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Improvement of methods of soil survey of territories using remote sensing and 3d-modeling

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Abstract. The effective planning and use of land resources depends to a large extent on the completeness and relevance of the digital data on the territory concerned. A modern solution for obtaining such data is the use of unmanned aircraft systems, with the presentation of the results in the form of digital elevation models and 3D-models. The article presents the practical results of the use of this technique on the example of a part of the territory with heterogeneous relief, shows its advantages with respect to the use of traditional analog data, the main directions and prospects of use for the rational use of land in land management and design of soil and environmental systems of agriculture.

Introduction. As a result of changing socio-economic conditions in Russia and the transition from a command-and-control administrative economy to a market economy, agricultural producers were faced with the need to independently plan the use of their land, based on their specific characteristics. Natural features and resource potential of land differ significantly depending on landscape conditions. The most important factor of differentiation is the terrain: differences in height above sea level, the nature of the surface, steepness, shape and exposure of slopes, the presence of forms of microrelief, etc. Depending on these factors, there are such important agronomic characteristics as heat and moisture content of soils and agrocenoses, the level of soil fertility, which in turn determine the entire technological complex of growing certain crops.

In the 60-80s of the XX century, information about the natural resources of the area was provided by the soil survey of the territory by the regional design institutes of the Giprosem system. The method of field soil survey of this period was based mainly on the use of aerial photographs as a topographical basis, as well as plans for land and forest management. Traditional soil maps can still be considered as a model of soil cover [1], however, given the gradual accumulation of variability of soil characteristics and the uncertainty of boundaries between elementary soil areas, the accuracy of such a model is limited by the subjectivity of the judgments of the soil scientist-cartographer. Topoplanes with relief lines were used mainly in areas with highly rugged terrain, as well as when conducting soil surveys of large and detailed scale for the design of reclamation (drainage and irrigation) systems.

Currently, the increased requirements for soil maps are implemented on the basis of expanding the composition of mapped features and studied dependencies, with the use of new methodological tools and techniques, including GIS technologies, with the involvement of information from other sections of soil science and related disciplines. An important direction in the development of methods for displaying the shapes of the earth's surface is 3D modeling based on the processing of aerial photography data obtained using modern unmanned aircraft systems of aircraft and helicopter types, as well as the application and subsequent automation of the procedure for processing the results of lidar survey using air laser scanners. The greatest attention in the development of this field is given to the modeling of real estate objects (especially in urban areas) [2-4], but the direction of using digital data for the design of soil and environmental systems of agriculture has not received wide coverage in the scientific and technical literature, which confirms the relevance of the study.

The object of research is selected part of the territory of LLC "Altair" Loktevsky district of the Altai territory. The site is named "Samarka". It is located in the foothills of the Altai plain. The relief of the studied territory is characterized by a significant dissection with a predominance of surfaces with an angle of inclination of 1.5...3.0°. The area of the site is 1920 ha. Coordinates from 50.9 to 50.95° North latitude and from 81.55 to 81.63° East longitude. The map of the soil survey of 1975 was used as the initial information basis.

The method of research work included a survey of the terrain using an unmanned aerial vehicle Supercam-250, equipped with a SONY alpha 6000 24.3 MP camera, a high-precision onboard receiver JAVAD TRE-G3TAJT, then a field soil survey, the production of a relief map and a soil map.
On the basis of the obtained digital material, a digital terrain model was formed, according to which a fragment of a 3D relief model of the studied area was created. For photogrammetric processing of the results, the Agisoft Photoscan software package was used, which sequentially created a sparse and dense array of points and directly a 3D model. For clarity, the results were presented in a model area characterized by relatively large height differences (from 256 to 358 m) with an area of 52 Hectares.

Results and discussion. The accuracy of the soil survey increases significantly when using a digital terrain model (DEM). In this work, the DEM was created based on digital aerial photography from unmanned aerial vehicle with a resolution of 9 cm per pixel, using marked reference and control points. The accuracy of DEM is about 25 cm in height, that fits to the contour interval of 1 m. Construction of the DEM and DTP (digital topographic plan) was carried out using the programs Photoscan (Agisoft, Russia) and GIS-View. The DEM was presented in two versions: 1) the high-altitude part of the DTP scale of 1: 2000 in the form of pickets and horizontals through 1 meter, superimposed on the orthophotoplane. In this embodiment, shows the major forms of mesorelief that should be mapped to the DTP at an appropriate scale; 2) the elevation matrix in which each pixel corresponds to a square on the surface of the size 0,5x0,5 m This option allows the DEM to refine the surface features, including the level of the microrelief forms and surface features with dimensions of tens of meters even with slight fluctuations in elevation.
In this work, the resulting digital mapping model allowed us to detail the surface features, including the level of microrelief-the slope of the surface in degrees, the direction of surface runoff and erosion, surface shapes and elements of the size of units and tens of meters with height fluctuations up to 1.0 m (Fig. 1).

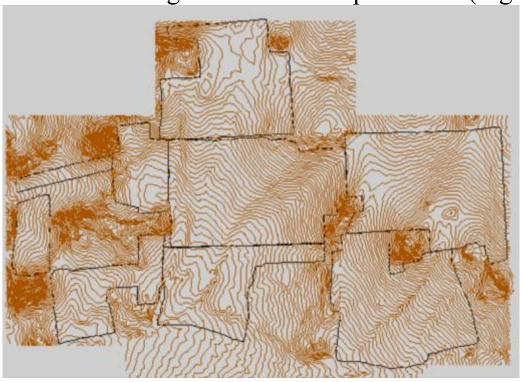

Fig.1. High-rise part of the DTP section "Samara". Isolines are drawn through 1 m. Straight lines are the boundaries of agricultural fields.

The thickening of the relief isolines reflects the location of local elevations in the studied space – hills, the soil cover of which is characterized by a low power of the humus horizon (12-15 cm) due to erosion processes, or almost complete absence of it, the output of gravelly rocks to the surface. Agricultural fields are located in spaces between the hills. There is a marked feature of the topography – the slopes are of complex shape, called accordion. This character of the slopes is particularly conducive to the development of linear erosion processes that form deep hollows and gullies in a short time.
As a result of processing the data of aerial photography of the research object, the following results were obtained:
- digital terrain model, presented as a gradient image (Fig. 2);

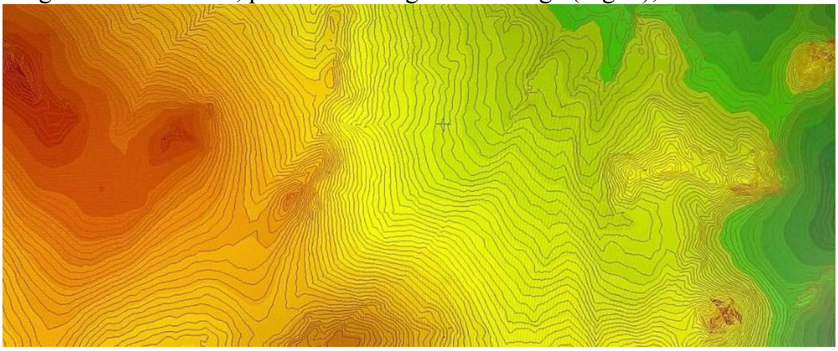

Fig..2. Digital model of the relief of the object of research

- spatial profiles that allow you to identify areas of the territory that are most susceptible to erosion processes and accordingly plan various reclamation activities (Fig.3.);

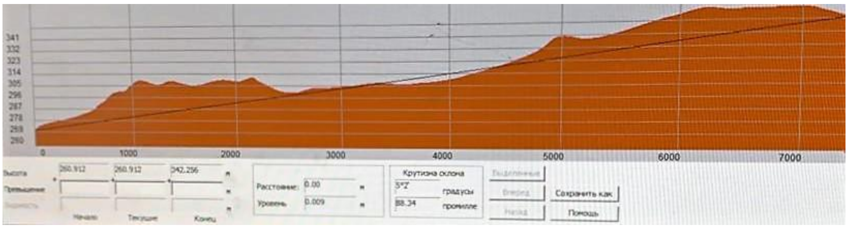

Fig. 3. Spatial profile of the simulated territory

- automatically generated statistical analysis of the simulated territory, necessary for calculating the volume of work and the economic component (Fig.4.);

Fig. 4. Statistical analysis of the simulated territory

- 3D-model of the territory with different gradient color, clearly displaying the features and heterogeneity of the terrain (Fig. 5).

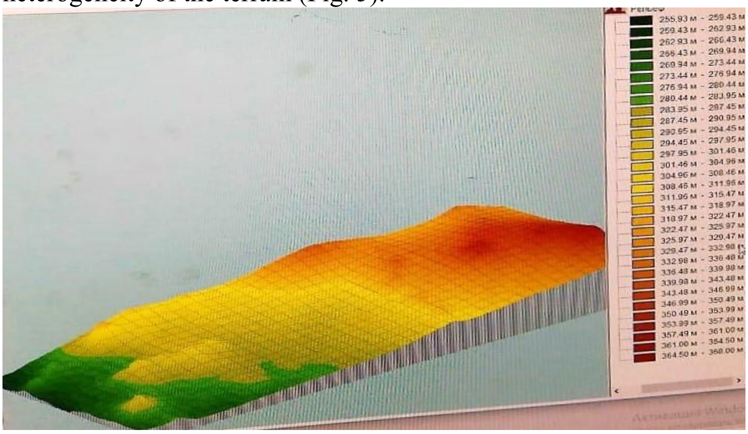

Fig. 5. 3D-model of the study area

These results allow us to identify two characteristic features. First, the heterogeneity of the slope surface and, as a result, the soil cover. It is significantly complicated by elements of micro-relief: micro-depressions and micro-hillocks, which is the cause of significant heterogeneity in the degree of soil moisture. Secondly, the model allows us to distinguish at least three high-altitude zones on the surface of the study area as a whole: high (marks in the range from 340 to 368 m above sea level), medium (from 284 to 340 m above sea level) and low (from 260 to 284 m above sea level). The boundaries between them provide greater accuracy of extrapolation of soil data obtained by the method of point soil sections. In addition, the presence of such a model significantly reduces the amount of ground soil survey associated with the identification of transition zones from one soil difference to another.

Conclusion. Modern technology, the use of digital data obtained by aerial photography as the basis for the formation of a single spatial territories, and functionality of existing software products for photogrammetric processing of results and creation of 3D-models significantly simplify the process of designing soil conservation systems of farming, organization of rational land use in land management and other fields. The use of such an integrated approach, in conjunction with the existing materials of soil and geobotanical surveys allows you to create a complete, comprehensive and up-to-date digital database of territories and automation of such work with a significant reduction in the use of human resources. In addition, the data obtained are the basis for various mathematical calculations in real time, including the volume of earthworks, land management activities, etc. The findings are demonstrated on the example of the study area, confirm the relevance and the scientific significance of the topic and are the basis for further research on this topic.

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