УДК 631.474

4.1.3. Агрохимия, агропочвоведение, защита и карантин растений (сельскохозяйственные науки)

ИСПОЛЬЗОВАНИЕ ГЕОИНФОРМАЦИОННЫХ СИСТЕМ В АГРОЭКОЛОГИЧЕСКОЙ ОЦЕНКЕ ЗЕМЕЛЬ

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В данной статье рассматривается возможность применение геоинформационных систем (ГИС) для агроэкологической оценки земель. Автор демонстрирует, как ГИС способствуют интеграции и анализу пространственных данных, что позволяет проводить оценку состояния рельефа, степени эродированности и связанных гидрологических показателей. Исследование основано на данных, полученных в Новокубанском районе Краснодарского края, где были выбраны участки с различным рельефом. С использованием цифровой модели рельефа (ЦМР), обработанной в QGIS и SAGA GIS, с помощью различных модулей (slope, aspect, TCA, TWI, LS-factor) автор провёл анализ геоморфологических условий исследуемой территории. Результаты показали, что ГИС-технологии адекватно отражают рельеф, гидрологические условия и степень эродированности территории, что подтверждается почвенно-ландшафтным картографированием. В статье предложена блок-схема использования ГИС для агроэкологической оценки земель

Ключевые слова: АГРОЭКОЛОГИЧЕСКАЯ ОЦЕНКА ЗЕМЕЛЬ, АГРОЭКОЛОГИЧЕСКАЯ ГРУППА ЗЕМЕЛЬ, ГИС, SAGA GIS

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4.1.3 Agrochemistry, agro-soil science, plant protection and quarantine (agricultural sciences)

USE OF GEOINFORMATION SYSTEMS IN AGROECOLOGICAL LAND ASSESSMENT

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This article discusses the possibility of using geographic information systems (GIS) for agro-ecological land assessment. The author demonstrates how GIS facilitates the integration and analysis of spatial data, which allows for the assessment of relief conditions, erodibility and related hydrological indicators. The study is based on data obtained in the Novokubansky district of the Krasnodar region, where plots with different topography were selected. Using digital elevation model (DEM) processed in QGIS and SAGA GIS, with the help of different modules (slope, aspect, TCA, TWI, LS-factor) the author analyzed the geomorphological conditions of the study area. The results showed that GIS-technologies adequately reflect the relief, hydrological conditions and degree of erodibility of the territory, which is confirmed by soil-landscape mapping. The article proposes a block diagram of GIS utilization for agroecological land assessment

Keywords: AGROECOLOGICAL EVALUATION OF EARTH, AGROECOLOGICAL GROUP OF EARTH, GIS, SAGA GIS

Introduction

Modern agriculture faces a number of serious challenges related to climate change, land depletion, ecological imbalance and the need to increase productivity to ensure food security. Under these conditions, the importance of effective land resource management based on scientifically proven data increases [1, 2].

Geographic information systems (GIS) provide a powerful tool for integrating and analyzing spatial data, opening new opportunities for agroecological land assessment.

GIS technologies make it possible to conduct highly accurate assessments of the state of soil and water resources, model spatial processes and phenomena such as erosion, salinization and changes in biodiversity, and also predict the consequences of various agricultural activities. With their help, it is possible to integrate remote sensing data, field research results and statistical data, which contributes to the formation of a comprehensive picture of the current state of agroecosystems and their dynamics [3, 4].

The use of GIS has already proven its effectiveness in practice, making it possible to optimize land use, minimize negative impacts on the environment and increase the resilience of agricultural systems to external influences. However, there are certain methodological and technical challenges, such as the need to improve methods for processing and interpreting data, adapting existing GIS applications to the specifics of local agro-ecological conditions and ensuring the availability of data for a wide range of users [2, 3, 5].

The purpose of this article is to consider modern approaches and methodologies for using GIS, to create a flow chart that clearly shows the use of GIS in agroecological land assessment. Understand the main models used in GIS for agro-ecological assessment and evaluate their adequacy based on a field survey.

Research conditions and methodology

The research was carried out using the example of the Novokubansky district of the Krasnodar Territory. For the study, several areas noticeably different in relief were selected to conduct tests with liquid complex fertilizers on different agro-ecological groups of lands (the studies conducted with liquid and liquid fertilizers were published in [7] and will not be considered in this article).

An analysis of the geomorphological conditions of the study area was carried out using a digital elevation model (DEM), built on the basis of ALOS PALSAR satellite relief images with an initial cell size of about 12.5 x 12.5 m. The images are available from the Alaska Satellite Facility website. Processing of the initial data took place in the geographic information systems QGIS (version 3.16.7) and SAGA (version 8.3.0).

The SAGA geographic information system provides a wide range of functions and modules that allow you to carry out various calculations and build models based on the available initial relief data. This article discusses the Basic Terrain Analysis tool, which includes 16 output data on terrain and hydrological indicators. For the initial agroecological assessment of the territory, the necessary modules are:

1. Slope (slope steepness) – shows the angle between the horizontal and tangential planes at a specific point [8]. Creates a slope grid, where at each point you can see the slope value in degrees. One of the main modules in agroecological assessment, it can be used to identify potentially erosion-hazardous areas.

2. Aspect – slope exposure, shows the direction of the slope relative to the cardinal points. It is important when assessing the development of erosion.

3. Total Catchment Area – processes cells from top to bottom to calculate stream flows, runoff accumulation and related parameters. Builds a

surface runoff distribution model based on DEM data. When analyzed, the model can show areas of water erosion that are formed when sediment moves down the slope.

4. TWI (Topographic Wetness Index) – topographic humidity index. The model value combines several parameters and shows areas with a potential lack or excess of moisture. The logical meaning of the model is described and discussed in the article by V.P. Stupin. [8].

5. LS-Factor– index of planar erosion potential, where L is the length and S is the steepness of the slope. The higher the coefficient value (red), the greater the influence of the relief on the processes of water erosion.

Results and discussion

Orographically, the relief of the study area has the appearance of a flat-undulating plain, with an average coefficient of dissection, including hollows and troughs of varying depths and degrees of incision. In fields that more often belong to the upland group of lands, there are microdepressions, depressions and other microrelief elements that play a role in the local redistribution of moisture (Fig. 1).

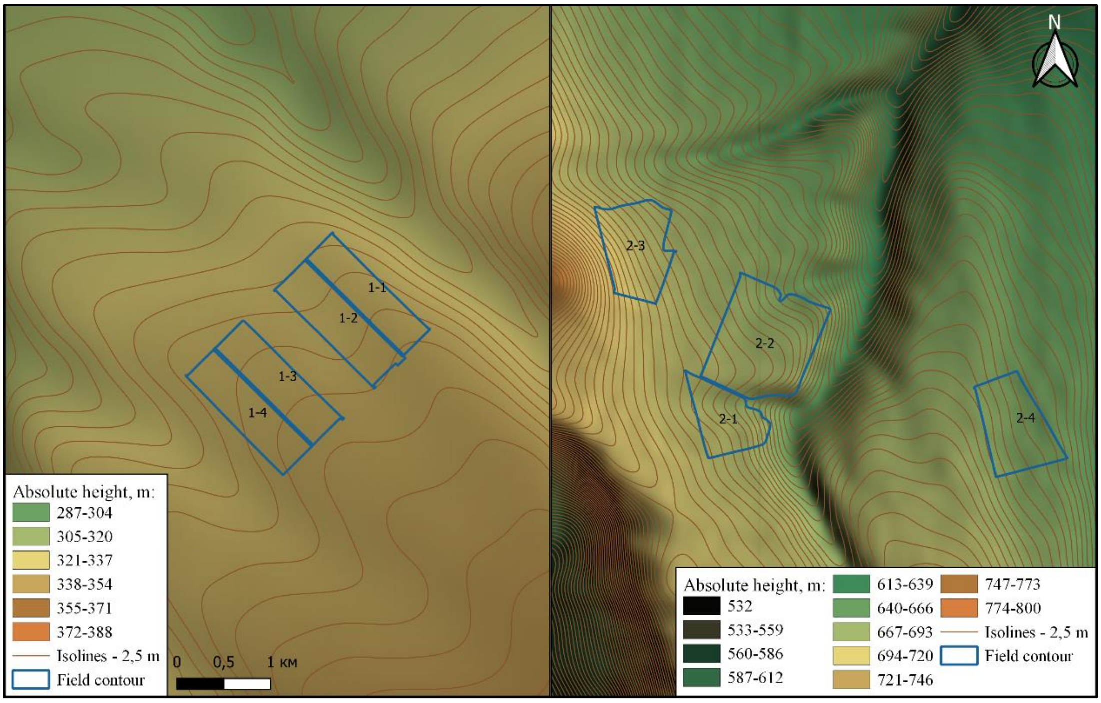

Figure 1. Digital elevation model cartogram

Creating a digital elevation model cartogram allows you to visually represent and analyze the relief features of a certain area. For research, areas belonging to various relief elements were selected - flat areas and areas located on slopes (Fig. 1).

The flat area is located in the middle part of a long watershed slope and is an almost horizontal surface with a slope of less than 1° (Fig. 2).

The sites of the second group are located in the middle and lower part of the slope of the watershed descending into the valley, with a slope of up to 3° of cold exposure (northeastern and eastern). [7].

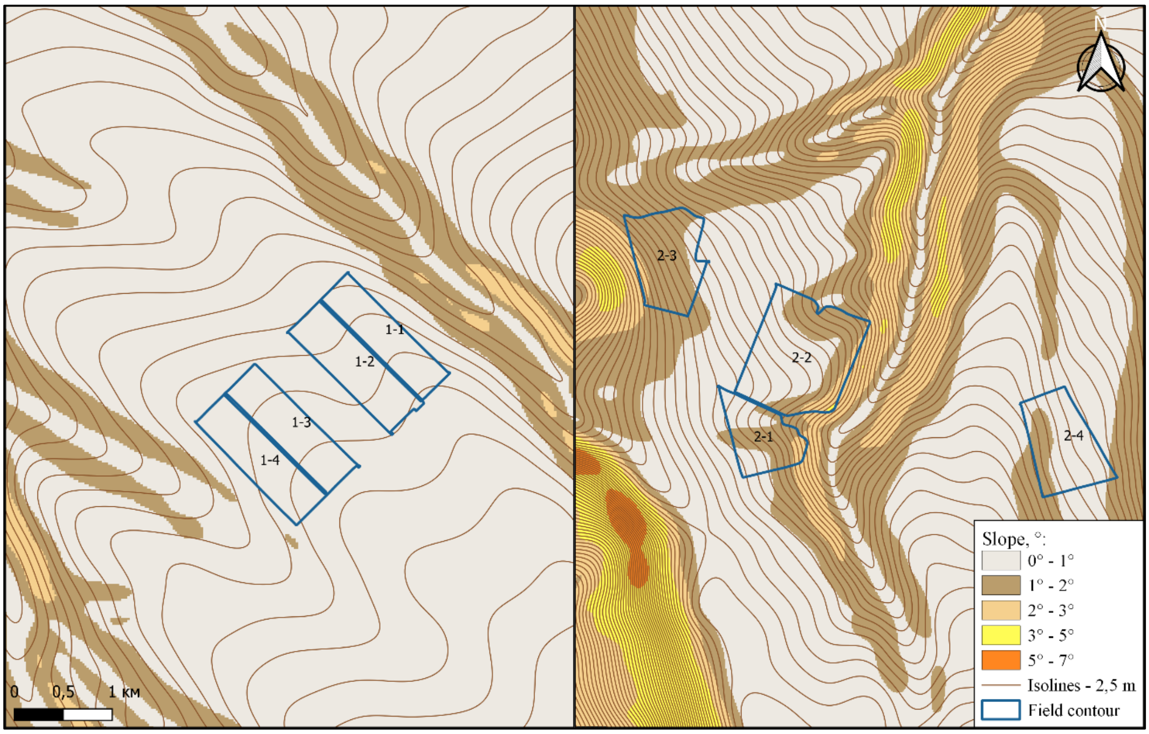

Figure 2. Cartogram of slope steepness (Slope)

On the cartogram of slope steepness (Fig. 2), groupings depending on the slope are shown in color. All fields participating in the study, located on a slope, have a concave shape and a steepness of up to 3°, which allows them to be classified as low-erosion lands.

Figure 3 shows a cartogram of watercourses built using a DEM (Total Catchment Area). This model shows the potential presence and direction of watercourses depending on the topography and slope steepness, and also displays places with the most likely excess moisture.

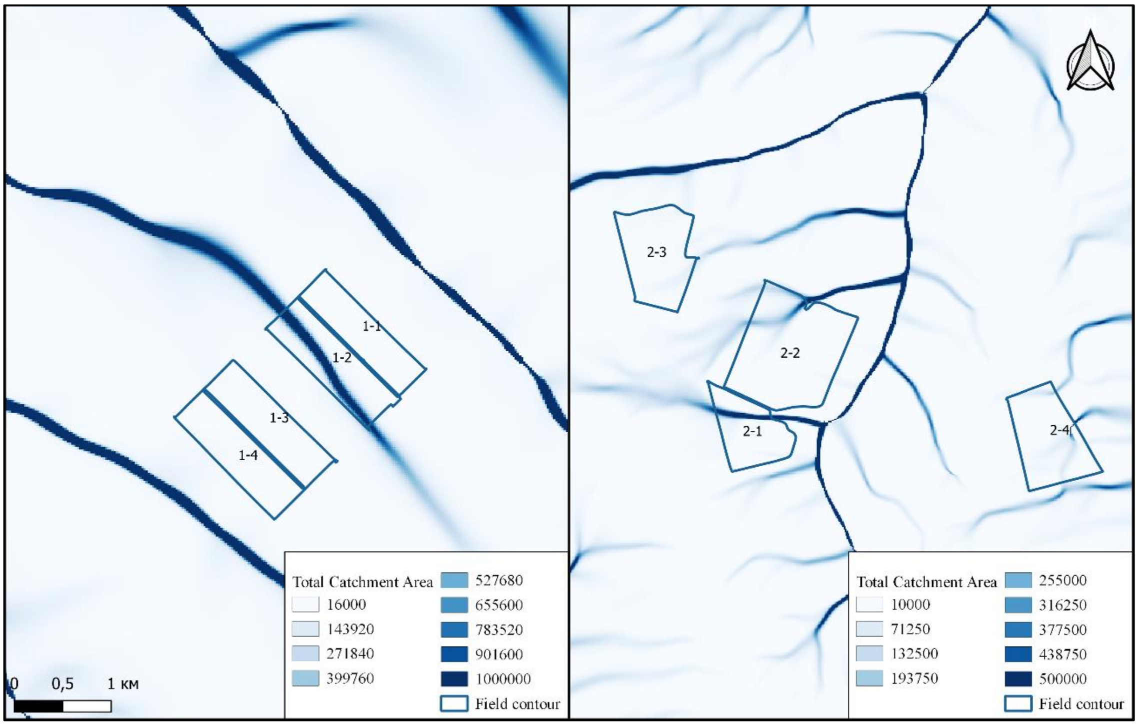

Figure 3. Cartogram of watercourses and catchment areas (Total Catchment Area)

In field 1-2 (upland area) there is a very noticeable watercourse, which during a field survey turned out to be a very weakly expressed depression passing through the entire field and the difference in moisture supply turned out to be insignificant. On the other hand, the presence and direction of watercourses correlates very well with the erosion group of landscapes; during the field survey, all the main watercourses indicated on the cartogram were confirmed. Taking into account that these fields are located on a slope, the presence of a significant number of small watercourses enhances the development of water erosion due to increased surface runoff.

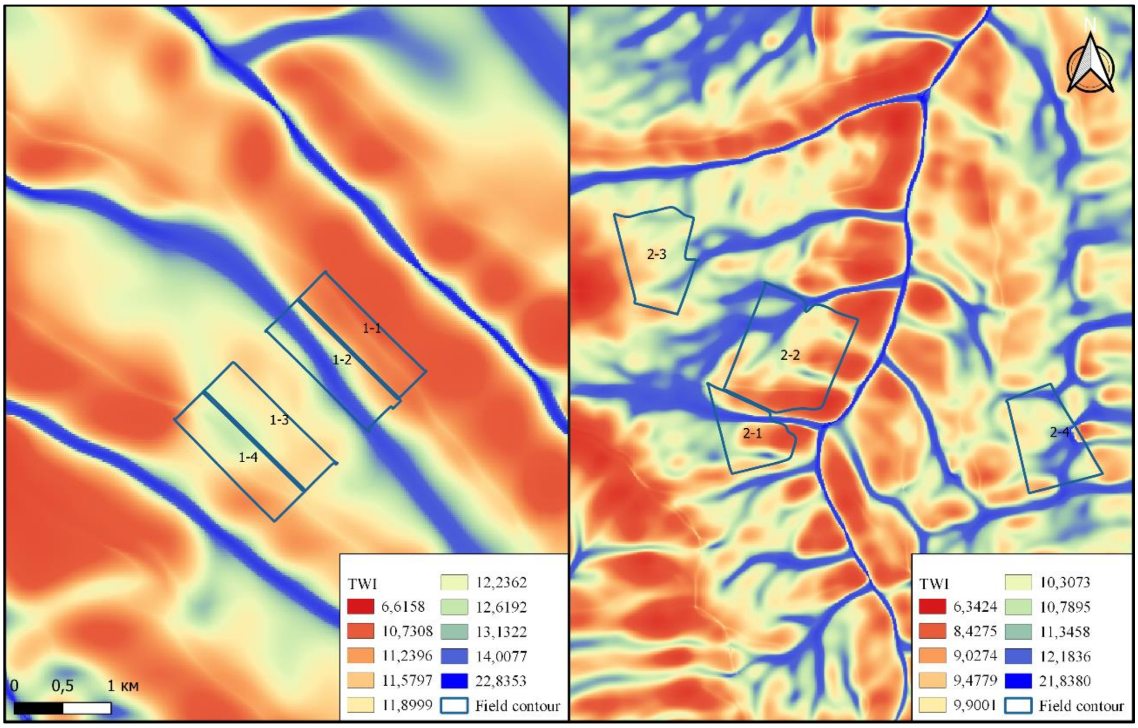

Figure 4. Topographic Humidity Index (TWI)

The topographic humidity index characterizes areas according to the degree of moisture supply and overall soil moisture, depending on the topography, slope, etc. (Fig. 4). This index was developed for areas with more complex terrain, since in flat areas (plain group) the indicators weakly correlate with real values. In our study, one of the differences between the selected agro-ecological groups of lands is moisture availability. Using the TWI index, you can visualize the relationship between moisture availability and landform. In areas classified as erosional lands, there is a pronounced lack of moisture on slopes of 2-3° (areas with lower moisture availability are shown in red) due to increased runoff.

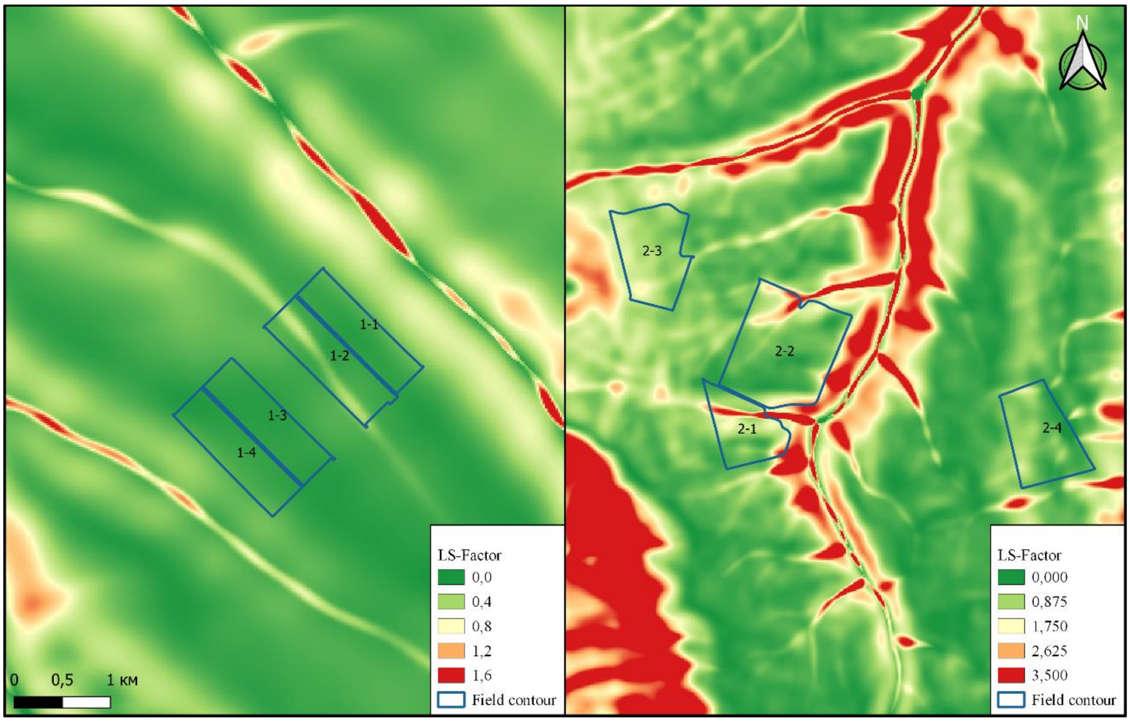

Figure 5. LS-Factor

LS-Factor is an index of planar erosion potential, where L is the length and S is the steepness of the slope. This parameter combines many variables, including the indices described above, taking into account the terrain and slope steepness. The physical meaning is that the greater the value of the coefficient (the maximum value is shown in red), the greater the influence of the relief on the processes of water erosion. Based on this index, it follows that on upland groups of lands the influence of relief on the development of water erosion is minimal compared to the erosive group of lands.

All indices and cartograms constructed using DEMs allow one to visualize and evaluate the contribution of relief to the formation and development of various processes, including water erosion.

On the slope exposure cartogram (Fig. 6), warm exposure is shown in red (this includes: south, southwest, west and southeast), and cold exposure is shown in blue (north, northeast, east and northwest).

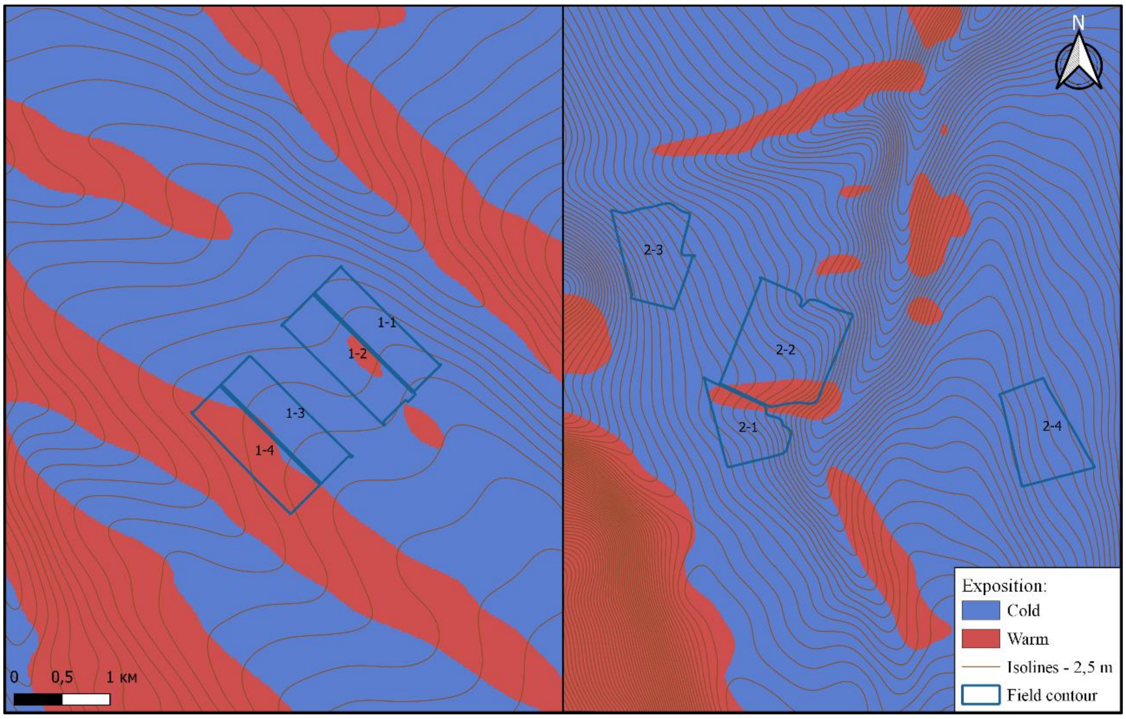

Figure 6. Cartogram of slope exposure (Aspect)

Slope exposure has a significant impact on microclimatic conditions and the intensity of soil loss. In years with unstable snow cover and frequent snowmelt (up to 2-3 times per winter), erosion processes intensify, especially on southern-facing slopes, since such areas have a high heat supply, which will significantly affect the potential for water erosion processes.

As a result of the analysis of data from a digital elevation model and models obtained on its basis, it is possible to evaluate the relief of the study area from different angles and make an assumption about the potential structure of the soil cover. To check and verify the data obtained, soil and landscape mapping was carried out; the nature of the survey and route points were set taking into account the models and the obtained relief data.

The first array of fields (1-1, 1-2, 1-3 and 1-4), confined to the flat landscape, is located in the middle part of a long watershed slope with a steepness of less than 1°. The soil cover is represented by typical thick heavy loamy chernozem on loess-like light clay (the thickness of the humus horizon is

80-100 cm). They are represented by automorphic soils, which predominate on flat, drained areas with minimal slope - the upland group of lands.

Fields 2-1, 2-2, 2-3 and 2-4 differ from upland lands, as they have limiting factors that do not allow them to be classified in this group. The main limiting factor is related to the relief and steepness of the slopes; such lands differ from upland lands in that they have uneven moisture and heat supply. The soil cover is represented by combinations of typical medium-thick chernozems of varying degrees of erosion, from slightly eroded to moderately eroded. They are distinguished by a shortened humus horizon compared to upland lands, and are also characterized by lower moisture availability and increased erosion processes [7].

Taking into account the landscape-ecological analysis of the territory and agroecological typification of lands, two groups significantly different in terms of agrolandscape conditions were identified: upland lands - represented by automorphic zonal soils and low-erosion lands - located on a slope of 1-3 degrees [6].

Effective management and improvement of agricultural and natural resources requires a comprehensive approach that includes the collection, analysis and integration of semantic and graphical data. Analysis of which allows us to draw up a flowchart for the use of GIS in agroecological assessment of land, taking into account the example described above (Fig. 7).

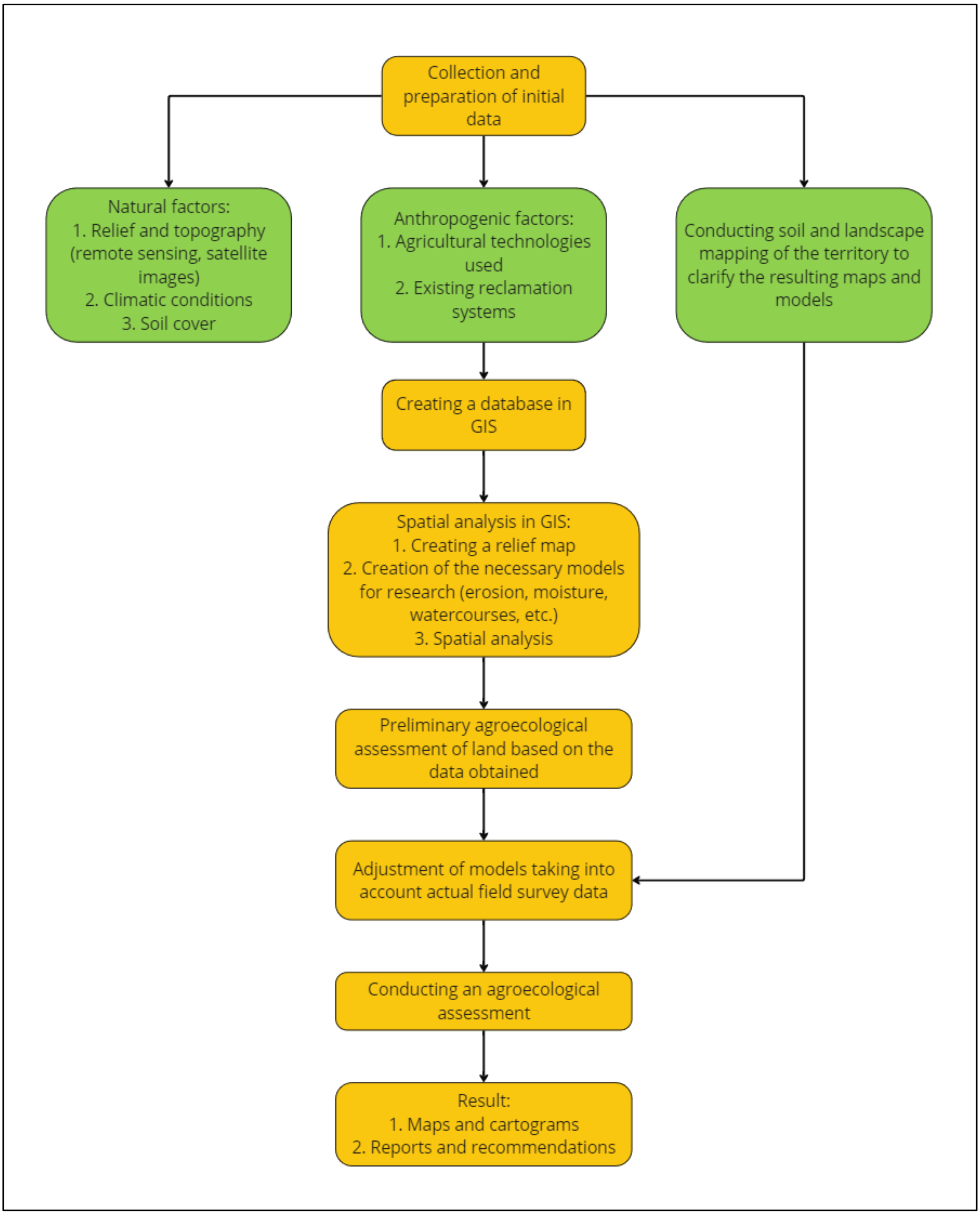

Figure 7. Flowchart of using GIS for agroecological land assessment

The flowchart uses a hierarchical approach, capturing the main stages and processes associated with the use of GIS for agro-ecological land assessment. Each block provides a visual representation of the process of using GIS for agroecological assessment of land, contains a description of the corresponding stage and assigned tasks.

Conclusions

The study demonstrates that soil-landscape mapping is an effective tool for identifying patterns of land cover change. These changes directly affect plant growth and development conditions, highlighting the importance of accurate mapping for agroecological land assessment.

A digital elevation model serves as a reliable tool for obtaining objective data necessary for a deep understanding of landscape structure and its impact on agro-ecological processes. Models developed on the basis of DEMs adequately reflect the relief, hydrological conditions and degree of erosion of the territory. The soil-landscape mapping carried out showed a regular change in soil cover and different conditions for the growth and development of plants using the example of the Novokubansky district of the Krasnodar Territory.

The resulting models reliably reflect the characteristic features of the relief, as well as the associated hydrological indicators and the degree of erosion. However, it should be noted that the topographic humidity index (TWI) and the cartogram of watercourses (Total Catchment Area) in upland areas (left side of the map) do not correctly display their functions and require the development of other approaches to interpreting processes.

During the field survey, the indicators of the moisture supply index of the territory on slope areas were confirmed, while on the upland group of lands the index incorrectly reflects the degree of moisture supply of the territory.

Taking into account the conducted research, we can say that the use of geographic information systems in modern agro-ecological assessment of the territory is an indispensable tool that provides a fairly large amount of adequate data based on DEM. The use of GIS facilitates more detailed preparation for field surveys and optimization of routes, which leads to reduced time and increased efficiency of field work.

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