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APPLICATION OF REMOTE SENSING TECHNOLOGIES TO DETERMINE THE CONTENT OF SOIL FERTILITY MAIN ELEMENTS

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Abstract

One has applied the method of remote sensing of the Earth to calculate the introduction of the optimal rate of basic elements of nitrogen, phosphorus and potassium in assessing the state of crops in the geoinformation platform OneSoil using the selection of productive areas of land use with dense, medium and sparse vegetation based on space image data. Rates of nitrogen, phosphorus and potassium application for land use, with an area of 44.4 ha, located outside the settlement of Tyniv, Drohobych district, Lviv region on sod-gley sandy soils according to the planned yielding capacity and optimal terms of growing crops in crop rotation.

Key words*: *remote sensing of the Earth, OneSoil geographic information platform, NDVI vegetation index, application rates of nitrogen, phosphorus and potassium

INTRODUCTION

The improvement of the efficiency of agriculture is possible only due to intensive use of highly fertile soils, restoration of unproductive and degraded lands. In order to assess the quality of agricultural land, it is advisable to apply modern geographic information technologies or remote sensing of the Earth for:
- creation of digital maps of agricultural lands and their classification;
- determination of soil fertility indicators – soil type, humus content and basic elements (N, P, K);
- monitoring the state of development of crops and forecasting their yielding capacity;
- assessment of economic indicators (productivity) and ecological condition (degree of pollution) of agricultural lands.

One applies remote methods for determining the major elements of soil fertility based on reflection in space images of electromagnetic waves of diverse zones of the spectrum by which their fertility can be identified [4]. S. Dovhyi S. [2], S. Kokan [4], V. Lialko [5], M. Popov [9], M. Stupen [11] have carried out the study of spectral reflectivity in the papers, where they investigated dependence of humus content and basic elements, humidity and mechanical composition of soils from the heterogeneity of the image in the space image.

MATERIALS AND METHODS

The fundamentals of scientific and methodological approaches to the research are operational satellite observations of soil condition and crop production in crop rotation on the territory of model land use. The research analyzed the data of space images to identify features of plant reflectivity according to the vegetation index NDVI, their variability and spatial heterogeneity in the geoinformation platform OneSoil [8]. The applied method of remote sensing of the Earth is based on the use of causal relationships between the properties of objects and their images or point data obtained using electromagnetic waves of different lengths [1]. We use the information obtained with the help of space-based remote sensing of the Earth to analyze the potential of agricultural lands, identify types of crops, forecast yielding capacity, plan the rate of application of mineral fertilizers.

RESULTS AND DISCUSSIONS

We use indirect features – the value of the vegetation index NDVI in accordance with the results of remote sensing technology application in order to study the state of soils for sowing. One fully reflects differentiation of the state of sowing in satellite images during the first stage of crop development. One observes that crops grow earlier and form a more closed vegetation cover on soils with higher humus content and moisture. Due to other physical and geographical conditions and soil fertility, there are areas without vegetation. When crops ripen, the non-uniform tone of the NDVI vegetation index image conveys their sparseness. Taking into account this information, one can make conclusions about the state of soil fertility and increase soil productivity.

The research object of the state of soils for sowing is land use, with an area of 44.4 hectares, located outside the village of Tyniv, Drohobych district, Lviv region on sod-gley sandy soils with a score of soil rating (bonitet) of 20 for arable land with a capital rent income of 15,206.52 UAH for Sambir and Zhydachiv natural-agricultural district [7]. These soils have an unfavorable water-air regime, but concerning nutrient reserves, they are potentially fertile.

Decrypting the state of the soil in the geoinformation environment OneSoil [8] on the example of land use, according to the satellite image data, one has used spectral characteristics of the vegetation index NDVI as of August 29, 2020 in the amount of 0.75, which reflects the highest productivity of crop growing to solve the problems of precision agriculture (Fig. 1).

Fig. 1. Thematic raster image of the highest productivity of the state of sowing according to the data of the vegetation index NDVI on August 29, 2020 in the geoinformation platform OneSoil
Source: on the basis of data [8].

The effectiveness of the application of remote sensing data of the Earth to determine the content of the key elements to improve soil fertility largely depends on compliance with a scientifically sound system of crop rotation and sowing and harvesting. The spring period after the snow cover melting provides the best time to obtain satellite images to decrypt the soil. Autumn plowing of fields is also optimal, as it is characterized by large areas of open ground, providing the ability to perform the function of effective seasonal monitoring of agricultural land, the main tasks of which are to implement the following tasks for the period [2]:

- October-March

1. the study of the dynamics of the snow cover;
2. the forecast of crop freezing;
3. an assessment of the flood situation.

- April-May:

1. the determination of the area for sowing;
2. the assessment of areas of degraded lands and dead crops;
3. the establishment of areas under monocultures;
4. determination of the spatial distribution of soil moisture;
5. temperature monitoring of certain areas of the underlying surface.

- June-July:

1. the assessment of the state of crops;
2. the determination of the area not for crops;
3. the identification of the area of crop infestation due to unfavorable weather conditions;
4. operational assessment of the state and mass of phytocenoses;
5. the determination of the contours of land plots to optimize fertilizer application;
6. forecasting and preliminary assessment of average yields from individual land areas.

- August-September:

1. monitoring of harvesting works;
2. the assessment of land readiness for the next season.

One has made crop rotation during 2016-2020 with the optimal date of sowing and harvesting for the Forest-Steppe zone [3, 6] based on satellite images in the online information platform OneSoil (Table 1) in order to achieve the planned crop yielding capacity on the example of the research object.

Table 1. Crop rotation system on the territory of land use during 2016-2020 in the geoinformation environment OneSoil.

Year	**Crop**	**Date**		**Planned yielding capacity, t/ha**
		sowing	**harvesting**	
2016	Winter wheat	September, 15	August, 15	4.3
2017	Sugar beetroots	March, 30	October, 30	51.7
2018	Barley	April, 1	November, 1	5.6
2019	Maize for grains	April, 15	October, 15	9.8
2020	Oats	March, 1	July, 1 л	1.9

Source: on the basis of data [3, 6].

Irrational use of agricultural lands, long-term plowing of lands without soil-preserving crop rotations, lack of optimal application of organic and mineral fertilizers, development of water and wind erosion processes lead to crop failure from growing crops [10]. It is of vital importance to assess the existence of basic elements of sodium, phosphorus and potassium in the soil to increase the productivity of agricultural lands. It is possible in the case of remote sensing methods using space imagery in the OneSoil geoinformation environment [8]. The study of the spectral reflectivity of plants and soil properties according to the vegetation index NDVI allows establishing the necessary standards for the application of mineral fertilizers in a particular area of land use according to the crop rotation system to obtain the planned harvest, which is shown in Figures 2-6.

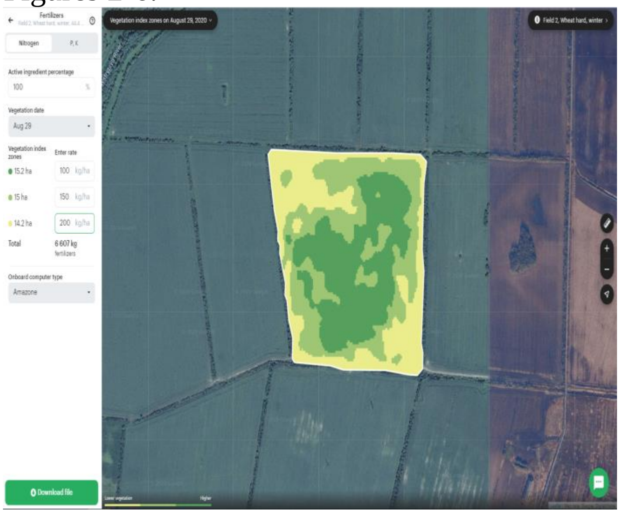

Fig. 2. Thematic raster for calculating nitrogen application during winter wheat cultivation in 2016 on the OneSoil geographic information platform.
Source: on the basis of data [8].

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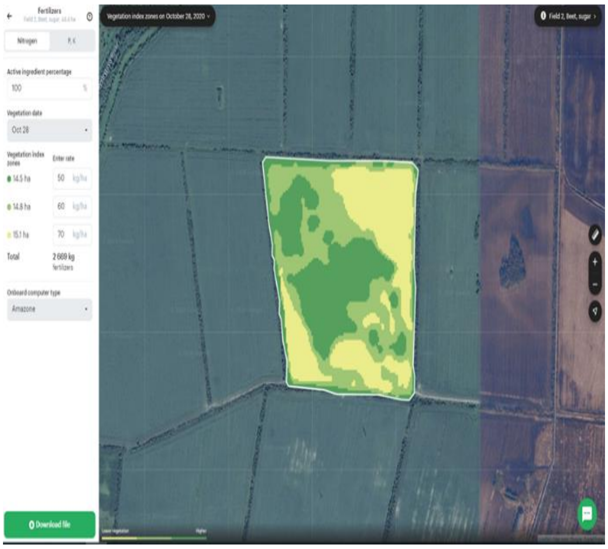

Fig. 3. Thematic raster for calculating nitrogen application in sugar beet cultivation in 2017 on the OneSoil geographic information platform.
Source: on the basis of data [8].

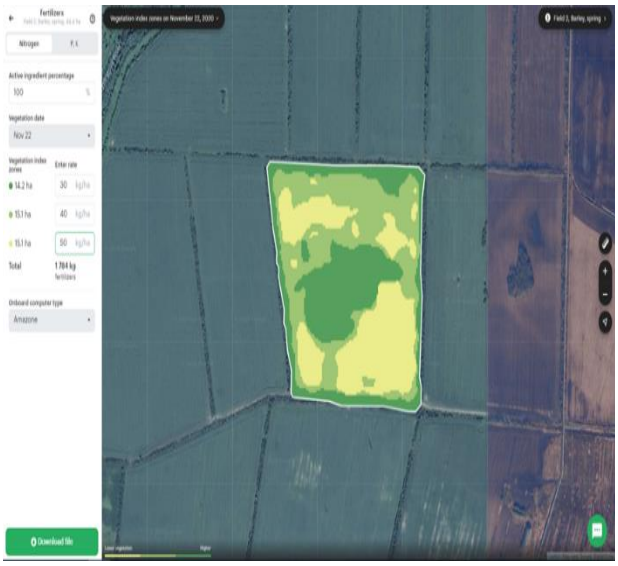

Fig. 4. Thematic raster for calculating nitrogen application in barley cultivation in 2018 on the OneSoil geoinformation platform.
Source: on the basis of data [8].

The amount of humus in the arable layer of sod-gley sandy soils on the territory of the studied land use is 2.5-5.0%. The content of mobile nitrogen is 2.5-11 mg, phosphorus - 0.6-5 mg, potassium - 1.2-6 mg per 100 g of soil [12], which indicates its insufficient supply of phosphorus and nitrogen.

Planning the application of nitrogen in the cultivation of crops in crop rotation during 2016-2020, one has used remote methods in the geoinformation environment OneSoil based on data from space images of the satellite Sentinel [8].

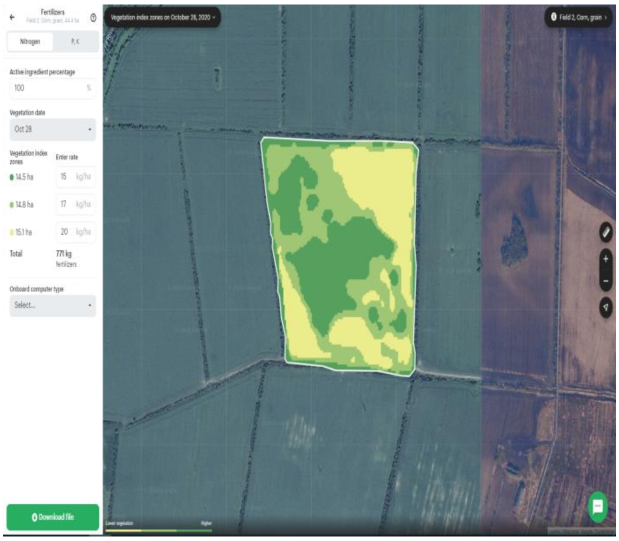

Fig. 5. Thematic raster for calculating the application of nitrogen in the cultivation of maize for grain in 2019 on the geoinformation platform OneSoil.
Source: on the basis of data [8].

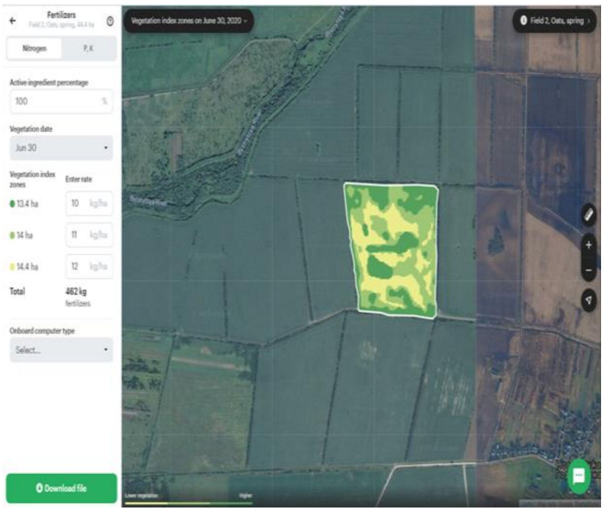

Fig. 6. Thematic raster for calculating nitrogen application in oat cultivation in 2020 on the OneSoil geographic information platform.
Source: on the basis of data [8].

Their application is based on the study of the spectral reflectivity and taking into account the spectral properties of sod-gley sandy soils in the land use, which is shown in Figures 2-6 and are presented in Table 2.

Using remote determination of the content of the main elements of nitrogen, phosphorus and potassium in the soil, information on its spectral properties according to the NDVI vegetation index in certain areas of land use with dense, medium and sparse crop vegetation in crop rotation, taking into account the planned indicators.

Table 2. Nitrogen application zones on the territory of land use during 2016-2020

Year	Crop	Due to the value of the vegetation index NDVI					
		land use area, ha			nitrogen application rate, kg/ha		
		dense vegetation	medium vegetation	sparse vegetation	dense vegetation	medium vegetation	sparse vegetation
2016	Winter wheat	15.2	15.0	14.2	100	150	200
2017	Sugar beetroots	14.5	14.8	15.1	50	60	70
2018	Barley	14.2	15.1	15.1	30	40	50
2019	Maize for grains	14.5	14.8	15.1	15	17	20
2020	Oats	13.4	14.0	14.4	10	11	12

Source: on the basis of data [8].

The results of the calculation of nitrogen application in the land use area based on the results of the application of the remote sensing method of the Earth are provided in Table 3.

Table 3. Calculation of nitrogen application on the territory of land use during 2016-2020

Year	Crop	Planned yielding capacity, t/ha	nitrogen application rate, kg	
			Calculated	actual (average)
2016	Winter wheat	4.3	6,607	6,680
2017	Sugar beetroots	51.7	2,669	2,664
2018	Barley	5.6	1,784	1,776
2019	Maize for grains	9.8	771	755
2020	Oats	1.9	462	488

Source: on the basis of data [3, 6].

The lack of basic elements of nitrogen, phosphorus and potassium in soils slows down plant growth. Considering the high cost of mineral fertilizers and the possibility of accumulation of their residues, which negatively affect product quality. The use of satellite imagery data allows for differentiated fertilizer application for the research object according to Table 4.

Table 4. Calculation of phosphorus and potassium application in the areas of land use during 2016-2020

Year	Crop	Due to the value of the vegetation index NDVI					
		phosphorus application rate, kg/ha			potassium application rate, kg/ha		
		dense vegetation	medium vegetation	sparse vegetation	dense vegetation	medium vegetation	sparse vegetation
2016	Winter wheat	29	31	32	17	19	19
2017	Sugar beetroots	48	51	53	160	172	178
2018	Barley	39	42	43	31	34	35
2019	Maize for grains	52	55	58	37	40	40
2020	Oats	14	15	16	9	10	10

Source: on the basis of data [8].

The rate of application of the main elements of phosphorus and potassium is the identification of crops in space images of sowing. One has identified and established the area of the zone with dense (14.95 ha), medium (14.75 ha) and sparse vegetation ha) in the geoinformation platform OneSoil in areas of land use during 2016-2020 in the crop rotation system in the space image in order to calculate the rate of accurate application of phosphorus and potassium [8]. Based on the data of application of the vegetation index NDVI, yielding capacity and terms of growing crops in crop rotation, one has established the optimal value of phosphorus and potassium application for the research object and compared it with its actual (average) values for the Forest-Steppe zone.

Table 5. Calculation of phosphorus and potassium application in areas of land use during 2016-2020

Year	Crop	Planned yielding capacity, t/ha	phosphorus application rate, kg		potassium application rate, kg	
			calculated	actual (average)	calculated	actual (average)
2016	Winter wheat	4.3	1,361	1,376	813	844
2017	Sugar beetroots	51.7	2,248	2,264	7,542	7,637
2018	Barley	5.6	1,834	1,865	1,479	1,510
2019	Maize for grains	9.8	2,440	2,442	1,730	1,776
2020	Oats	1.9	665	666	429	444

Source: on the basis of data [6, 8].

Applying the method of remote sensing of the Earth on the example of the research object, the yielding capacity of crops in crop rotation is increased by 15-20% while reducing the cost of mineral fertilizers by 10-30% in the amount of 150-260 UAH/ha.

CONCLUSIONS

The proposed approach to the method of remote sensing of the Earth involves the use of data from the vegetation index NDVI, the value of which correlates with the degree of development and cultivation of crops in crop rotation and the planned yielding capacity. The vegetation index NDVI allows dividing the land use area into zones with dense, medium and sparse vegetation, which are diverse in their productivity. The established areas should be used when compiling agrochemical cartograms to provide plants with the basic elements of nitrogen, phosphorus and potassium. Differentiated application of mineral fertilizers requires the application of geographic information systems in the practice of precision agriculture.

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