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Methods of remote sensing in ratial use of land resources

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Abstract

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One of the most important issues of our time is the use of existing natural resource potential, especially land resources. Variety of ownership forms and ensuring their equality in modern Russia served as a condition for development of many forms of agriculture, the formation and development of new and effective forms of agriculture management for the country. Also, the motivation of citizens to a more rational use of available land resources and introduction of rational methods of environmentally safe land use has increased. These circumstances caused an urgent need for objective information on land resources, control of changes in the use of land, especially agricultural land.

The use of remote sensing data is of particular interest in obtaining estimates of land use. Remote sensing today is a huge variety of methods and techniques for obtaining images of the earth's surface, it's subsoil, water bodies in all ranges of electromagnetic spectrum and radio band. Also the possibility of different options for creating images, with different degrees of visibility and detail. Today's methods of remote sensing are modern automated information systems for collecting and processing information on available land resources, which are now increasingly being introduced in agricultural areas. According to the data obtained from remote sensing, the structure and dynamics of agricultural landscapes are studied. Positive and negative aspects of agricultural impact on the land are analyzed. Tasks of state land monitoring are solved.

Key words: remote sensing; land resources; aerial photography; scanning

Introduction

For rational use of land resources it is necessary to form a single information resource on the processes leading to the degradation of the soil cover, the state of fertility and the actual use of agricultural land. As a result of this the development of methodological approaches to the use of geological information technologies in order to optimize land use and rehabilitation of degraded areas, cartographic registration and forecasting of changes is of paramount importance (Wu et al., 2016).

Climate and special aspects of land use affect characteristics of the soil cover. Soil cover is a layer of living, dry or dead vegetation covering the surface of the soil. Information on soil cover is generally a good indicator for controlling the level of land use. Remote sensing allows us to estimate the area of dry or dead vegetation, which just like living vegetation, protects the soil from wind and water erosion. These results provide a more accurate estimate of the risk zone from wind and water erosion than before (Guerschman et al., 2014).

Usually soil cover monitoring uses the estimation of the amount of photosynthetic active material on the surface as a substitute of vegetation cover in remote sensing images. For Example, Lu and co-authors use for this purpose vegetation indices, such as normalized differential vegetation index (NDVI) (Lu et al., 2003a). These indices were successfully applied in the soil erosion model for subsequent assessment of losses and development of soil erosion tendencies (Lu et al., 2003b).The main drawback of this approach based only on NDVI is that the nephotosynthetic component of the soil cover, which includes stubble, rotted grass and leaf litter cannot be distinguished from arable land. As a result of this , the efficiency of soil erosion modeling is reduced (Guerschman et al., 2009).Besides, not being taken into account the erosion that occurred due to mechanical effects of different aggregates on the soil when treating the soil cover (Rakhimov et al., 2018). According to Kustas & Anderson (2009) the use of thermal infrared light has a wider range of applications in hydrological modeling, ecosystem assessment, weather and water forecasting, as well as crop yields.

There are two main areas of study of land cover based on remote sensing; environmental management and environmental studies. Environmental management ensures the distribution and control of land use while maintaining environmental functions. Environmental management refers to scientific analysis of processes (both natural and caused by mankind) related to determination of land cover (Aplin, 2004).

Bastiaansen et al. (2000) studied the possibility of using remote sensing data to obtain accurate information about the conditions and processes occurring on the earth's surface. These studies have shown that the quantitative assessment of soil-vegetation-atmosphere transport processes can lead to a better understanding of relationship between the growth of agricultural crops and distribution of land resources (Wim et al., 2000).The science of remote sensing has become an important and universal tool for organization of careful use of natural resources by government agencies, environmental protection organizations and industrial enterprises (Philipson & Lindell, 2003; Stow et al., 2004; Gross et al., 2006). For the rational use of resources, the use of satellite remote sensing technology is of particular importance. This technology allows monitoring the dynamics of the landscape over large areas, including areas where access is difficult or dangerous. It also lightens the extrapolation of expensive ground-based measurements (Li et al., 2003; Schuck et al., 2003; Kennedy et al., 2009).

More than a hundred years ago the American society of agronomists was created. Back then no one could have imagined that we would be able to study the earth's surface distantly using remote sensing methods. At that time people used observation to qualitatively assess the vegetative characteristics (strength, light, etc.) of plants. The development of special devices such as sensors for measuring the spectral reflectivity or emissivity of plants has created new methods for improving the control of crops using remote sensing methods (Hatfield et al., 2008).

Over the past three decades remote sensing technologies and techniques have undergone significant changes. They received a set of tools operating at a wide range of visualization scales that may be of interest and importance to designers and land surveyors. Combined with the easy access to remote sensing data as well as data cost reduction and increased resolution from satellite platforms, remote sensing technology seem to be able to exert more influence on the process of planning in management of land resources, which are associated with monitoring changes in soil and vegetation cover and land use at different spatial scales. Modern remote sensing technology allows us to collect and analyze data from terrestrial, atmospheric and orbital platforms, linking them to GPS data, GIS layers and data functions and new modeling capabilities (Franklin, 2001). This has made remote sensing a valuable source of information on land cover and land use. As the demand for increasing volumes and quality of information grows and as technologies continue to improve, remote sensing will become even more important in the future (Wong & Sarker, 2014).

Remote sensing and geographic information system provide vital tools that can be during analysis at the district as well as micro level. Remote sensing provides an overview and data on the temporary use of land resources (Nigam, 2000). Technologies that are based on remote sensing and geographic information system can be used for planning and sustainable development of region territories (Singh and Kumar, 2012). Land use planning based on land resource assessment and spatial orientation planning as a part of GIS can ensure proper land allocation to achieve sustainable agriculture (Bhermana et al., 2013; Vikhe & Patil, 2014). Although geographic information systems and remote sensing are well-known information technologies, the value of which for land and natural resource management is now widely recognized.

Main advantages of remote sensing include the high speed of obtaining data on large areas of the earth's surface, as well as the ability to obtain information about objects that are almost not accessible for research using other methods. The need to obtain reliable information about land plots is noticed by both state and municipal authorities in land resource management, determining the direction of prospective development of human settlements, conducting rational land and tax policy and private entities of land law that use land in agricultural production. As part of the fight against desertification, remote sensing makes it possible to monitor areas that are at risk in the long-term perspective, to determine the factors of desertification, to assess the depth of their impact, as well as to provide the necessary information to persons responsible for decision-making on the adoption of appropriate environmental protection measures (Tokareva, 2010; Shovengerdt, 2010). As part of resistance against desertification, remote sensing allows us to monitor areas that are at risk in the long term. Remote sensing also helps to determine the factors of desertification, to assess the depth of their impact as well as to provide the necessary information to those responsible for decision-making on the introduction of appropriate measures to protect the environment (Tokareva, 2010; Shovengerdt, 2010).

The purpose of these studies is the analysis and methodological justification for the use of remote sensing methods for the rational use of land resources.

Methods

There are two technologies of space photography: recording with photographic systems and scanner systems. Remote sensing is carried out by special devices or by sensors in other words. Sensors can be passive and active. Passive sensors capture reflected or emitted natural radiation. Active sensors are able to emit the necessary signal themselves and record the signal's reflection from an object. Passive sensors include optical and scanning devices operating in the range of reflected solar radiation, including ultraviolet, visible and close range infrared light. Active sensors include radar devices, scanning lasers, microwave radiometers, etc.

The most common type of remote data today is digital images taken by space scanners. These devices register reflected from the earth's surface solar radiation in several spectral ranges (visible and infrared) and the images thus carry a huge amount of important information about the structure and state of vegetation, expressed in quantitative, digital form. As an alternative, people use flying drones in combination with space images and the use of GIS technologies.

Flying drones (UAV)equipped with cameras and highly sensitive sensors. UAVs are able to examine agricultural areas of impressive size in a few hours. Information collected by cameras and sensors on the UAV allows a farmer to create electronic maps of fields in 3D format, calculate the Normalized Difference Vegetation Index (normalized vegetative index) for the purpose of effective fertilization of crops, inventory work, protection of farmland, etc.

The main problem when working with data obtained by UAVS is the limited capabilities of hardware and software to create the final product (orthophotoplan) from hundreds and thousands of digital images. For these purposes photogrammetric systems can be used. There are many photogrammetric systems such as EnsoMosaic (Finland), TopoAxis, Agisoft PhotoscanPro, PCIGeomatica (Canada), PHOTOMOD, Talka, PostflightTerra3D (Switzerland) and249 others. Each of these programs has its own capabilities and limitations. Each of these programs has its own capabilities and limitations. To obtain orthophotos and a digital model of the area that will satisfy regulatory documents, it is necessary to follow strictly a certain sequence of actions when performing photogrammetric and cartographic works. The obtained theoretical and practical results allow us to get a conclusion about the possibility of applying digital images from UAVs in engineering-geological studies, geographical studies, cartographic support of sustainable development of territories and rational use of land resources (Galeyev, 2017).

Results

When organizing the rational use of land resources, remote sensing is one of the fastest and most accurate sources of data on land plots. According to the results of aerial photography obtained using UAVs, it is possible to keep records and control the state of agricultural land, create electronic maps of fields, predict crop yields, identify degraded and forested lands of agricultural producers, work on the organization of territory for agricultural enterprises, etc. Analysis of information obtained from aerial photographs helps to determine the terrain, size of fields, borders of water bodies (lakes, rivers, swamps) and roads.

The use of flying drones for land management can significantly reduce the cost of renting aircraft and at the same time provide greater efficiency due to the high mobility of the UAV (Guide to aerial photography, 1988). The complex use of remote sensing data has proved to be effective. In preparation of initial data for development of measures for the effective use of agricultural land in the city Ufa which is a district of the Republic of Bashkortostan, images that were taken by a UAV in 2017 and orthophotos (scale 1:10000) for the summer of 2007 were used (Figure 1).

The obtained initial data becomes the material that helps us to create a geographic information system for the organization and management of agricultural production. For example, point application of fertilizers, the definition of agrochemical properties of soils, etc. In this process both foreign and domestic information products are used.

Based on the obtained images and orthophotos, layer-by-layer registration of the obtained initial materials in the geoinformational product is performed. This means that the

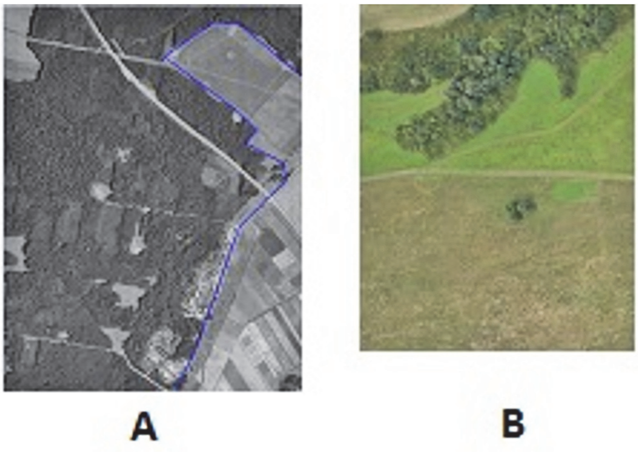
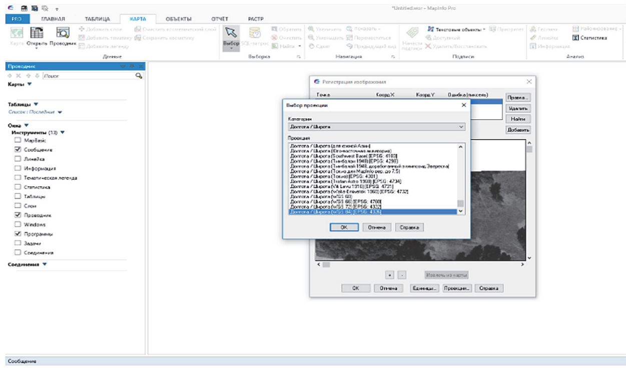


Fig. 1. *A*) Orthophoto with a scale of 1:10 000 flight of 2007; *B*) Aerial photo taken by a UAV in 2017

orthophotos plan must be attached. For this we specify the type of projection, the coordinate system and 4 points at the edges and 1 in the center with coordinates.

Attachment is going by an already registered orthophoto. A characteristic point is selected on the plan (it can be crossing of roads, house edge, etc.) and on that spot the point of attachment is placed. At the same time this point is located on the orthophoto, from which its coordinates are extracted. These coordinates are automatically recorded in the selected



Fig, 2. Attachment of initial data

attachment points on the plan. Based on this, the coordinate is assigned. Registration is carried out by at least 5 points. The accuracy of registration is directly affected by the number of attachment points (Figure 2).

Unfortunately, the time difference between the plan and orthophotos is 7 years. As a result of this, when the plan is applied on the orthophotos, even with a sufficiently accurate registration, the images may not be identical. For this, the program provides an option to optimize the bitmap. After the plan registering the program creates a file with the points and their coordinates. Automatic vectorization takes place

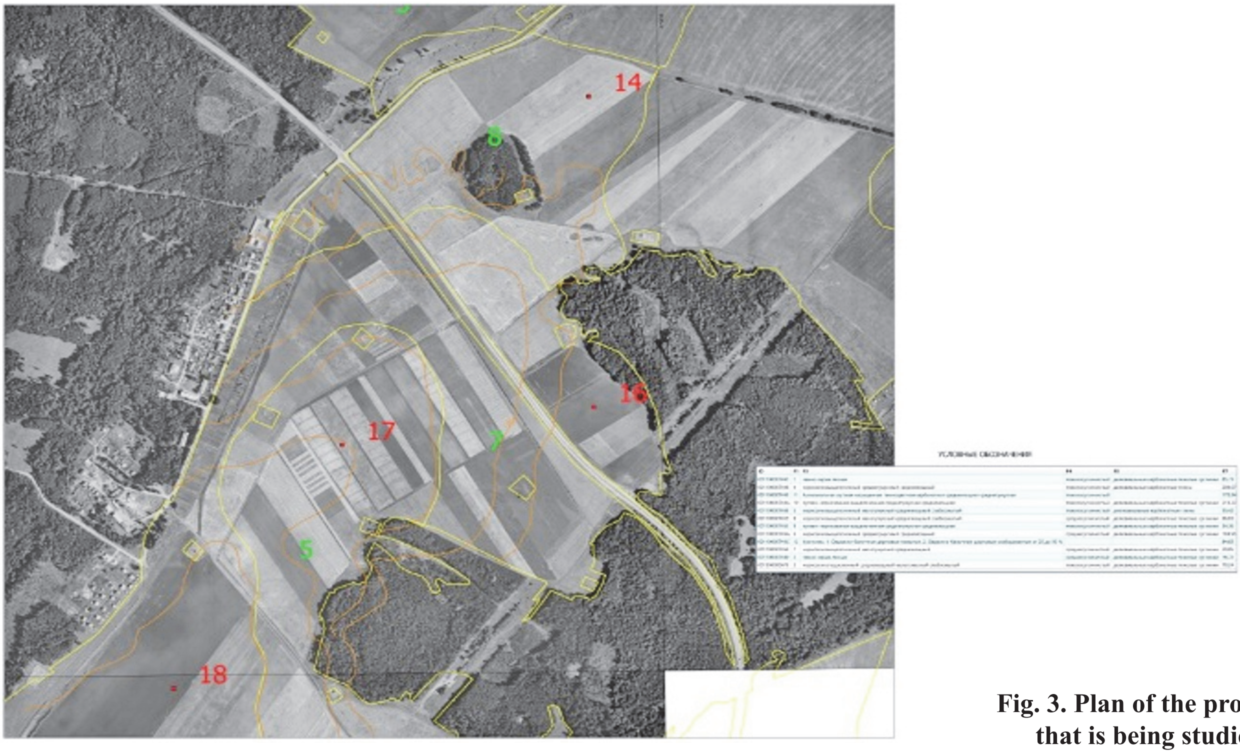


Fig. 3. Plan of the property that is being studied

almost without human participation, but is not suitable, for example, for tracing fields, as automatic tracing goes on all the same lines on the map with certain characteristics.

The field boundary lines are exactly the same as the boundary lines of rivers, houses and other territories. In this case all objects on the map will be traced. Automatic vectorization is suitable, for example, for drawing topography. To outline agricultural contours, the polygon tool is perfectly suitable. Placing points in places where the direction of the line changes and drawing the entire contour, the polygon closes at the end and becomes an area object with such characteristics as the coordinates of the corners and centroid. The borders of neighboring fields often coincide with each other, so there is no need to draw a common side twice. In the point alignment mode it is possible to combine the lines in such a way that there is no clutter of the map and that eliminates errors (Figure 3).

After the contour tracing process is complete, the topology validation process is a mandatory step. Errors are found on the map. Requirements for vector maps are the same as for paper maps. General rules of cartographyare followed here. They are already included in the program. Next (or during vectorization progresses), each object is given a unique name, for example, the contour number or the name of the river. The name must be unique, because later semantic information will be attached and the program performs a comparison of the name in the table of objects with the name in the data table.

On such technology the contour of the site was created and the plan of the investigated land plot was prepared for field researches.

After field registration of sampling points, the obtained list of geographical coordinates is loaded into MapInfo as a table of adaptive data with the numbers of sampling points, which are applied to the cartographic basis. The next step is to load the same data into QGIS and render it. Download of the same data that we created in MapInfo is done easily, because QGIS interprets these types of data.

Visualization is the creation of a thematic map. In QGIS it is implemented through an interpolation module or by creating a thermal map. In our case, the interpolation module was used. Use of known values of a quantity at certain points to estimate unknown values at unknown points is called spatial interpolation. Due to the high cost, limited time and resources data collection is usually done on a limited number of spots. In GIS, interpolation of obtained values allows you to build a raster image, pixel values of which are estimated values derived from the point data (Figure 4).

It is possible to use different visualization of single-channel false colored or multi-channel multi-color accord-

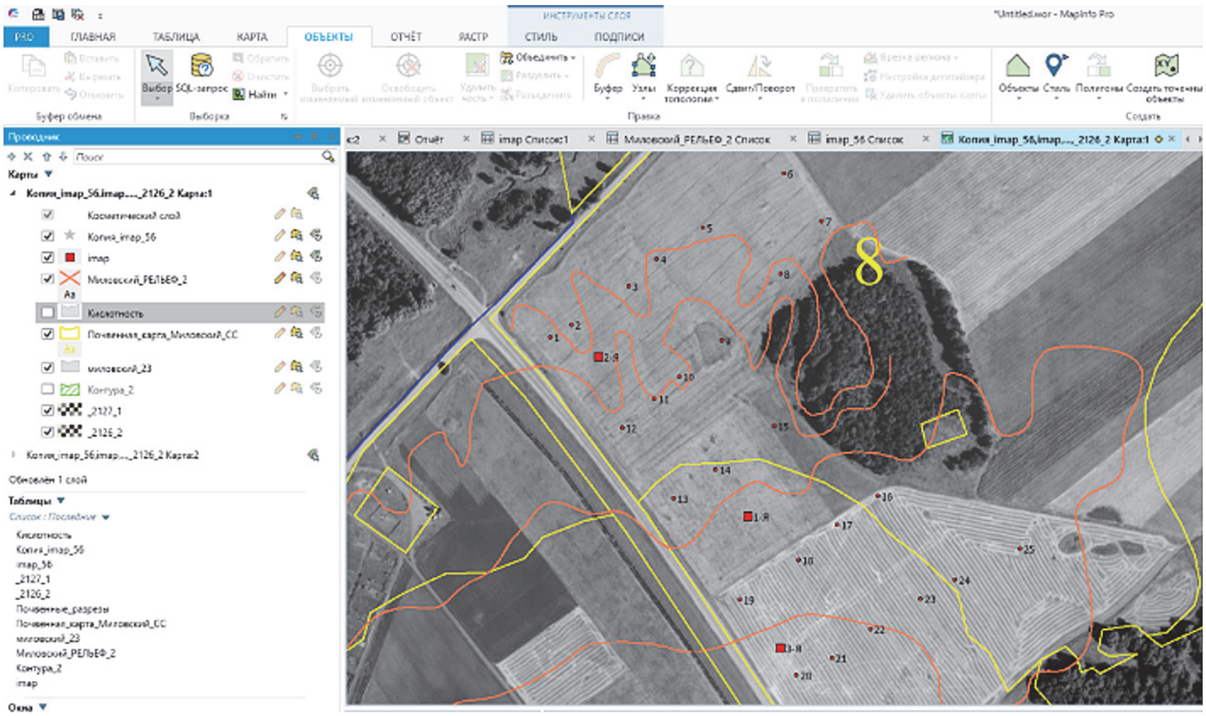


Fig. 4. Application of sampling points on a cartographic base

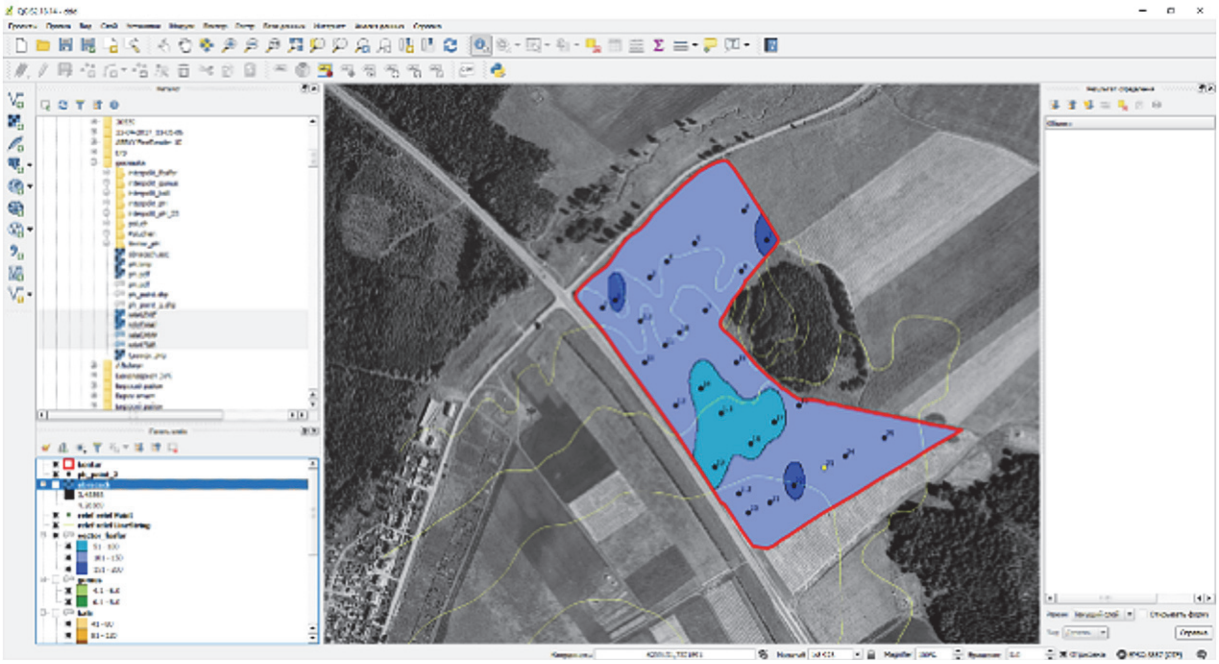


Fig. 5. Cartogram of mobile phosphorus content

ing to the classification of soil agrochemical properties. Figure 5 shows a cartogram of mobile phosphorus, which allows determining the application dose of appropriate fertilizers to a specific area. The process of cartogram creation for other indicators of agrochemical properties of soil is similar.

Thus, the GIS subsystem provides the cartographic component of precise farming. As a result we get multi-layer maps of the area with the possibility for layout of raster (images, scanned maps, etc.) vector maps (topographic base, field maps, thematic maps, etc.) and matrices (relief surface, soil quality features, yield, etc.). On the basis of maps records of farmland, agrochemical monitoring, visualization of equipment movements and display of monitoring state of objects are kept (Figure 5).

Discussion

Given the large percentage of ageing of the topographic maps currently in use, it is necessary to update the topographic maps on the basis of new aerial and spatial photography or other methods of remote sensing of the earth's surface. Existing land surveying methods for accuracy, efficiency, economic efficiency do not meet the requirements of science and practice, in particular arising during geodetic support, navigation and study of geodynamic processes.

Modern space technologies make an important contribution to the development of Russia's agro-industrial complex. For Russia, with its enormous territories the use of remote sensing data for monitoring agricultural land is of particular relevance. According to the data obtained using remote sensing methods, an accurate map of the field with a characteristic for each land plot is created. The agricultural producer is able to allocate rationally resources between the fields. This helps to avoid overspending resources where they were previously used in excess, and to increase the productivity of those areas of the field that previously did not get enough fertilizers, plowing or watering. Based on created digital maps, a precise dose of fertilizers, seeds, water is calculated and prepared for a specific area in the field. These instructions can be used in agricultural machinery, which is equipped equipment with a global satellite navigation system. This type of machine will be able to determine the required dose of applied nutrients, eliminating gaps and overlaps between treated plots.

The use of remote sensing data of different spatial resolutions will significantly reduce the time spent on environmental and economic damage assessment. Also, the use of remote sensing allows for rapid assessment and timely decision-making activities for the management and regulation of land. The use of satellite images taken at different times will allow us to detect erosion and desertification on land areas in time in the tasks of monitoring the intended use of the land fund.

According to Ishbulatov et al. (2018) remote sensing data is applied in the assessment of the arable lands fertility.

Thus, in modern conditions it is important to create accurate digital maps for rational use of land resources using remote sensing.

Conclusion

Research in the field of application of aerospace technology, analysis and generalization of practical experience in aerial photography offer a comprehensive approach for processing operational data. It consists in the use of systematic principles of research and implementation of remote sensing of agricultural land.

Practical importance is the development of methods, algorithms and software for automated data analysis of remote sensing for agricultural land, allowing accelerating the process of obtaining reliable data and improving the efficiency of agricultural enterprises. Thus, the availability of remote sensing data for government authorities and producers of agricultural products will increase the information in decision - making when monitoring the productivity of agricultural land; obtaining information on reclaimed lands, etc.

Thus, the use of remote sensing methods may be able to bring significant economic effect in the rational use of land resources, in monitoring of agricultural land in the size of 1000 hectares in average costs 50000 rubles. When using traditional methods the cost is over 90000 RUB (cost reduction to 45-50%). When creating topographic maps we save up to 70% of the cost.

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