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The Technology of Cultivating Agricultural Crops Based on Ortho photomaps, Digital and 3-D Surface Models

A. B. Abuova, S. A. Tulkubayeva, Yu. V. Tulayev, S. V. Somova, M. B. Tashmukhamedov

***Abstract*: In 2018, on the basis of the production-and-demonstration range of the Zarechnoe experimental farm in the Kostanay region, a precision agriculture demonstration site was created with the area of 2,000 ha. The range was surveyed using aerial photography and NDVI images.**

Field state monitoring and prompt planning by the result of field state monitoring with the use of GeoScan 101 unmanned aerial vehicles allow improving the efficiency of the soil and climatic resources by 10 – 30 %. In the main stages of image processing and analysis, maps of Normalized Difference Vegetation Index (NDVI) and Green Normalized Difference Vegetation Index (GNDVI) were built with the use of near infrared (NIR), red (RED), red edge (REDEDGE), and green (GREEN) spectral band.

***Index Terms*: precision agriculture, technology transfer, unmanned aerial vehicle NDVI, GNDVI, terrain digital model, orthophotomap, yield.**

I. INTRODUCTION

One of the challenges in laying out and monitoring field experiments is prompt monitoring of plants' vegetation throughout the experiment. The most promising method of remote monitoring of industrial field experiments is the use of earth remote sensing (ERS) [1].

In recent years, satellite images have been intensively used for the tasks related to predicting the spatial distribution of the environmental data. However, this source of information has a number of drawbacks, the main of which are the following: high cost of the images; limited possibility of obtaining the images in short time and with required frequency; the need for decoding the images; errors caused by weather conditions, clouds, and haze [2].

In this respect, a promising alternative to this method is the use of radio-controlled unmanned aerial vehicles (UAVs). The use of UAVs for monitoring and collecting the remote sensing data allows a significant cost reduction in the research study and accelerates obtaining relevant data with a high temporal and spatial resolution [3, 4].

In European countries, the achievements of space technology are widely used in agriculture, ranging from GPS, which allows determining the location of machinery, organizing parallel driving, monitoring the operation of control devices, using images in the near-infrared range for determining crops' grow heterogeneity, and their further alignment with the use of systems and machinery for precise fertilizing. Most agricultural farms in Germany are equipped with computers and modern machinery. Every farmer has access to soil maps and aerial photographs [5].

Surveying the agricultural fields with the use of aerial photography allows optimizing the technical operations (for example, determining the time and dosages of introducing agrochemicals) and determining various plant stresses, which contributes to decreasing the costs of crop products [2].

Aerial photography is widely used in precision agriculture technologies, which is based on the low-scale differentiated approach to the "field-sewing" system as an object of management [6].

New methods based on the analysis of aerial images are the promising alternative methods for assessing the availability of plant nutrients and the necessity of using agrochemicals [2].

II. MATERIALS AND METHODS

The studies were performed by the scientists of the Kostanay Research Institute of Agriculture. According to the aim of implementing the scientific-technical program "Transfer and adaptation of the technologies for precision agriculture in crop production by the principle of "demonstration farms (sites)" in the Kostanai region" on the basis of the Zarechnoe experimental farm, a demonstration site with the area of 2,000 ha was created in 2018.

To determine the main elements of nutrition, agricultural monitoring of the fields was performed in this area, and digital maps were made based on the variability data (elementary plots 10 ha each), with the sampling layer thickness of 0 – 20 cm. The agrochemical examination was made in the system of coordinates. The data of the hydrochemical research study were populated into the information and analytics service.

The site was monitored with the use of aerial photography (using UAV) and NDVI images.

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***** Correspondence Author (s)

A. B. Abuova*, Kostanay Research Institute of Agriculture, Zarechnoye village, Kostanay district, Kazakhstan.

S. A. Tulkubayeva, Kostanay Research Institute of Agriculture, Zarechnoye village, Kostanay district, Kazakhstan.

Yu. V. Tulayev, Kostanay Research Institute of Agriculture, Zarechnoye village, Kostanay district, Kazakhstan.

S. V. Somova, Kostanay Research Institute of Agriculture, Zarechnoye village, Kostanay district, Kazakhstan.

M. B. Tashmukhamedov, Kostanay Research Institute of Agriculture, Zarechnoye village, Kostanay district, Kazakhstan.

Monitoring was performed by using the NDVI and GNDVI using the NIR, RED, REDEDGE and GREEN spectral bands.

NDVI is a normalized relative vegetation index, a simple quantitative indicator of the photosynthetically active biomass (commonly referred to as the vegetation index).

Aerial photography of the studied area was performed at the altitude of 300 m with the use of the Micasense Red-Edge camera of the UAV (GeoScan 101), ensuring timely obtaining of the photographic images of the site in various bands of the electromagnetic spectrum. The aerial photography data are the source data for building orthophotomaps, the digital surface model, and the 3-D model.

The main advantages of aerial photography of the fields using UAVs are high productivity and promptness of the data, the reliability of information, and the possibility of detailed analysis and assessing the state of the agricultural field. With that, clouds are not important, like in the case with satellite images.

After the territory survey, an agronomist analyzes the overall state of the agricultural land. In the reference fields, the agronomist performs measurement using a portable device — N-tester, which determines the level of plants' nitrogen nutrition by the relative chlorophyll content in the leaves of the plants. Healthier plants contain more chlorophyll, compared to the less healthy ones. The results are shown in conventional units. The measured values are used for determining the need for additional fertilizing.

III. RESULTS

By the results of the aerial survey, the following products have been formed for each field: an orthophotomap, a dense cloud of points, a digital model of the terrain (height map), a processed digital model of the terrain, and a textured geolocated model of the terrain (a 3-D model).

An orthophotomap is a photographic plan of the terrain on the precise geodetic basis obtained by aerial photography with subsequent conversion of the aerial images into an orthogonal projection with correction of the aerial image distortion (due to the terrain and deviations of the aerial camera axes from the vertical during the photography).

Based on the created orthophotomaps, index maps of vegetation condition were built. In studying the objects by multispectral images, the characteristic ratios between the values of objects' brightness in various spectral zones are important, rather than the absolute values. Such images show the searched objects with more brightness and contrast, compared to the initial image (Figures 1, 2).

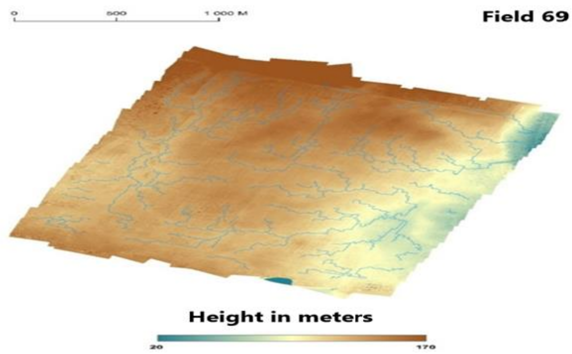

Fig. 1: Digital model of the terrain and water streams in field No. 69, 2018

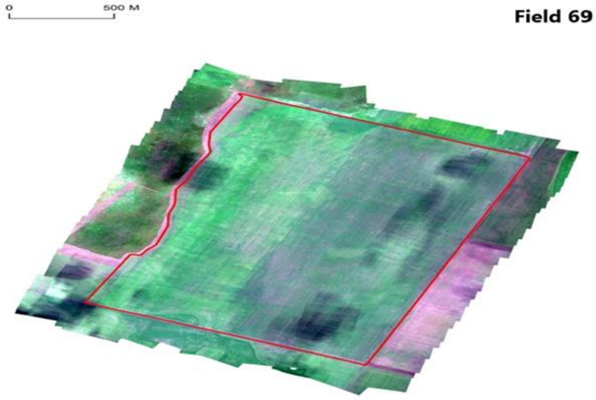

Fig.2: Orthophotomap for field No. 69, 2018

Due to the favorable natural conditions and high resolution of the images, the borders of the fields could be viewed in more detail. This resulted in an accurate definition of field borders and determination of their area. In the course of field calculation, their useful areas were accounted for, in other words, the areas that are directly cultivated by the machinery, without nearby field roads and regardless of the characteristics of the terrain that cannot be agriculturally cultivated (Figure 3).

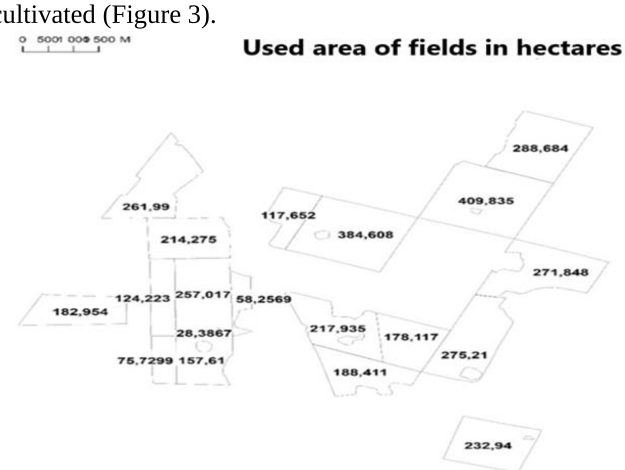

Fig. 3: Measured areas of fields, ha

The phenological observations during the vegetation period were performed by sight and with the use of NDVI images provided by an informational and analytical service.

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NDVI calculations are based on two most stable (not depending on other factors) areas of the spectral curve of vascular plants' reflection. In the RED band of the spectrum, the maximum absorption of solar radiation by the chlorophyll of vascular plants occurs, while the RED band contains the area of the maximum reflection by the cell structure of the leaves.

The high photosynthetic activity (usually related to dense vegetation) results in a lower reflection in the RED band of the spectrum and a higher reflection in the NIR band. The ratios of these indicators allow clearly distinguishing the plant communities from other natural objects, and analyzing them (Figure 4).

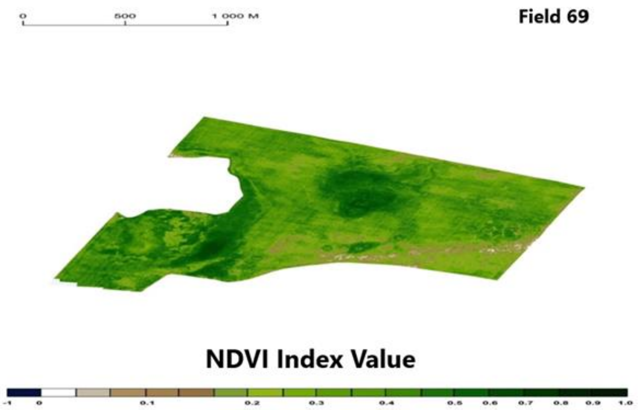

Fig. 4: Distribution of NDVI values for field No. 90, 2018

GNDVI is similar to NDVI, except for the fact that it measures the GREEN spectrum from 540 to 570 nm, rather than the RED spectrum. This indicator is less sensitive to the chlorophyll concentration than NDVI. The obtained GNDVI images where normalized by the values of the N-tester by the data of ground measurements.

The level of chlorophyll content is an indicator of ripeness and plants' health. For obtaining a more complete picture of the state of agricultural fields, maps of the overall distribution of the GNDVI values normalized to the readings of the N-tester were built using a map maker (Figure 5).

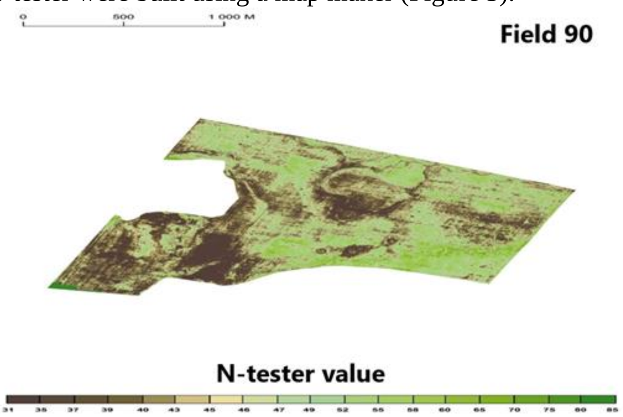

Fig. 5: Distribution of GNDVI values for field No. 90, 2018

According to some scientists, comparison of the NDVI obtained by remote and ground surveys over the three years of observation has shown that for grain crops, the greatest differences between the results of ground and remote assessments were noted in the initial phase of development (25 – 33 %), and the smallest — during the NDVI peak in the stage of ear formation. In addition to the necessary procedure of atmosphere correction, the results of satellite imaging must be subjected to calibration by ground reference objects: a pond, asphalt, plowed soil without vegetation, crops on various fertilizer backgrounds. Calibration requires using a sensor with an active source of radiation in the RED and NIR bands of the spectrum, for example, Green Seeker [7, 8].

The Green Seeker TM device allows determining the value of NDVI of agricultural crops.

By the results of a flyover, maps of the differentiated introduction of micronutrient fertilizers were built. Prescription maps are built based on the state of the vegetation (Figure 6).

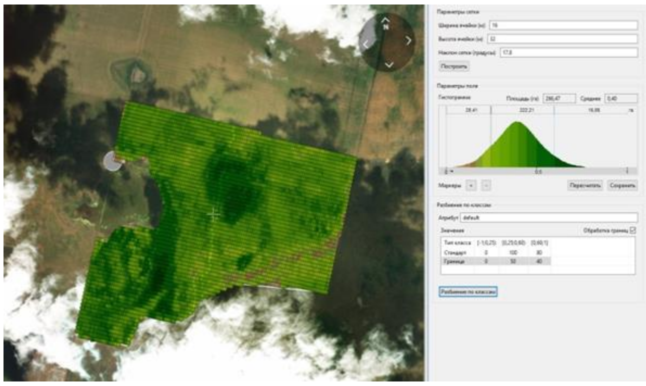

Fig. 6: Stages of creating a process map of differentiated fertilizer introduction for field No. 90, 2018

By the results of the second flyover, prediction of the yield was obtained for the area of 2,000 ha. In field No. 107, the yield should be above the average; in fields No. 105, 106, 104, 119, 99, 90, 94-2, the yield should be moderate; and in fields No. 101, 103, 94-1 the yield should be below medium. The actual yield of agricultural crops in the fields in the conditions of 2018 was as follows (Table 1).

Table 1: The actual yields of agricultural crops in the experimental plot, 2018

Field number	Crop	Yield rate, t/ha
107	Wheat (Omskaya 36)	24.9
107	Rape (Lipetsky)	8.1
119	Wheat (Omskaya 36)	20.9
105	Wheat (Omskaya 36)	33.2
106	Wheat (Omskaya 36)	24.6
104	Sunflower (Almaz)	17.5
101, 103	Wheat (Omskaya 36)	23.8
94	Wheat (Omskaya 36)	30.4
94	Rape (LipKar 2014)	10.4
99	Wheat (Omskaya 36)	19.7
90	Wheat (Omskaya 36)	26.1
Wheat average yield		25.4

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The research studies show that when individual elements of the precise agricultural system are used on low humus black soils of light and medium loamy particle composition, acceptable yields of most crops that are common in the agriculture of North Kazakhstan may be obtained. Higher wheat yields were obtained in fields No.90, 94, and 105. The average yield rate of spring wheat in the Kostanai area in 2018 was 12.8 kg/ha.

IV. DISCUSSIONUNITS

During the research, in the main stages of image processing and analysis, maps of NDVI and GNDVI were built with the use of NIR, RED, REDEDGE and GREEN spectral bands.

By the results of comprehensive analysis of index maps, heterogeneities were found in the distribution of the NDVI and GNDVI values, and in the overall state of the fields. Heterogeneities of distribution were mainly related to the orthographical conditions and the heterogeneity of the background in terms of nutrition with the main elements.

V. CONCLUSION

Creating orthophotomaps will help to correctly determine plants' field germination, predict the yield, and adjust the time and order of crops' harvesting.

At the end, the quality of sowing works (fail-places, gaps), and germination completeness are assessed based on multispectral images. These images are used for additional seeding or replanting of the crops for the maximum use of land resources. The obtained data are used for building maps of differentiated mineral fertilizers' introduction to each field individually. This allows the rational introduction of fertilizers and aligning agricultural crops for increasing the yields.

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