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 The work used outdated cartographic materials of 1984, obtained in the Department of Agriculture of the Sargat District.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 cartographic document 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 importance 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 vehicle (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 agroecosystems 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 Sargsky 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).

| Horizon, depth, cm | Morphological features |
|-------------------|-----------------------|
| 0 – 2 cm          | Old sod field.         |
| 2 – 8 cm A1 6     | 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. |
| 8 – 20 cm A2 12   | Fresh, compacted, whitish, heavy clayloam, lumpy-powder-like, newly formed structures of SiO2 (max. content) iron compounds to the ferrous form. |
| A2Bg 20 – 45 cm 25 | 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.

| The amount of units 0.25-10 mm, % | pH of water suspension | Number of waterproof units, % |
|-------------------------------|-----------------------|-------------------------------|
| 2 – 8 A1 6                   | 46.00                | 8.20                          | 98 |
| 8 – 20 A2 12                 | 54.21                | 6.60                          | 4  |
| 20 – 45 A2Bg 25              | 63.71                | 6.15                          | 0  |

At the same time in the horizon A1 there is a good water resistance and a weakly aggregated structure. In horizon A2, 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 classification (figure 2).

On the basis of cartographic material of 1985 a new soil map of Shcherbakinsky rural settlement of Sargsky district of Omsk region was created (figure 1).
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 solothese. In the central part meadow-marsh alkali soils and meadow alkali blacksoils are widespread.

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. 1. Soil map of the Shcherbakinsky rural settlement created using QGIS software in 2018.](image)

![Fig. 2. Agro soils grouping of the Shcherbakinsky rural settlement.](image)

**TABLE III.** ANALYSIS OF THE BLOCK STRUCTURE SPACE OF SHERBAKOVS'KAYA 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 SHERBAKOVS'KAYA 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| 6650800.0    | 665.08      |
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.

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