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VISUALIZATION OF AREA ILLUMINATION OF THE TERRITORY OF NATIONAL ARBORETUM PARK "SOFIIVKA" THROUGH GIS TECHNOLOGIES

The purpose of the research is to substantiate the need for the use of GIS technologies in the study of the illumination degree of garden and park plantings. The paper also focuses on the versatile relief characteristics of the territory of the National Arboretum "Sofiivka" of the National Academy of Sciences of Ukraine by conducting 3D modeling and creating digital models based on it. The models are determined by individual levels of insolation sections of the "Sofiivka" territory. They are aimed at optimal selection of planting sites for park vegetation depending on the needs of specific species, conducting zoning and visualizing the illumination of the territory. Studies Methodology. Topographic maps of scale 1:10000 were used to determine the illumination of areas of the Sofiivka park. The research also utilized GIS technologies and created 3D models of various terrain characteristics. Additionally, the SURFER software package was applied. Research Results. Based on the example of the Sofiivka Arboretum in Uman, the study considers the use of GIS technologies for the analysis of illumination for the site selection in the project development and the maintenance of parks and their plantations. The illumination of certain areas of the territory makes it possible to appropriately place objects (gardens, buildings, etc.) when creating projects. In particular, for parks, GIS technologies allow choosing suitable places for certain plants. The amount of light falling on a given area depends mainly on its relief, and for a small area, it is determined by its slope and orientation. So, the specified problems were solved using a digital model of the relief and the SURFER software package. For the first time, a digital model of the relief of the Sofiivka National Arboretum of the National Academy of Sciences of Ukraine was created using a 1:10000 scale topographic map with a relief section of 1 m. Based on it, a 3D relief model of the park territory, models of slope steepness, exposure and illumination of individual areas were built for the first time and their visualization was made. The offered images clearly show all the features of the relief in connection with the level of insolation, that is, the illumination of the territory, which is necessary for the needs of horticulture. Experimental studies using GIS technologies resulted in proving the possibility and necessity of the territory zoning of the park according to lighting. The lighting zoning of the territory according to the CDM allows the planting site selection of park vegetation depending on its optimal needs. The proposed technique contributes to targeted selection and diversity in plantations.

Key words: relief; park vegetation; solar radiation; modeling.

Introduction
Thesis Statement and Sources Review

The need to calculate the indicator of illumination of the territory, or solarization, often arises during the design, creation and maintenance of city parks and squares. The use of geoinformation technologies for this purpose allows not only to perform the necessary calculations efficiently and quickly, but also to visualize the obtained results with the help of computer technology and demonstrate them to customers of various park projects without significant labor and resource costs.

The work at the National Arboretum "Sofiivka" of the National Academy of Sciences of Ukraine, which belongs to the cultural heritage of the Ukrainian people, considered the use of geoinformation technologies (GIS) for the visualization of illumination when selecting areas during the project development and the maintenance of parks and their plantings.

The illumination of certain areas of the territory makes it possible to appropriately place objects (gardens, buildings, etc.) when creating projects. In particular, for parks, GIS technologies

allow choosing suitable places for certain plants, etc.

It is possible to solve the specified problems using a digital elevation model (DEM) and the SURFER software package, since the amount of light falling on a given area depends mainly on its topography, and for a small area, it is determined by its slope and orientation.

The analysis of publications shows that GIS technologies have taken hold in modern cadaster and land management and have become a key element in zoning territories by subject. There are a number of serious studies on the accumulation of solar energy carried out by [Levchenko, Shynkarenko, 2000; 2002; 2003].

These scholars have created a method of numerical analysis of the processes of absorption of solar energy by areas of the earth's surface, which can be used to conduct numerical studies related to finding the amount of solar energy received by areas of real terrain. An approach to solving the problems of surface-slope soil erosion research using the grid-surface mechanism is proposed. A key role in it is played by the DEM in the form of a grid surface. Together with the methods of its analysis it allows us to conduct a numerical analysis of the processes of water erosion of soils, providing such data (length, steepness, slope profile, etc.) that are difficult to obtain in other ways.

In general, in our opinion, the problem of solarization of the Earth's surface is quite widely presented in modern scientific publications. In particular, Korean scientists consider the method of mapping solar radiation based on GIS technologies [Yosoon Choi, Jangwon Suh & Sung-Min Kim, 2019]. American scientists [Stapleton, Wilen & Molinar, 2019] also present the developed soil solarization technology for gardens and landscapes. Although the research data are partially related to the purpose of this publication, they are connected with the study of technical means.

Spanish scientists A. Sanches-Navarro, R. Jimenez-Ballesta, A. Jirona-Ruiz and others. proposed rapid response indicators for predicting changes in soil properties due to solarization or biosolarization on intensive horticultural crops in semi-arid regions Sánchez-Navarro et al., 2022]. These authors developed an experimental model with four treatments in the Campo de Cartagena area (Spain).

The general research objective of these scholars was to use rapid response indicators to determine the changes occurring in soil properties due to the implementation of these solarization or biosolarization methods. At the same time, we note that the above-mentioned authors did not consider the topic of illumination visualization of large areas of territory.

Quite close to the topic of this publication are the studies of Lviv scientists – specialists in the field of landscape architecture and horticulture – N. Ya. Melnychuk, Ya. V. Genyk, S. P. Melnychuk and M. M. Paslavskyi. They highlight the peculiarities of the green plantings formation at urban ecosystems, focusing on some aspects of illumination of garden and park plantings in connection with the influence of microclimatic indicators [Melnychuk, Genyk, 2019; Melnychuk, et al., 2020].

These works emphasize the need to optimize the structure of forest parks and parks in Lviv, to improve the landscape planning and spatial organization of green zones. According to the comparison features of microclimatic indicators, namely the illumination of the above-ground surface, the authors distinguish three groups of areas: dark, medium-illuminated, and light.

O. O. Svitlichnyi and other scholars conducted a study of the spatial and temporal variability of soil moisture, which provides an important basis for assessing ecological (for forest restoration) and economic (for agriculture) conditions at the micro- and mesoscales [Svetlitchnyi, Plotnitsky, Stepovaya, 2003].

B. S. Busygin, H. M. Korotenko, and S. L. Nikulin systematized the domestic and foreign experience of using space remote sensing data, methods of transformation of multi-level and multi-temporal data sets, and software tools for their processing in the creation of a national Internet center for soil condition monitoring and development of methods for controlling the seasonal dynamics of soil processes [Busygin, Korotenko, Nikulin et al., 2016].

Publications related to the topic of this article, as well as topographical and geodetic direction of research are thoroughly reviewed in works [Horlachuk, Rudyi, Kravets, 2018; Rudyi, et al., 2021]. These authors note that in horticulture there is often a need to calculate the solarization index. The use of geo-information technologies for this purpose allows not only to perform the

necessary calculations efficiently and quickly, but also to visualize the obtained results with the help of computer technology and demonstrate them to customers of garden projects without significant costs of labor and resources. The researchers also analyzed the factors causing the danger of landslides in the territory of the Sofiivka National Arboretum of the National Academy of Sciences of Ukraine [Rudyi, Kyselov, Kravets, 2020].

The principles of building a situation when justifying the use of certain land plots for the respective purposes are formulated in the work [Samoilenko, Dibrova, 2019]. These authors emphasized, in particular, that the situation is based on the parameter of the degree of anthropization of the landscape. Such an index is the share of areas for geoecologically positive (or geopositive) and geoecologically negative (or geonegative) land use systems. Works in the field of horticulture are also close to our research [Chaploutskyi, 2014; 2016], however, GIS technologies were not used here.

Thus, the analysis of the considered publications shows that the goal of our research is relevant, as evidenced by the presence of numerous works that are similar in subject matter to ours [Melnychuk, Genyk, Melnychuk, Paslavskyi, 2020; Rudyi, Kyseliov, Kravets et al., 2021; Navarro, Ballesta, Ruis et al., 2022]. We emphasize the need to develop a methodology for zoning territories on public squares, at forest-park zones and other similar infrastructure facilities according to lighting. The use of GIS technologies to solve this problem will have significant practical potential in the future.

Purpose

The purpose of the research is to conduct the territory zoning of the National Arboretum "Sofiivka" of the National Academy of Sciences of Ukraine based on the illumination of the slope surfaces and to visualize it.

The main objectives of research:

– substantiation of the need to use GIS technologies in researching the illumination degree of garden and park plantings;

– conducting 3D modeling and creating a digital elevation model of the park territory based on it;

– modeling of the exposure of the slopes of individual sections of the park;

– determining the insolation levels of individual areas of the "Sofiivka" territory for the optimal selection of planting sites for park vegetation depending on the needs of different species.

The *object of the study* is the territory of the Sofiivka National Arboretum of the National Academy of Sciences of Ukraine. The subject of the study is the zoning of the park's territory by illumination depending on the topography of its surface.

Research methodology

Experimental studies were carried out using cartographic materials provided by the Research Institute of Geodesy and Cartography. A DEM was created for the object under study, for this, fragments of two sheets of a topographic plan on a scale of 1:10,000 with a relief section of 1 m were digitized using the SURFER package (Fig. 1). Geodetic points with spatial coordinates were used in the modeling. The size of the side of the grid was 3 m. The plot of land is located in Uman district of Cherkasy region, within the administrative boundaries of the Uman urban territorial community. The park boundary is outlined with a blue line.

Main Points

Analysis of results. Fig. 2 shows digital images (models) of the relief of the territory, reflecting its various aspects – a 3D model of hypsometry (Fig. 2, *a*), the steepness of the slopes (Fig. 2, *b*) and their exposure (Fig. 2, *c*), as well as a visualization of the illumination of the park territory with the applied relief (Fig. 2, *d*).

The analysis of the hypsometric characteristics of the relief indicates the presence of height differences of more than 50 m (absolute heights range from approximately 180–230 m). On elevations of the relief, the horizons stretch almost flat; as they approach the thalweg, they become more and more winding. This is especially noticeable on the right bank of the Kamyanka River (the tributary of the Umanka, the Southern Bug basin), dissected by ravines.

In the context of illumination of the territory of the arboretum, it should be noted that the slopes of the southern exposure are less fragmented than the slopes of the northern exposure. This creates prerequisites for the successful cultivation of plantations of light-loving species of trees and shrubs.

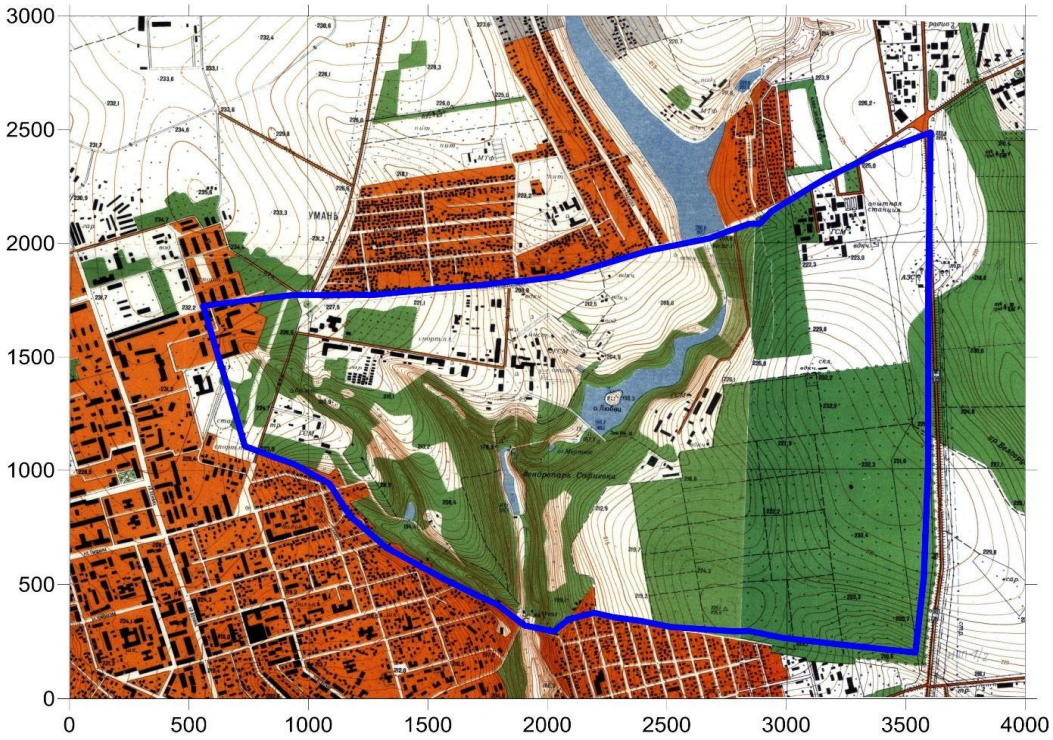

Fig. 1. A fragment of a topographical plan with the "Sofiivka" arboretum marked by a blue line

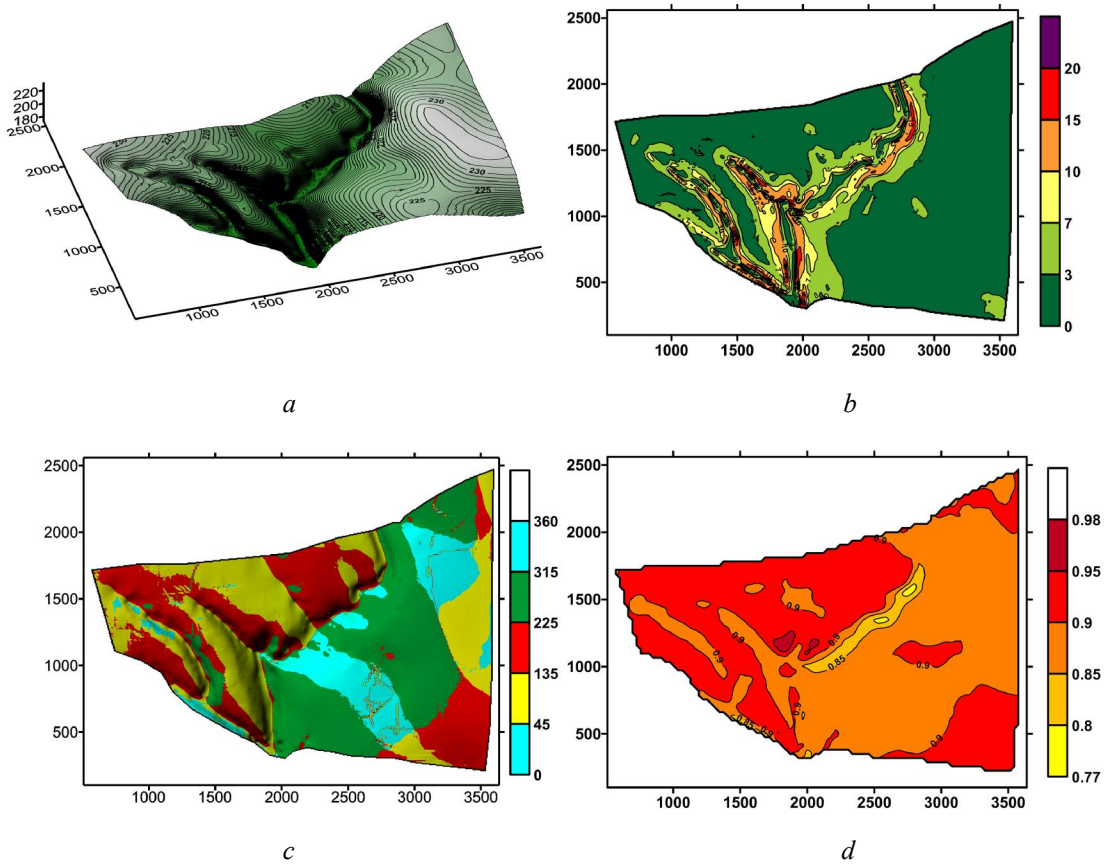

Fig. 2. Digital model of the relief of the "Sofiivka" arboretum: a – a relief space model of the arboretum with horizontals and changing intensity of the green colour depending on the altitude; b – the steepness of the slopes of plots of the arboretum; c– a model of orienting several plots of the arboretum (exposition); d – visualization of the illumination of the territory of the arboretum with applied relief

The scale in Fig. 2, *b* shows that the steepest slopes are located in the valley of the Kamyanka River, and the gentlest – on the elevated areas of the arboretum (English Park, Hrybok meadow, etc.). As you approach the river, the steepness of the slopes gradually increases, which is generally characteristic of the structure of the river valley.

Despite the fact that the Kamyanka River flows from north to south and, therefore, it is appropriate to distinguish the slopes of the western and eastern exposure. Nevertheless, among the slopes of the ravines that open in the Kamyanka, the southern ones are more gentle. This, of course, contributes to the organization of park plantings.

The scale in Fig. 2, *c* shows the orientation in degrees relative to the north of the slopes of the park. The gentle slopes are limited mainly to the northern and western parts of the arboretum, while they have mainly a southern exposure. These images clearly show all features of the relief in connection with the level of insolation or illumination of the territory, which is especially necessary for garden and park workers. At the same time, this image, like the previous ones, testifies to the favorability of the relief, in particular the exposure of the slopes, for arranging plantings of light- and heat-loving species of trees and shrubs.

The scale in Fig. 2, *d* illustrates the level of illumination of certain areas of the territory of the Arboretum "Sofiivka". This indicator does not differ significantly on the slopes of northern and southern exposure; more significant are the differences in the degree of illumination relative to leveled and steeply sloping areas. The highest level of illuminance is noted for the plakor, water-dividing surfaces (regardless of the exposure), the lowest – the bottoms of ravines.

It is also worth noting that even the lowest illumination indicators, compared to the rest of the park area, are quite high, exceeding 75 % of the maximum possible level. The amount of solar radiation depends on the angle C between the normal to the Earth's surface and the direction to the Sun. To determine the angle C, the formula was used [Rudyi, et al., 2012]:

$$\cos C = \cos H \sin i \cdot$$
$$\cdot \cos\left(180 - A \pm \arccos \frac{\sin \varphi \cdot \sin H - \sin \delta}{\cos \varphi \cdot \cos H}\right) +$$
$$+ \sin H \cdot \cos i$$

where H – the Sun's height; i – slope angle; A – slope exposure; φ – geographical latitude of the place of observation; δ – declination of the sun.

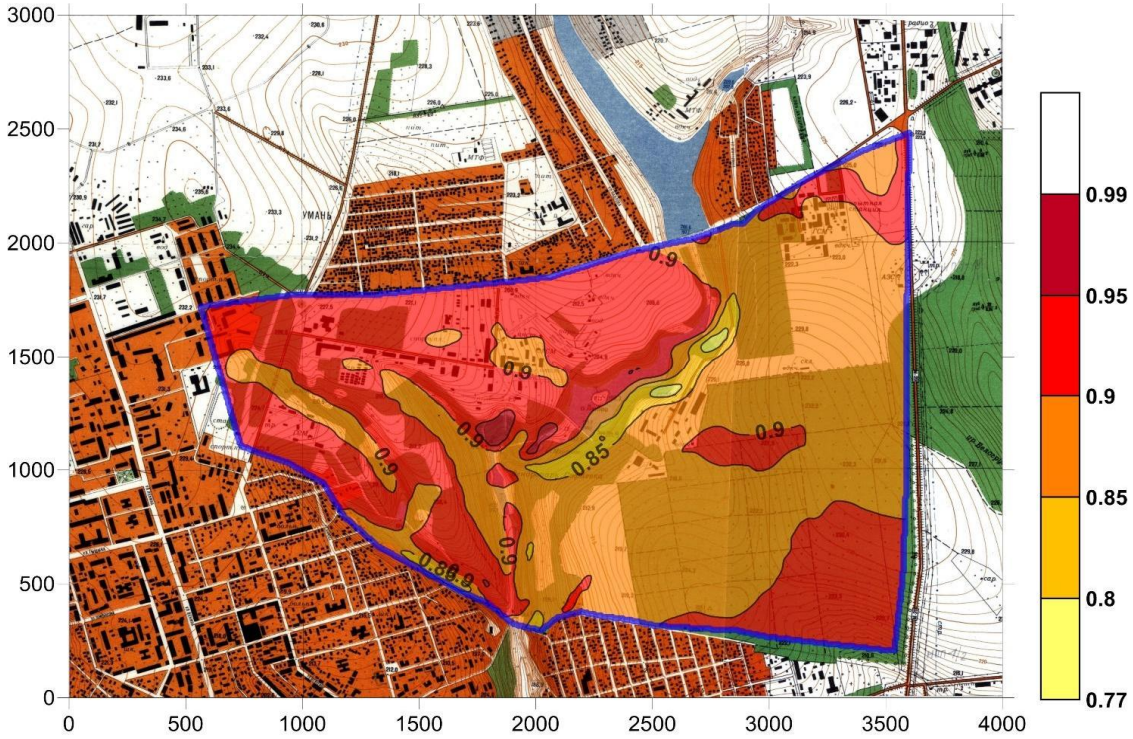

Fig. 3. A map of distribution of the illumination of the territory combined with an original topographical plan

Based on the obtained digital model, the zoning of the studied territory was performed according to the degree of illumination. Fig. 3 shows a fragment of a topographical plan sheet of the arboretum with the level of illumination of the territory. The change in the color of the filling from light yellow to dark red corresponds to an increase in the intensity of heating of certain areas of the park. The scale characterizes the amount of solar radiation in fractions from the maximum value, which is equal to 1. The comparison of the specified value with the horizontal indicates that its highest values are confined to the most exposed, mostly elevated, areas. On the contrary, the lowering of the relief, localized in the river valley and ravines, which are characterized by high indicators of the steepness of the slopes, correspond to relatively low values of illumination.

The novelty of the study. Compared with the latest data of Lviv scientists [Melnychuk, Genyk, 2019; Melnychuk, Genyk, Melnychuk, Paslavskyi, 2020], according to whom the areas of parks and squares are divided into the three categories mentioned above, the results of our study will allow us to visualize data on the illumination of garden and park plantings continuously, that is, continuously in space and time.

The **practical significance** of the study lies in the possibility of using the visualization of garden plots to achieve an optimal selection of tree and shrub species.

Conclusions

As a result of experimental studies using GIS technologies and analysis of the obtained data, the importance of the territory zoning of the park according to lighting has been proven. Lighting zoning of the territory according to the DEM allows planting site selection for park vegetation depending on its need for lighting. The proposed method does not exclude the need for purposeful selection and variety in plantations.

The analysis of the arboretum DEM design indicates the possibility of distinguishing three zones based on the hypsometry of the relief, steepness, exposure and illumination of the slopes: 1) northwestern, characterized by higher absolute heights, low steepness of the slopes, their significant illumination, but northern exposure; 2) central, characterized by the lowest absolute heights, the presence of steep slopes and their relatively low illumination; 3) south-eastern, characterized by the highest values of absolute heights in the park, the gentleness of the slopes, their high level of illumination and southern exposure.

Therefore, we believe that it is the southeastern part of Sofiivka that has the most favorable conditions for growing park plantations, including exotic ones, as for the temperate climate zone, and thus demanding of lighting conditions. So, in order to continue and multiply the glorious traditions of decorative gardening in the Sofiivka Park, the roots of which go back to the end of the 18th century, it is advisable, in particular, to arrange plantations of such species on the slopes of the southern and southeastern exposure.

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ВІЗУАЛІЗАЦІЯ ОСВІТЛЕНОСТІ ДІЛЯНОК ТЕРИТОРІЇ НАЦІОНАЛЬНОГО ДЕНДРОПАРКУ "СОФІЇВКА" ІЗ ВИКОРИСТАННЯМ ГІС-ТЕХНОЛОГІЙ

Мета досліджень – обґрунтувати необхідність застосування ГІС-технологій для дослідження ступеня освітленості садово-паркових насаджень, різнобічної характеристики рельєфу території Національного дендропарку "Софіївка" НАН України за допомогою 3D-моделювання та створення на його основі цифрових моделей, пов'язаних із визначенням рівнів інсоляції окремих ділянок території "Софіївки" задля оптимального підбирання місць посадки паркової рослинності залежно від потреб конкретних порід, здійснення зонування території. Для визначення освітленості ділянок території парку "Софіївка" використано топографічні карти масштабу 1:10000, застосовано ГІС-технології, зокрема створено 3D-моделі різних характеристик рельєфу та використано пакет програм SURFER. На прикладі уманського дендропарку "Софіївка" розглянуто використання ГІС-технологій для аналізу освітленості для вибору ділянок під час розроблення проєктів та експлуатації парків і їх насаджень. Освітленість певних ділянок території дає змогу, створюючи проєкти, відповідно розмістити об'єкти (садово-паркові насадження, будівлі тощо). Зокрема, для парків ГІС-технології дають можливість підібрати відповідні місця для певних порід. Оскільки кількість світла, що потрапляє на задану ділянку, залежить, передусім, від її рельєфу, а для невеликої ділянки визначається її нахилом та орієнтацією,

то з використанням цифрової моделі рельєфу й пакета програм SURFER розв'язано вказані задачі. Вперше із застосуванням топографічної карти масштабу 1:10000 із перерізом рельєфу 1 м створено цифрову модель Національного дендропарку "Софіївка" НАН України. На її основі вперше побудовано 3D-модель рельєфу території парку, моделі крутизни схилів, експозиції та освітленості окремих ділянок. Пропоновані зображення наочно відображають усі особливості рельєфу залежно від рівня інсоляції, тобто освітленості території, що необхідно для потреб садово-паркових господарств. У результаті виконаних експериментальних досліджень із використанням ГІС-технологій доведено можливість та необхідність зонування території парку за освітленістю. Зонування освітленості території за ЦМР дає змогу підбирати місця посадки паркової рослинності залежно від оптимальної потреби. Запропонована методика сприяє цілеспрямованому підбиранню та розмаїтості насаджень.

Ключові слова: рельєф; паркова рослинність; сонячна радіація; моделювання.

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