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USING SATELLITE IMAGES TO ASSESS THE STATE OF ARABLE FIELDS ON THE EXAMPLE OF THE EAST KAZAKHSTAN REGION

This article proposes a methodology for assessing the state of arable fields based on the use of Sentinel 2 satellite data. The essence of this methodology is cluster analysis of NDVI vegetation index profiles for a number of years, as well as expert analysis of the obtained results. The proposed method for assessing the state of arable fields has been tested on the example of arable lands of East Kazakhstan Agricultural Experimental Station LLP. This method can be used to optimize crop placement.

Keywords: *cluster analysis, precision agriculture, normalize differentiative vegetation index, Satellite data.*

Introduction. Increasing crop yields is one of the main factors for food security. The sustainable development of this factor depends on the timely provision of comprehensive data on the current state of arable fields, contributing to the adoption of more effective decisions that affect the growth of agricultural production. The study and assessment of the current state of arable fields can no longer be carried out only by traditional methods, since at a single point in time, a detailed coverage of the terrestrial study of huge areas is not possible. For this purpose, over the past years, comprehensive studies of Earth remote sensing (ERS) data [1-3] and images obtained using unmanned aerial vehicles (UAVs) [4-6] have been carried out.

In recent years, data from the European Space Agency's Sentinel 2 satellite [7-8], which was launched in 2015, have been actively used in solving such problems. The Sentinel 2 satellite is equipped with an optoelectronic multispectral sensor for surveying with a resolution of 10 to 60 m in the visible, near infrared and short-wave infrared regions of the spectrum, including 13 spectral channels, which guarantees the display of differences in the vegetation cover [9]. The new spectral capabilities of the satellite provide more acceptable possibilities for studying monitoring of the state of vegetation cover and arable fields.

Most of the sown areas in East Kazakhstan are grain crops, mainly spring wheat, and a large area of mountainous and foothill zones is occupied by barley [10]. These crops are of great economic importance and are used for food, technical and feed purposes. Accordingly, the assessment of the state of the arable fields of these crops is of great practical interest not only for producers, but also for potential consumers.

The purpose of this study is to develop a methodology for assessing arable fields within the boundaries of a separate field for small agricultural enterprises. The proposed method

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includes the following stages: preliminary processing of satellite images, calculation of the values of the NDVI (Normalized Difference Vegetation Index) and implementation of the k-means clustering algorithm.

Research objects. As an object of research, the arable lands of the East Kazakhstan Agricultural Experimental Station LLP (EKAES), organized in 2008, were analyzed. The land use of EKAES consists of 12 land plots (Fig. 1), the area of which is 4 115 3 hectares. Figure 1 shows a map of EKAES fields as of 2021. Test fields are marked on the map.

Figure 1 – Map of EKAES fields

EKAES is located on the right bank of the Irtysh River, 3 km north of Ust-Kamenogorsk. The main site of the farm is located within the foothill-steppe black soil zone. The most widespread on the territory of the farm are ordinary medium-thick black soil, in some places in combination with washed-out analogs. These soils are mainly formed on loess-like sediments. The main agricultural crops of the farm are spring wheat, barley, soybeans, sunflowerers and potatoes. In this paper, fields of spring wheat are investigated.

The methodology proposed by the authors for the assessment of arable fields is based on the analysis of the results of the NDVI (Normalized Difference Vegetation Index) using Sentinel 2 data.

The results of the analysis of scientific publications show that the vegetation index NDVI can be used as a tool for measuring crop productivity [11], determining the phenological stages of plant development [12], predicting yield [13] and a number of other tasks [14]. NDVI - Normalized Difference Vegetation Index - is a simple quantitative measure of the amount of photosynthetically active biomass (commonly referred to as the Vegetation Index). The choice of this particular index can be explained by the fact that it can be calculated for multichannel images of any resolution and provides sufficient information for analyzing the state of vegetation cover, as well as arable fields in the study area [15].

The NDVI is calculated as follows:

$$NDVI = \frac{NIR - RED}{NIR + RED}, \quad (1)$$

where *NIR* – reflection in the near infrared region of the spectrum; *RED* – reflection in the red region of the spectrum. According to this formula, the density of vegetation (NDVI) at a certain point in the image is equal to the difference between the intensities of reflected light in the red and infrared ranges, divided by the sum of their intensities [16].

Initial data and their pre-processing. The Sentinel-2 data were downloaded from the official website of the Copernicus Earth Satellite Monitoring System (<http://scihub.copernicus.eu/>). The pictures were taken from May 2 to August 2 for the last two years in accordance with the cycle of the growing season of grain crops.

The processing of multispectral data and the creation of vector layers of arable fields was carried out in the free open source system Quantum Gis (qgis.org), which supports a variety of vector and raster formats. The selection of the studied area of the field boundaries was carried out manually. To correct and improve satellite images, the following types of preprocessing were carried out in the QGis environment:

- geometric correction;
- radiometric calibration of images;
- radiometric correction of atmospheric influence;
- restoration of missing pixels;
- contrasting;
- filtration.

Research methods. The main purpose of cluster analysis is to divide the set of objects and features under study into homogeneous groups, or clusters, in a certain sense [17]. In this study, cluster analysis of soil conditions within the boundaries of a separate field is based on the application of k-means clustering and hierarchical clustering methods and comparing the results obtained.

The k-means method is one of the popular iterative data clustering methods. It is fast and effective in application [18]. The principle of operation of this algorithm is described using the example of a raster image. The pixels of the image are used as objects, and their color is used as a characteristic.

Algorithm description:

1. The number of clusters is chosen – the number k .
2. Next, k of points is randomly selected from a given image. In the first step, these points will be considered the «centroids» of the clusters. Each cluster has one center.
3. All points of the image are distributed in clusters. The distance from a point to each center of the cluster is calculated, and the point is referred to the cluster, the distance to the center of which will be the smallest.
4. When all the points of the image are distributed across clusters, the clusters are recalculated. The arithmetic mean of all points belonging to the cluster is taken as the new center of the cluster [18-19].

The k-means method aims to minimize the total intraclass variance:

$$V = \sum_{i=0}^k \sum_{x_j \in C_i} (X_j - \mu_i)^2, \quad (2)$$

where X_j are vectors of characteristics, k is the number of clusters, C_i are clusters, μ_i are cluster centers. To reduce the dependence on unsuccessful choice of centers, the algorithm

is often run several times with different centers, and then the solution with the least variance V is chosen [20].

Results and discussion. NDVI values are calculated for each image according to the data of the corresponding channels and formula (1). The general clustering algorithm can be represented as performing the following steps:

Stage 1. The stage performs clustering of the NDVI values for each date separately using the k-means method. The number of clusters is predetermined: $k = 4$. The results of this clustering with the belonging of the NDVI values to a certain class form the initial data for their subsequent clustering.

Stage 2. Clustering of data generated in accordance with stage 1 is carried out for all images of the entire growing season. As a result, cluster solutions are formed for each tested field for the studied years, the results of which are shown in Table 1.

Table 1 – Clustering results

K-means	
Field 1 –2020 year	Field 2 – год 2020 year

Field 1 – год 2021 year	Field 2 – год 2021 year

Based on the visual presentation of the results, it can be assumed that the arable fields form four natural clusters, where points outside the field are marked in black. In accordance with the results obtained for each cluster, the main descriptive statistics were calculated, the results of which are presented in Table 2. Green clusters are clusters with higher indices, red clusters with lower indices. Color visualization of clusters and analysis of statistics show that NDVI indicators have a positive trend: in 2021 compared to 2020, the share of the green cluster increased compared to the share of the red cluster. As for the values of the indicators themselves, their comparison over the years is incorrect, since different crops were sown: sunflower in 2020, wheat in 2021. However, the maps received allow assessing the most depleted areas of the field, for which additional agro-technological operations associated with spot fertilization are required.

Table 2 – Descriptive statistics of NDVI by clusters

Cluster	Mean	Count	Min	Max	Sd
Field 1 - 2020 year					
1. green	0,3016	7950	0,0616	0,7905	0,2083
2. blue	0,5603	3128	0,1133	0,8010	0,1257
3. red	0,2766	28448	0,0701	0,7365	0,1732
Field 1 - 2021 year					
1. green	0,4980	97702	0,0804	0,8312	0,2818
2. blue	0,6451	5599	0,0986	0,8256	0,1387
3. red	0,4245	27555	0,0791	0,8301	0,2727
Field 2 - 2020 year					
1. green	0,2925	58944	-0,1183	0,7361	0,1881
2. blue	0,5953	2832	0,1847	0,8255	0,1203
3. red	0,2194	47920	0,0877	0,8312	0,3361
Field 2 2021 year					
1. green	0,5297	93280	0,1019	0,8265	0,1833
2. blue	0,5258	9944	0,1031	0,8279	0,2199
3. red	0,4654	47608	0,0893	0,7846	0,1607

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Conclusion. In this work, a cluster analysis was carried out, revealing the zones of heterogeneity of two fields of the experimental agricultural farm, based on the NDVI indicators. The main concept of precision farming is based on the concept of the existence of heterogeneities within the same field. To assess and identify these heterogeneities, the latest technologies are used, such as global positioning systems (GPS, GLONASS), special sensors, aerial and satellite imagery, as well as special programs developed for agricultural management. In this work, we used satellite images and developed our own software module in Python that calculates and clusters indicators NDVI. The results obtained can be used to

plan sowing, calculate the rates of application of fertilizers and plant protection products, more accurately predict yields and financial planning for 2022.

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ШЫҒЫС ҚАЗАҚСТАН ОБЛЫСЫ МЫСАЛЫНДА ЕГІСТІК АЛҚАПТАРЫНЫҢ ЖАҒДАЙЫН БАҒАЛАУ ҮШІН СПУТНИКТІК СУРЕТТЕРДІ ПАЙДАЛАНУ

Бұл мақалада Sentinel 2 спутниктік деректерін пайдалануға негізделген егістік алқаптарының жағдайын бағалау әдістемесі ұсынылған. Бұл әдістеменің мәні бірнеше жыл бойындағы NDVI вегетациялық индексінің профилдерінің мәндерін кластерлік талдауда және алынған нәтижелерге сараптамалық талдауда жатыр. Егістік алқаптарының жай-күйін бағалаудың ұсынылған әдістемесі «Шығыс Қазақстан ауыл шаруашылығы тәжірибе станциясы» ЖШС егістік алқаптары мысалында сыналды. Бұл әдістемені дақылдарды орналастыруды оңтайландыру үшін қолдануға болады.

Түйін сөздер: кластерлік талдау, нақты егіншілік, NDVI, спутниктік деректер.

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ИСПОЛЬЗОВАНИЕ СПУТНИКОВЫХ СНИМКОВ ДЛЯ ОЦЕНКИ СОСТОЯНИЯ ПАХОТНЫХ ПОЛЕЙ НА ПРИМЕРЕ ВОСТОЧНО-КАЗАХСТАНСКОЙ ОБЛАСТИ

В данной статье предлагается методика оценки состояния пахотных полей, основанная на использовании спутниковых данных Sentinel 2. Суть данной методики заключается в кластерном анализе профилей вегетационного индекса NDVI за ряд лет, а также в экспертном анализе полученных результатов. Предложенная методика оценки состояния пахотных полей апробирована на примере пахотных угодий ТОО «Восточно-Казахстанская сельскохозяйственная опытная станция». Данную методику можно использовать при оптимизации размещения посевов.

Ключевые слова: кластерный анализ, точное земледелие, NDVI, спутниковые данные.