

Efficiency of Using Earth Remote Sensing Data for The Rational Use of Agricultural Land

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The study of agricultural production and land use in the north-east of Kazakhstan is based on the data obtained after processing medium spatial resolution space images of Kazakh (KazEOSat-2, KazSTSat) and foreign (Sentinel-2, Landsat-8) satellites for the period from May to September 2017 - 2021. It is shown that the use of methods of objective remote sensing allows for comprehensive monitoring of agricultural land of the country. The authors have developed scientifically substantiated methods of evaluation of the main indicators of pastures with a total area of 8,127,000 ha and crops with an area of 1,211,000 ha in the steppe and arid-steppe zones of Pavlodar region of Kazakhstan.

1. Introduction

One of the main directions of using remote sensing (RS) data in agriculture is the analysis of the effectiveness of agricultural land use. Since the 1990s and up to the present time in Kazakhstan, there have been constant transformations in the use of agricultural land due to political, economic, environmental and other aspects. The issue of rational use of land resources occupies a key place in the state policy in the sphere of agriculture of the country. Land resources of the country, as a spatially extended object, require considerable funds and efforts for management and control, therefore measures on active implementation of remote sensing methods in the sphere of land relations are undertaken (ZAKON.KZ, 2022). The need for research in this area is the provision by land users of unreliable and/or distorted information about the current state of agricultural land. Traditional cartographic materials in the form of land management and household planning schemes are often poorly informative or inaccurate due to the use of outdated irrelevant information base (Khabarov et al, 2019). State statistics and agricultural land records in this case become biased, making it difficult to assess the efficiency and control of agricultural land use. In (Zelman et al, 2019), current remote sensing (RS) methods for analysing the environmental condition of agricultural land are considered. Remote sensing methods are widely used in agribusiness in the United States, Canada, European Union countries, India, Japan, and others. The best-known examples of existing systems of agricultural monitoring are MARS project (The Monitoring of Agriculture with Remote Sensing), developed by the European Commission Joint Research Centre for Agricultural Land Monitoring which provides information on areas under crops and crop yields broken down by states and regions as well as by individual farms. The monitoring results are used for tax control of producers, development of a flexible system of prices and quotas, planning of export-import operations, and other activities. The authors Vasilyev et al. (2020) noted that the implementation of "smart" land use is impossible without improving the quality of spectral imagery. The novelty of this study lies in the fact that previously similar results were not presented for sown pastures in the Pavlodar region of Kazakhstan. Most often, the authors considered pastures separately from crops. In this article, the authors combined and considered rangelands and croplands in the aggregate, processing and analysing land using remote sensing data for soil assessment. The aim of this work is to assess the rational use of rangelands and cropland in the Pavlodar region of Kazakhstan by reliable satellite

land assessment based on the use of medium spatial resolution imagery of domestic (KazEOSat-2, KazSTSat) and foreign (Sentinel-2, Landsat-8) spacecraft.

2. Materials and methods

The study area is located at the coordinates from 77°24'56.2 "E east longitude and from 51°55'42.4 "N north latitude and covers 1211 hectares in Pavlodar region of Kazakhstan. According to the taxonomy of soils chestnut type of soils is the dominant soil unit in the territory of this site. The geographical location of the selected representative profiles is shown in Figure 1.

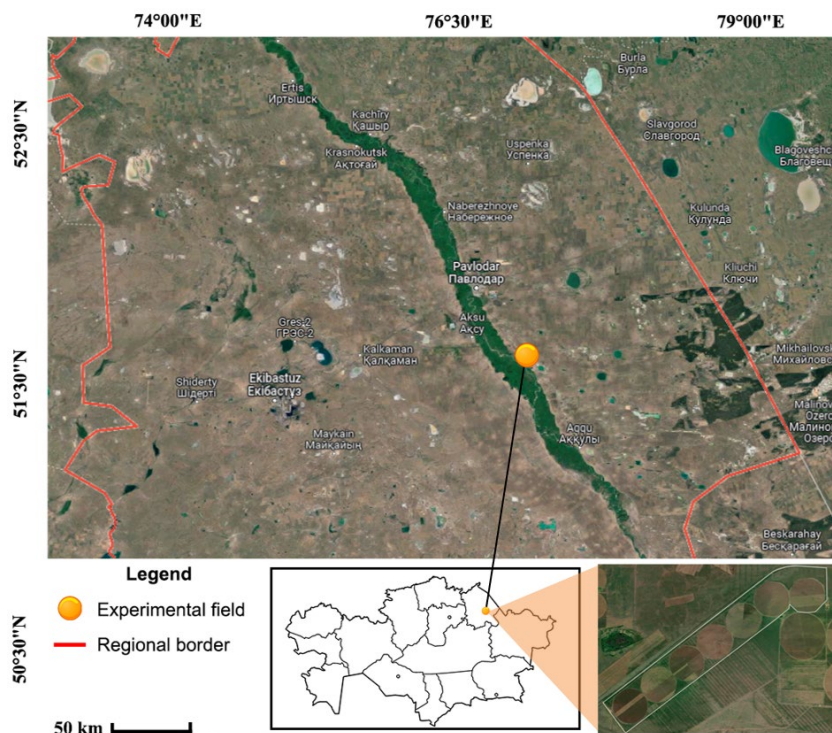


Figure 1: Study area and experimental field

To analyse agricultural production and land use in the north-east of Kazakhstan based on remote sensing data, satellite images (KazEOSat-2, KazSTSat) and foreign satellites (Sentinel-2, Landsat-8) were used as initial data from May to September 2017 - 2021. Assessment of vegetation condition on test plots was carried out using index values: NDVI - vegetation development of plants; NDWI - normalised difference water index, SWIR - short-wave infrared range; MSAVI - modified soil vegetation index; RECI - chlorophyll index. We determined the fraction of absorbed photosynthetically active radiation FAPAR, which quantitatively depends on canopy structure, optical properties of plant elements, atmospheric conditions and angular configuration, and the biophysical parameter characterizing projective coverage of soil surface - FCOVER, calculated on the basis of remote sensing data.

3. Results and discussion

Analysis of the ecological condition of agricultural land is an important procedure in the agricultural industry, which is necessary for the instant detection and prevention of existing violations of agricultural land. For effective carrying out of the specified procedure it is necessary, to have actual and reliable information about the objects under study. Earth remote sensing data serve as a source of such information. Very important in the stage of space images processing is the process of interpretation and decoding - recognition of objects on the ground by detecting their content with designation in conventional signs of qualitative and quantitative characteristics. The obtained materials allow timely detection of irrational use of agricultural lands and elimination of violations. Given the wide range of covered vertical zonality and zonality of the territory of Kazakhstan, it is necessary to adapt methods of remote monitoring for each region and each soil and climatic zone. In the present work we

propose methods of evaluation of the main indicators of agricultural resources (arable land, pastures) for steppe and dry-steppe zones of Pavlodar region of Kazakhstan.

For the spatial analysis of pastures, a digital map of pastures of the region was created (Figure 2).



Figure 2: Map of pasture lands of Pavlodar region according to satellite medium-resolution remote sensing data (KazEOSat-2)

Figure 2 was built by the authors on the basis of their own data from the KazEOSat-2 satellite, by stitching tiles and processing satellite images, and is the property of the authors of the article. In order to create a basic map of the area of interest using satellite images with colour equalization and stitching lines to minimize the differences between individual images, mosaics were created in Erdas IMAGINE software. When mapping, rangelands in the agricultural land category were considered. The area of pastures of the zone of interest amounted to 8,127,000 ha. The zonal affiliation of the territory was conditionally allocated. For reliable interpretation of remote sensing data on estimation of main indicators of pastures, ground-based data collection on reference polygons (about 120 polygons) by route survey on the territory of Pavlodar region was carried out. The reference polygons were formed on the homogeneous landscape belonging with detailed description of vegetation cover. Based on the data obtained, certain dependencies between the sub-satellite survey data and spectral characteristics of reference sites were revealed, which were applied for description and interpretation of remote sensing data during monitoring of pastures of the region.

According to field surveys, 5 main vegetation formations of steppe and dry steppe pastures of the Pavlodar region were identified, which include 53 species from 19 families of higher plants: Austrian-wormwood, fescue, feather grass, wheat grass formation of seeded hayfields and pastures, cereal formation. The selected plant formations formed the basis for the description of the vegetation cover of the steppe and dry-steppe zones of Pavlodar region according to remote sensing data. The main plant species, the dominants of the studied plant communities (cereals, motley grasses) differ in architectonics and are characterized by species-specific rates

of development. Consequently, the value of vegetation indices of different vegetation species will be unequal in different phases of development.

According to the results of the analysis of vegetation indices of RS data for the vegetation period 2021 showed a significant advantage of biophysical parameters (BFP) in describing individual plant formations. Vegetation indices mainly characterize development, dynamics and biomass volume, but do not reflect specificity of individual plant formations. Of all known and used indices characterizing the state of vegetation, FAPAR proved to be the most informative. For example, FAPAR values are stable during the season for fescue and feather grass formations. The Austrian wormwood formation is also stable during the season, but the values are an order of magnitude higher than the previous formations. From the maximum value in May to the minimum value in September, this diagram is characteristic of the anthropogenic agrocenosis - seeded hayfields. The same characteristics of FAPAR are shown by cereal formation, but there is stability in July-August.

The dynamics of the biophysical parameter of vegetation FCOVER in Pavlodar region relative to the identified plant formations is shown in Figure 3.

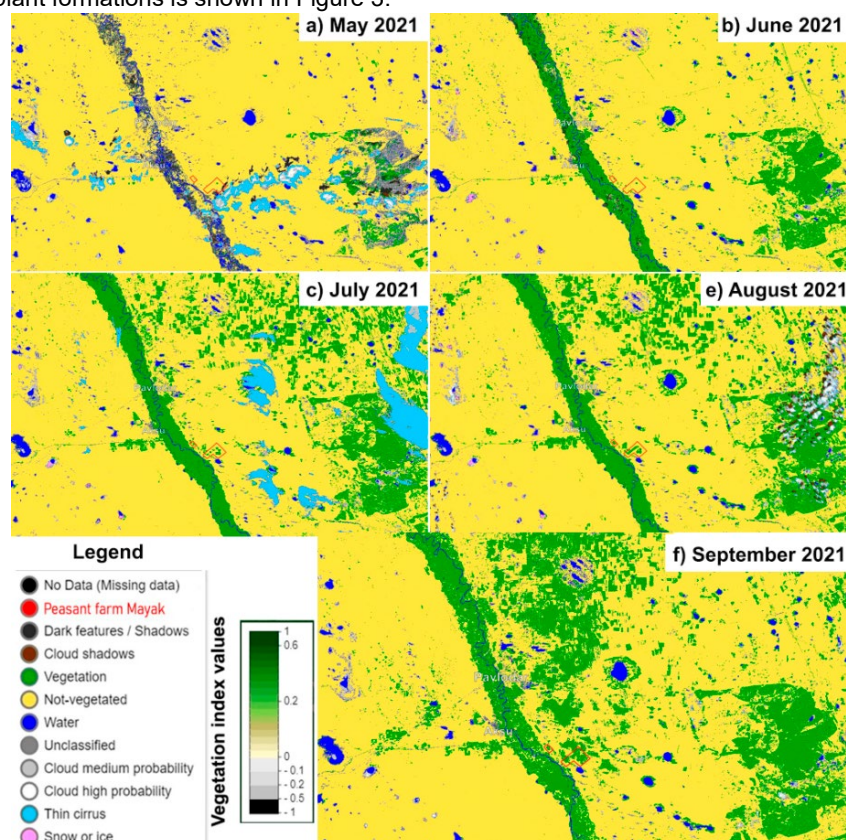


Figure 3: Dynamics of the biophysical parameter of vegetation FCOVER in Pavlodar region in relation to the selected vegetation formations according to satellite data (Sentinel - 2)

The values of the indices characterizing the state of vegetation in Figure 3 were calculated and presented by the authors of the article based on the processing of images obtained from the Sentinel-2 satellite, which are in the public domain. It was found that the FCOVER parameter during the vegetation period of Austrian wormwood formation, decreases for vetch and cereal formations, and changes during the season for fescue and feather grass formations. Knowledge of the spatial location of plant formations provides information on the fodder potential of an area and contributes to effective planning of pasture rotation considering seasonal fodder capacity and productivity of pasture vegetation.

Monitoring of rational use of arable lands based on remote sensing data is carried out in two main directions: assessment of target use and assessment of soil fertility changes.

For evaluation of arable lands of the region under study the map of land use of the test site - the farm "Mayak" is developed. The resolution and spectral capabilities of modern spacecrafts allow for a complete analysis of the soil cover. Evaluation and visualization of a complex multifactorial process made it possible to obtain quantitative parameters of high particles based on the processing of large datasets. Chestnut soils occur over a wide area. Chestnut soils were formed in a zone of dry steppes under conditions of insufficient moisture and

poor vegetation. The main criterion for differentiation of chestnut soils is their degree of humus content. The humus horizon reaches up to 30 cm, their humus content is 1.3 - 2.9 %. Chestnut type of soils is the dominant soil unit in the territory of this site. A detailed soil survey was carried out on an irrigated plot of 1,211,000 ha (Figure 4).

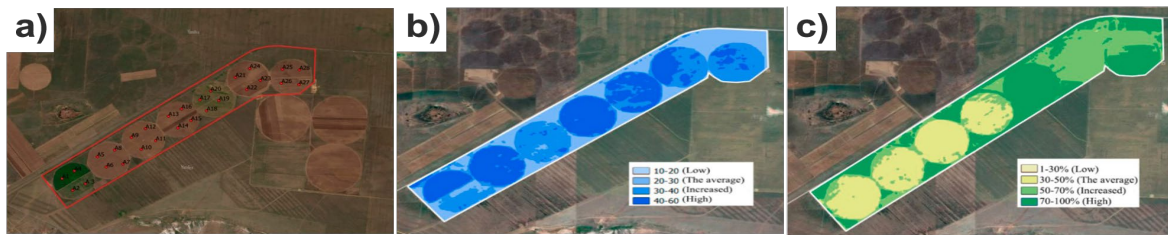


Figure 4: Cartogram of agrochemical elements content in soil of the test site in Pavlodar region: a) - space image; b) - cartogram of soil phosphorus and potassium content; c) - cartogram of nitrogen content in soil; (all data were obtained from space images of the KazEOSat-2 satellite)

Figure 4 was built by the authors on the basis of their own data from the KazEOSat-2 satellite, by stitching tiles and processing satellite images, and is the property of the authors of the article.

On the basis of space images, maps were constructed that characterize 6 spectral indicators of the state of vegetation: NDVI - normalized difference vegetation index, NDWI - the normalized difference water index, SWIR - Short-wave Infrared imaging, NDRE - normalized difference Red Edge index, MSAVI - modified soil vegetation index, as well as chlorophyll index RECI (Figure 5).

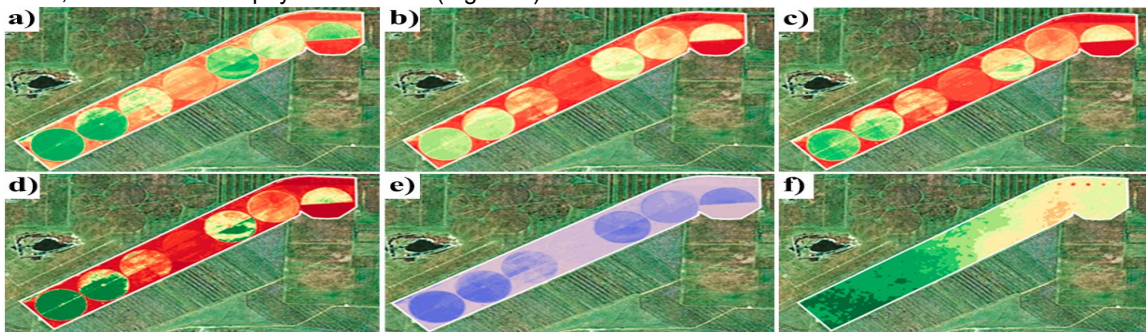


Figure 5: Cartogram of spectral indices of Pavlodar region test site: a)-vegetation index NDVI; b)-NDRE normalized difference Red Edge index; c)-MSAVI modified soil vegetation index; d)-chlorophyll index RECI; e) - NDWI; f) - elevation map; (data obtained using satellites Sentinel - 2, Landsat-8)

The values of the indices characterizing the state of vegetation in Figure 5 were calculated and presented by the authors of the article based on the processing of images obtained from the Sentinel-2 and Landsat-8 satellites, which are in the public domain. A similar combination of spectral indices, shown in Figure 5, reduces the influence of soil noise and vegetation cover. NDWI is used to detect flooded agricultural land, detect flooding in fields, and identify wetlands. NDVI is the most common vegetation index, and NDVI can also be used throughout the crop season, except when vegetation cover is insignificant and thus its reflectance is too low. Prediction of efficiency of different combinations of NDVI methods, namely RF, BRT and SVM was performed according to the method described earlier by Beisekenov et al. (2021a). The research methodology and the importance of nitrogen as an indicator of productivity, which is an important element for assessing the growth condition of the crop, fertilization levels, and its application as an indicator of productivity has been described by Ruiz et al. (2019). Following the recommendation of Zhou et al. (2019), total soil nitrogen content was studied using Sentinel-2 satellite multitemporal backscatter coefficient in mapping, and different combinations of environmental variables were constructed. Based on the spectral indices of crops in the test field, a correlation was established between nitrogen levels during crop growth and crop yields from May through September. The obtained spectral indices using remote sensing of lands are further used in the method of crop yield forecasting described by Beisekenov et al. (2021b). Numerous benefits of vegetation indices in remote sensing also help to improve the quality of production of agricultural complexes. In contrast to ground-based data collection methods, satellite imagery allows: cost savings in drone operation, data processing and interpretation; coverage of more areas compared to aerial imagery, lower field monitoring costs, data analytics in a shorter time and in a preferred format, and observation of fields regardless of wind strength.

4. Conclusion

In the present study, using remote sensing data of the Pavlodar region of Kazakhstan, we assessed the productivity and condition of pastures, interpreted the main types of vegetation, developed maps of spatial differentiation of the main elements of arable nutrition, assessed the rational use of land resources with a total area of 8,127,000 ha. To analyse agricultural production and land use in the north-east of Kazakhstan, satellite images of Kazakh (KazEOSat-2, KazSTSat) and foreign satellites (Sentinel-2, Landsat-8) for the period from May to September 2017 - 2021 were used as input data. According to field surveys, 5 main vegetation formations of steppe and dry-steppe pastures of Pavlodar region, including 53 species from 19 families of higher plants were identified. Assessment of the sown areas of agricultural crops on the basis of actual remote sensing data and the use of modern geoinformation technologies allowed to identify the content of the main nutritional elements in the soil. It was determined that the humus horizon of the test plot area of 1,211,000 ha reaches up to 30 cm with the humus content of 1.3 - 2.9 %. As a result of this study, the effectiveness of the use of remote sensing methods to assess the rationality of agricultural land use was proved. It is shown that the creation of Kazakhstan's own space system, consisting of a constellation of one high-resolution satellite KazEOSat-1 and two medium-resolution satellites KazEOSat-2, KazSTSat allowed very accurate assessment of the differences and heterogeneity of the soil cover and the spatial differentiation of the basic nutrients on the test plots. The development of works in this direction contributes to reducing the cost of studying the state of the fields, carry out work on the prediction of yield and a number of others to improve land management.

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