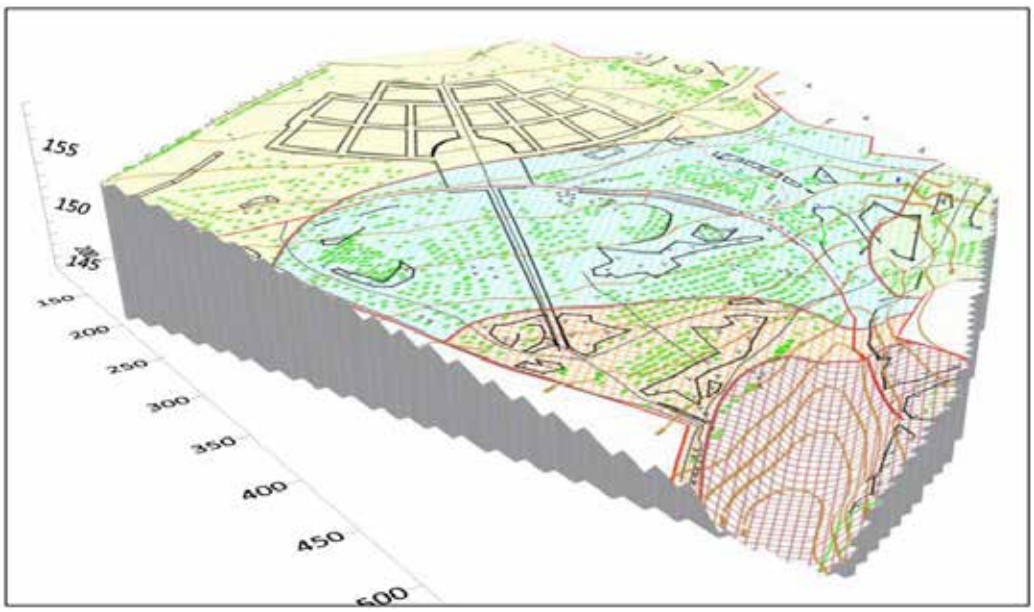

Fig. 4. Digital model of the location of objects on the territory of the arboretum

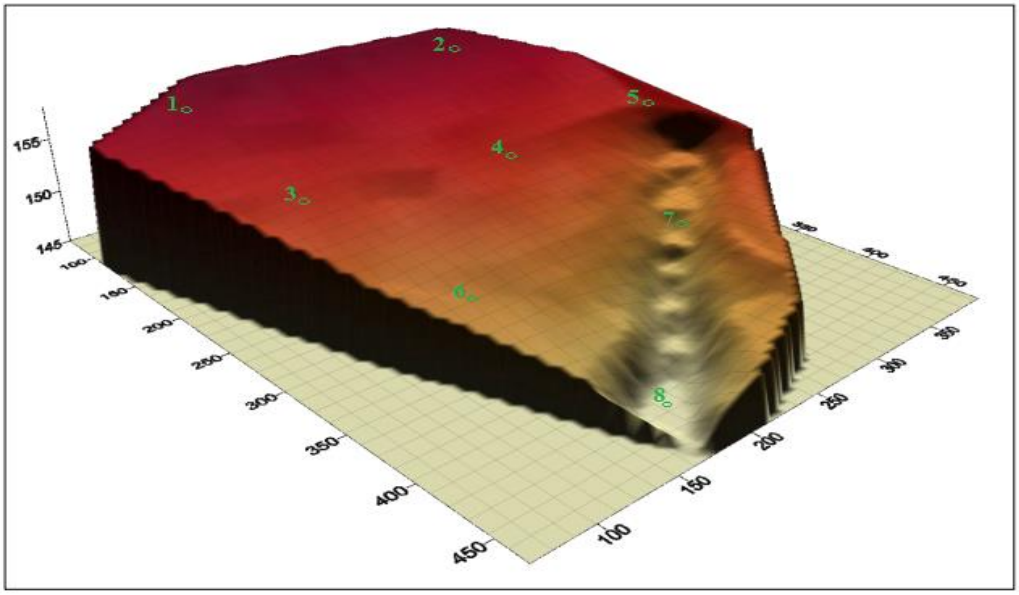

Fig. 5. Digital relief model of the arboretum territory (1_0, 2_0... – place and number of soil sample selection)

Table 1

Concentrations of heavy metals in the studied soils

Elements	Concentration (average value), mg/kg								
№	1	2	3	4	5	6	7	8	GDK
Iron	3,37	3,54	78,23	85,43	29,45	50,92	289,08	227,17	-
Manganese	40,62	16,43	228,97	147,85	103,94	52,57	185,15	215,45	50,00
Zinc	1,81	2,48	12,12	21,81	17,75	12,14	15,98	9,65	23,00
Cuprum	1,16	0,86	1,15	1,16	1,28	1,17	1,67	2,23	3,00
Nickel	2,45	3,49	2,85	2,73	4,24	3,96	3,78	4,74	4,00
Plumbum	2,47	3,75	4,53	4,89	3,59	3,18	6,52	7,12	2,00
Chromium	1,83	3,72	2,41	5,16	5,67	5,24	6,92	6,23	6,00
Cadmium	0,17	0,19	0,52	0,63	0,63	0,42	0,57	0,73	0,70

The highest concentrations of heavy metals were found in places of lower terrain, near the highway that borders the park, and in areas with a steep slope. Studies of the influence of the position of the site on various relief elements and exposures on the properties of soils are limited to date [10].

The statistical processing of the obtained results was aimed at revealing the relationship between the content of heavy metals and a number of indicators that could affect their accumulation: distance to the highway, depth of the sample, steepness of the slope and the average height of the sampling point.

Conclusions. Thus, GIS modeling of the nature reserve fund of the arboretum is a key tool for ensuring sustainable management and preservation of biodiversity. It makes it possible to analyze the complex relationships between different components of the ecosystem, taking into account various influencing factors, and to develop effective strategies for the management and development of the territory with the minimization of the negative impact on the natural environment. Given the constant changes in the ecosystem and the growing anthropogenic pressure, modeling becomes an important tool for adapting management strategies and responding to new challenges.

The key advantages of using GIS are its flexibility and scalability. GIS can process large amounts of data from a variety of sources, including satellite imagery, map data, aerial photography, and spatial observations. This allows you to take into account various aspects of the natural environment and carry out a comprehensive analysis of the relationships between them. In addition, GIS allows for high accuracy and reliability of modeling results through the use of geospatial analytical methods and tools. The application of digital research methods has great potential for improving the management and conservation of natural resources.

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