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The Effectiveness of Digital Technologies in Soil Cover Monitoring

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***Abstract*—In this paper, the current state of the soil cover on the basis of remote sensing materials of the Earth on the example of Shcherbakinsky rural settlement of Sargatsky district of Omsk region was studied. The studied area is located in the forest-steppe zone of Western Siberia. In the paper multispectral images of the space vehicle (SV) Landsat 8 (USA), with a resolution of 30 m per pixel was used. These images allow monitoring of the Earth's surface at intervals of once every 16 days with an approach area of 185 km in nadir. Computer processing of a series of multispectral space images (MSI) by synthesis method was carried out using the licensed software package ENVI 5.0. (manufactured by ESRI). The work used outdated cartographic materials of 1984, obtained in the Department of Agriculture of the Sargat District. When creating the electronic cartographicdocument of the studied area (based on satellite data), the digital basis of agricultural lands was initially created. Digitization of obsolete material was carried out in the software package QGis (QGIS Desktop). For the first time for the territory of the forest-steppe zone of Western Siberia with the use of different-time images by a space vehicle LANDSAT 8, the spatial-temporal change in the structure of agricultural lands over the past twenty-five years was revealed. The work was carried out in the framework of research commissioned by the Ministry of Agriculture and Food of the Omsk Region: "Development and technology implementation for the introduction of unused land in the Omsk region".**

Keywords—soil cover, remote sensing of Earth, soils cartography, GIS-technologies.

I. INTRODUCTION

Over the past decades, the flooded areas have become almost ubiquitous in Russia. Currently, about 9 million hectares of land for various economic purposes are being flooded in Russia, including 5 million hectares of agricultural land and 0.8 million hectares of built-up urban areas. The area of flooded land, established on the land cadastre database for overmoistened and wetlands has increased by 50 % since 1980.

Despite the mportance of the problem, many land flooding aspects have not yet been sufficiently investigated, the issues of diagnosis and classification of flooded lands have not been resolved. The analysis and generalization of the available materials showed that there is no single system for obtaining information about the land condition. There are only spilled materials to determine the extent of flooding, which are not always comparable due to the different principles and methods of obtaining them.

To date, remote methods based on satellite data are being actively implemented to obtain operational data on flooding processes. In order to quickly obtain data on the processes of flooding, remote methods based on satellite data are being actively introduced.

The goal of the research is to develop a digital cartographic material for the analysis of the current state of the soil cover (on the example of Shcherbakinsky rural settlement of Sargatsky district of Omsk region).

Research tasks:

- To carry out thematic data processing of space survey materials performed by Landsat 8 space vehile (USA).
- On the basis of a clustering method with use of the QGIS software complex the spatio-temporal change of structure of agricultural grounds of the Shcherbakinsky rural settlement to be revealed.
- To carry out soil survey of the studied area with sampling;
- Identify agricultural lands out of agricultural circulation and create an interactive soil map based on QGIS SOFTWARE.
- Identify ways to save costs while soil survey conduction.

II. LITERATURE REVIEW

Over the past 10 years, geographic information systems and satellite monitoring systems of the Earth's surface have become of great importance not only in agriculture, but also in other areas of analysis and forecasting of natural and anthropogenic processes. On the development of the system of remote sensing of the Earth can be found in the series of works "Decoding multizone aerospace images» (Kravtsova V. I).

In the works of Savin I. Yu., Prudnikova E. Yu., (Soil Institute named after Dokuchaev V. V.) a huge analysis of the methods of monitoring the soil cover, its mapping, the use of satellite imagery in agricultural insurance, ground penetrating radar diagnostics of humus state of the blacksoil cover, the identification of erosion processes using unmanned aerial vehicles [1, 2, 3].

To date, aerospace monitoring systems of the Earth surface and in particular agrocenoses are being actively

implemented by the "Agrophysical Research Institute" (St. Petersburg, Russia). In the works by Yakushev V. P. [4] the methods of using vegetation indexes to analyze the state of vegetation, identify factors of destabilization of agrocenoses in the growth of various crops, the use of various mathematical models in the study of soil and plant systems of agricultural landscapes, the study of optical characteristics of cultivated plants, soils and weeds are being considered in details.

The developed methods of various research teams allow to minimize the cost of effective land use and obtaining quality products [5,6,7,8,9].

III. Research methodology

Academic novelty consists in the fact that for the first time for the studied area of Shcherbakinsky rural settlement of Omsk region, located in forest-steppe zone the study of the territory left agricultural circulation in the process of flooding on the basis of materials of remote sensing of the Earth with the use of high-resolution multispectral data was carried out. For the first time for the territory of Western Siberia signs of decoding of potentially fertile fallow lands with establishment of priority of their introduction into agricultural circulation are developed.

The research object is the soil cover of agricultural lands of Shcherbakinsky rural settlement of Sargatsky district of Omsk region. The research subject was the reflection regularities on satellite images of the agricultural lands condition of the forest-steppe zone of Western Siberia, depending on the features of their use.

Computer processing of a series of multispectral space images (MSI) by synthesis method was carried out using licensed software systems ENVI 5.0., Qgis. At the same time, the possibility of combining the exposure ranges for the elements of the solar radiation spectrum from 0.4 to 0.9 nm, and color channels in the RGB (red-green-blue) system was taken into account. When combining the range and channel, we obtain a color synthesized image that helps to establish objectively existing differences between the studied objects.

The analysis of multispectral satellite images in the ENVI software complex goes through a number of stages:

1. Image georeferenciation with the source material (outdated soil map).

2. Multispectral images classification to identify the complexity of the Earth's surface.

In this paper, the North-Eastern part of the district was studied, where in middle low ridges and lakeside areas, which prevail in this part of the district, hydromorphic salt flats, malts and meadow soils are formed, and on the few elevated elements of the relief – gray forest soils.

The laying of the section on the hay revealed the presence of meadow malt fine-soddy small-humus heavy soloth, the morphological description of which is given below (table 1).

Section 16. MT 287. The coordinates of a tie: N 55,38365°, E 73,32057°, h 104 m.

Boiling from the HCl is not detected until 58 cm. Gleyzation with 20 cm.

TABLE I. Morphological features of soils

Horizon, depth, cm	Morphological features
Ад $\frac{0-2}{2}$ см	Old sod field.
A1 $\frac{2-8}{6}$ см	Dry, loose, light gray, with a whitish tint, heavy clayloam, lumpy-powder-like, new formations of SiO2 in the form of powder on soil aggregates. The root systems of plants are in the horizon.
A2 $\frac{8-20}{12}$ см	Fresh, compacted, whitish, heavy clayloam, lumpy-powder-like, newly formed structures of SiO2 (max. content) iron compounds to the ferrous form.
A2Bg $\frac{20-45}{25}$ см	Moist, compacted, whitish-bluish, heterogeneous, with ochreous spots, heavy clayloam, blocky-cloddy, new formations of SiO2 in the form of powder on soil aggregates, iron compounds in nitrous and oxide forms.

The humus and eluvial horizons of soloth have a weakly aggregated structure, alkaline and neutral reaction of the medium (respectively). The humus horizon has a well-arched structure (table 2). Agronomic assessment of this soil will be limited by the reaction of the environment and the capacity of the humus horizon.

TABLE II. Characyeristics of a meadow fine-soddy small-humus heavy heavy clayloam soloth

The amount of units 0,25-10 mm, %	pH of water suspension	Number of waterproof units, %
A1 $\frac{2-8}{6}$		
46.00	8.20	98
A2 $\frac{8-20}{12}$		
54.21	6.60	4
A2Bg $\frac{20-45}{25}$		
63.71	6.15	0

At the same time in the horizon A 1 there is a good water resistance and a weakly aggregated structure. In horizon a 2, the structure is also weakly aggregated and not waterproofed.

Based on the obsolete cartographic material data, the soil map was corrected on the basis of remote sensing and GIS technologies and an interactive soil map was created, which allows characterizing each individual soil area (figure 1). According to the soil map, the lands of Shcherbakinsky rural settlement were divided according to the soil suitability classificationg (figure 2).

On the basis of cartographic material of 1985 a new soil map of Shcherbakinsky rural settlement of Sargatsky district of Omsk region was created (figure 1).

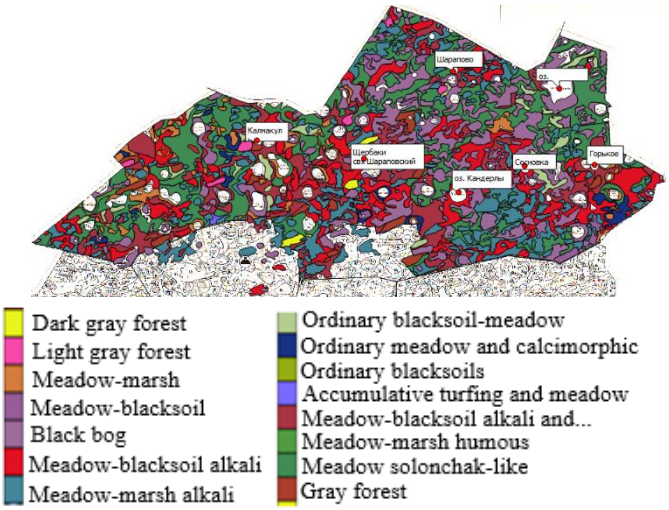

Fig. 1. Soil map of the Shcherbakinsky rural settlement created using QGIS software in 2018.

In the north of the Shcherbakinsky rural settlement, meadow-marsh humus and marsh lowland soils are predominated. In the north-western part of the settlement the most part is occupied by meadow solonchak-like soils with complexes of solothes. In the central part meadow-marsh alkali soils and meadow alkali blacksoils are widespreaded.

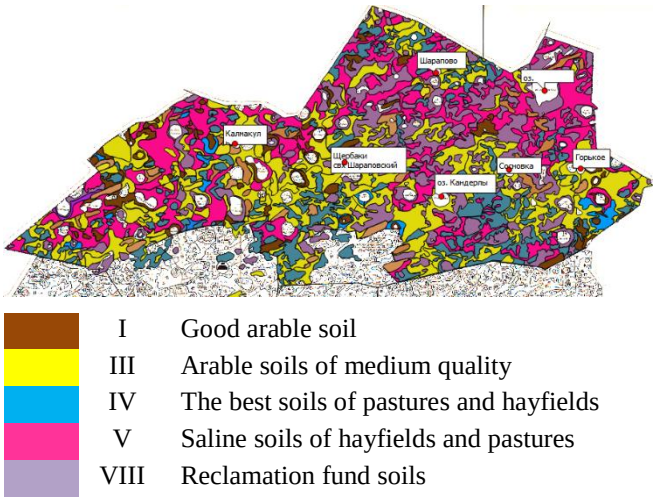

Fig. 2. Agro soils grouping of the Shcherbakinsky rural settlement.

The central part of the rural settlement is represented by arable soils of average quality. The north is occupied by saline soils of hayfields and pastures and soils of reclamation fund. There is a small percentage of good quality soils throughout the settlement.

When identifying the structure of land for the first time used the method of analysis (overlay method) multispectral data by andsat 7 and 8 space vehiles. The data of the land plots of the period 1992 and 2017 were compared using the synthesis of pseudo-colors in the NIR-RED-GREEN synthesis variant, which allowed identifying the categories of land and their areas with the greatest accuracy (table 3, 4). This technique is considered on the example of several rural settlements of Sargatsky district of Omsk region.

TABLE III. ANALYSIS OF THE BLOCK STRUCTURE SPACE OF SHERBAKOVSKAYA RURAL SETTLEMENT IN 1992. (PIXEL BY PIXEL DATA ANALYSIS)

Object of research	Number of pixels	%	Square	
			Square meters	*ha*
1. Farm field	66645	14.2	59980500.0	5998.05
2. Layland	81438	17.4	73294200.0	7329.42
3. Buildings	4380	0.9	3942000.0	394.20
4. Water objects	158406	33.8	142565400.0	14256.54
5. Forest	157050	33.5	141345000.0	14134.50

TABLE IV. ANALYSIS OF THE BLOCK STRUCTURE SPACE OF SHERBAKOVSKAYA RURAL SETTLEMENT IN 2017 (PIXEL BY PIXEL DATA ANALYSIS)

Object of research	Number of pixels	%	Square	
			Square meters	*Square meters*
1. Farm fields	69464	14.5	62517600.0	6251.76
2. Layland	105367	22.1	94830300.0	9283.03
3. Water objects	201290	42.2	181161000.0	18116.10
4.Forest	100410	21.0	90369000.0	9036.90
5.Buildings	9980	12.9	6650800.00	665.08

Based on the analysis of multispectral data received from the Landsat 8 space vehicle (spatial resolution of 30 m in pixel), it can be seen that the main area of the settlement is occupied by water objects or objects of high humidity (bogs, flooded meadows, etc.). Also, more than 7 thousand hectares are in the laylands, almost all natural landforms have been introduced into the arable land.

In order to study the soil state and form a soil map without the use of digital technology requires multiple visits to the area with the laying of the soil section, sampling and analysis. In the conditions of the northern woodland grass and taking into account the 3 categories of complexity of land per 100 hectares, at least two trips to the area will be required. You will need to lay 2 soil crossovers, 8 semi-hols and 10 heelings [10, 11]. In this analysis of 5 layers of structure, granulometric composition, pH, water strength and 2 layers of humus, exchange cations costs will be about 120 thousand rubles. In addition to the high cost of research for soil analysis will require significant time.

Modern digital technologies significantly reduce the time and money spent on land use assessment. The analysis of satellite images of the studied territory with the subsequent cluster processing of images at carrying out soil and agrochemical survey of lands allows not to divide sites into blocks on 100 hectares and not to carry out trips with all complex of researches. This is possible due to the fact that the currently used software allows you to select homogeneous in their properties and composition soils and combine them into clusters. In the study area it was possible to identify 5 groups of lands, which were grouped into clusters and highlighted in different colors (figure 3).

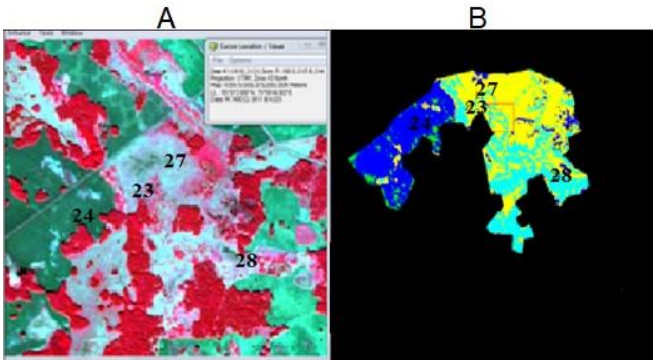

Fig. 3. Clustered image processing of the Shcherbakinsky rural settlement (a-multispectral image; B - processing by clustering method; the numbers shown the places of cuts laying and heelings)

When carrying out soil and agrochemical survey of lands it is enough in the center of each of the allocated clusters to outline points and to carry out tripss in the necessary volume. Thus, on these 1000 hectares not 20, but only 5 trips will be required. You will need to make 5 sections, 20 semi-hols and 25 heelings. Comparison of cost characteristics of works on the offered technique on 1000 hectares is shown in figure 4.

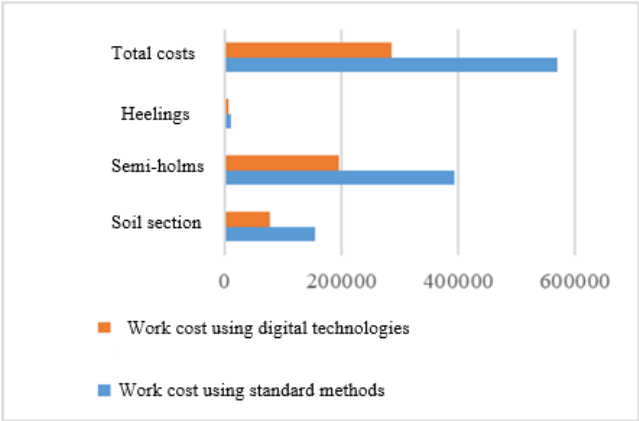

Fig. 4. Comparative characteristics of digital technologies effectiveness in soil survey.

Calculations have shown that the total cost of work carried out by the old method on 1000 hectares cost 570 thousand rubles the savings can be up to 50% (the work cost using the new method is 287 thousand rubles. In addition to financial cost savings, there is a saving of time and labor resources. The results obtained in the course of the research allow to draw a conclusion about the economic feasibility of using digital technologies in the soil cover monitoring.

IV. Conclusions

When applying spatio-temporal analysis of remote sensing data it was found that in the studied area of Sherbakinsky rural settlement is currently fallow arrays of about 9 thousand hectares, which should be involved alternately in agricultural use; some areas (so far, according to the map, and soil maps) should be transferred to the category of hayfields and pastures as a result of flooding of the territory for the rational use of land resources.

Thus, the modern GIS use with the use of actual data of remote sensing of the Earth allow us to conduct a comprehensive analysis and monitoring of any territory of the globe; to identify potentially fertile fallow land masses, which is currently an urgent task in the agricultural production.

References

[1] A. N. Kashtanov, Yu. I. Vernyuk, I. Yu. Savin, V. V. Shchepot'ev, P. A. Dokukin, D. V. Sharychev, K. A. Li, "Mapping of Rill Erosion of Arable Soils Based on Unmanned Aerial Vehicles Survey," Eurasian Soil Science, Vol. 51, No. 6, pp. 479-484, 2018. https://doi.org/10.1134/S1064229318040051

[2] I. Yu. Savin, I. A. Dragavtseva, N. Ya. Mironenko, N. N. Sergeeva, V. V. Domozhirova, A. S. Morenets, and S. V. Ovechkin, "Geoinformation evaluation of soil resource potential for horticulture in Krasnodar region and the Republic of Adygea," Eurasian Soil Science, Vol. 49, No. 4, pp. 481-487, 2016. https://doi.org/10.1134/S1064229316040104

[3] E. Yu. Prudnikova and I. Yu. Savin, "Satellite assessment of dehumification of arable soils in Saratov region," Eurasian Soil Science, Vol. 48, No. 5, pp. 533-539, 2015. https://doi.org/10.1134/S1064229315050075

[4] V. Badenko, D. Kurtener, and V. Yakushev, "Evaluation of Current State of Agricultural Land Using Problem-Oriented Fuzzy Indicators in GIS Environment," Computational Science and Its Applications – ICCSA 2016, Vol. 9788, pp. 57-69, July 2016 [International Conference on Computational Science and Its Applications, 2016] https://doi.org/10.1007/978-3-319-42111-7_6

[5] Plotnikov D.E., Kolbudaev P.A., and S. A. Bartalev, "Identification of dynamically homogeneous areas with time series segmentation of remote sensing data," Computer optics, Vol. 42, No. 3, pp. 447-456, 2018. (in russ.) https://doi.org/10.18287/2412-6179-2018-42-3-447-456

[6] S. A. Bartalev, D. E. Plotnikov, and E. A. Loupian, "Mapping of arable land in Russia using multi-year time series of MODIS data and the LAGMA classification technique," Remote Sensing Letters, Vol. 7, No. 3, pp. 269-278, 2016. https://doi.org/10.1080/2150704X.2015.1130874

[7] S. Y. Kudryashova, L. Y. Ditts, A. V. Chichulin, A. S. Chumbaev, G. F. Miller, and A. N. Bezborodova, Ecological-geographical aspects of soil complex types allocation at the Ukok Plateau using remote sensing studies," Contemporary Problems of Ecology, Vol. 5, No. 5, pp 516-521, 2012. (in russ.) https://doi.org/10.1134/S1995425512050046

[8] A. I. Mikheeva, O. V. Tutubalina, M. V. Zimin, and E. I. Golubeva, "A Subpixel Classification of Multispectral Satellite Imagery for Interpetation of Tundra-Taiga Ecotone Vegetation (Case Study on Tuliok River Valley, Khibiny, Russia)," Izvestiya, Atmospheric and Oceanic Physics, Vol. 53, No. 9, pp. 1164-1173, 2017. https://doi.org/10.1134/S0001433817090213

[9] I. A. Bobrenko, O. V. Shumakova, N. V. Goman, Y. I. Novikov, V. I. Popova, and O. A. Blinov, "Improving competitiveness of the wheat production within the siberian region (in terms of the omsk region)," Journal of Advanced Research in Law and Economics, Vol. 8, No. 2 (24), pp. 426-436, 2017.

[10] L. V. Berezin and M. R. Shayakhmetov, " Methodological basis of the study of natural-resource potential of the region," Omsk Scientific Bulletin, No. 1 (108), pp. 146-149, 2012. (in russ.)

[11] M. R. Shayakhmetov and I. A. Dubrovin, "Precision Agriculture - the way to the resource conservation," Omsk Scientific Bulletin, No. 1 (118), pp. 197-200, 2013. (in russ.)