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METHODOLOGY OF ZONING APPLICATION FOR AGRICULTURAL CROPS CULTIVATION ON THE BASIS OF SPACE IMAGERY

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Abstract

One has carried out the monitoring of rapeseed cultivation on the example of land-use area of 69.7 hectares, located on the territory of Busk district of Lviv region outside the settlement Baluchyn according to the artificial satellite Sentinel-2. One has identified the state of its sowing, which is characterized by the maximum value of the NDVI vegetation index on July 1, 2019, and indicates the developed vegetation for harvesting. Areas with high, medium and low rapeseed vegetation are displayed using the numerical taxonomy method of optical brightness based on the analysis of multispectral land-use scan data in the Crop Monitoring geo-information system. One has done biological yielding capacity prediction using obtained values of vegetation index NDVI, NDRE, MSAVI and RECI in each zone of land use, which indicates the sparse vegetation of rapeseed with low yield and therefore requires the application of additional organic and mineral fertilizers in the low vegetation area with an average of 41 hectares per the research object. The obtained results of the use of geo-information technologies according to space monitoring data are proposed to be applied for the estimation of the state of sowing, yielding capacity prediction, the performance of agrarian and technical operations at all stages of agricultural development.

Key words: *geo-information systems, space monitoring, remote sensing of lands, zoning, vegetation index, yielding capacity, land use, agricultural crops cultivation*

INTRODUCTION

To begin with, the monitoring of the state of crop cultivation due to modern conditions without the remote methods and GIS application is impossible. Considering the development of current GIS technologies, space multispectral scanning, high resolution of global positioning systems, new opportunities are emerging to monitor the quality of the crops.
V. Dankevych and Ye. Dankevych [1], V. Liulchyk, O. Kachanovskyi and S. Bulakevych [6], A. Soloviova [7], N. Stupen, M. Stupen, and O. Stupen [9], V. Zatserkovnyi [10] researched the application of GIS technology in agricultural production management in their scientific works. However, one has not fully used the issues of soil mapping based on phyto-indication and other methods of remote sensing, so they should be considered as a promising direction for further investigations in the field of remote sensing.
Due to the proper level of information support for space imagery in agriculture, we have made proposals for the application of zoning techniques for monitoring and classification of crop production using Crop Monitoring geoinformation software [2], where one has done an appropriate assessment of crop convergence status by thematic raster results of the vegetation index based on Sentinel-2 artificial satellite data.

MATERIALS AND METHODS

One has applied the method of zoning of the territory by values of the thematic raster of the vegetation index of the estimation of the state of agricultural crops cultivation due to the taxonomic method. Its essence lies in the fact that one determines the values of the characteristic X_{ij} by n indicators for the

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territory of the research object. We take these indices as coordinates in n-dimensional space and determine for each pair of units taxonomic distances [10]:

$$d_{ij} = \sqrt{\sum_{j=1}^{n}(X_{ij} - X_{kj})^2} \quad (1).$$

Conducting zoning, one has used high-resolution space imagery obtained from the Sentinel-2 artificial satellite for detailed observation over a long time. The satellite allows optical and near-infrared imaging implementing a slit image capturing approach, thereby obtaining images with high measurement and imaging-visibility properties by providing NDVI, NDRE, MSAVI, RECI, vegetative indices with a resolution of 10, 20, 30 and 60 m regularly every ten days, masks of acreage – once a month and maps of land use – twice a season [6].

RESULTS AND DISCUSSIONS

We have carried out the study on the example of land use area of 69.7 hectares, located on the territory of Busk district of Lviv region outside the settlement Baluchyn. The area of land use is contrasting according to the structure of the soil cover, and thus differs from each other by the results of the NDVI vegetation index on the space image over a small period of time (Fig. 1 and 2).

Fig. 1. The image of the NDVI vegetation index for land use on July 1, 2019.
Source: on the basis of data [2].

Considering satellite imagery, as of July 1 and 3, 2019, we observe a significant difference in the values of the NDVI vegetation index for the research object, which is detected automatically using Crop Monitoring geo-information software [2]. The result of the study is the identification of the sowing state of rapeseed cultivation, which is characterized by the maximum NDVI value as of July 1, 2019, as one can see from the raster image in Fig. 1, and indicates the developed vegetation for harvesting according to space imagery.

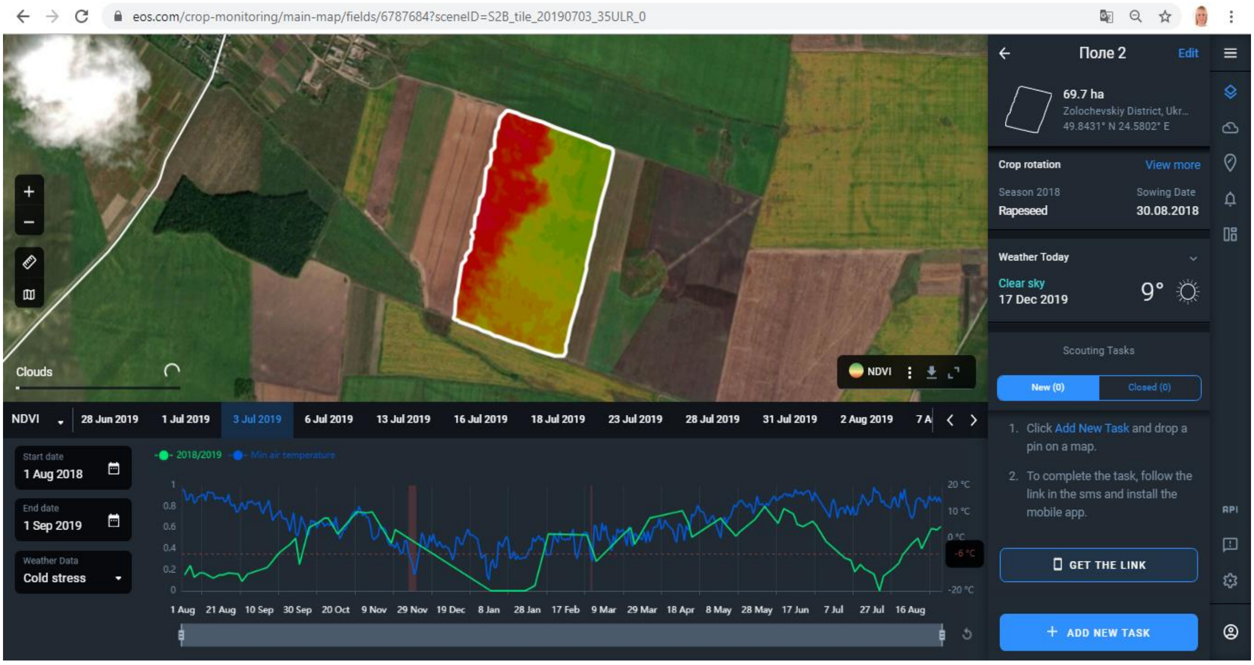

Fig. 2. The image of the NDVI vegetation index for land use on July 3, 2019.
Source: on the basis of data [2].

Next, we opt for the contrast field areas considering the light tone on the space image for conducting zoning using the method of the numerical taxonomy of optical brightness. An algorithm for applying zoning to construct a raster image of a field was created based on the analysis of multispectral scan data in the Crop Monitoring geoinformation system [2]. As a result of their automated calculation, we determine the optical brightness intervals as taxa, on the basis of which the areas of rapeseed cultivation in the land use area are reflected. For instance, we show the zoning image of rapeseed cultivation according to the NDVI index value (Fig. 3). It is a quantitative indicator of the amount of photosynthetic active biomass used to estimate the state of vegetation [6].

Fig. 3. Land use zoning for rapeseed cultivation according to the NDVI Vegetation Index on July 1, 2019
Source: on the basis of data [2].

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Further automatic image tracing according to NDRE data allows estimating the area of land use with high vegetation of rapeseed cultivation (Fig. 4). Normalized Difference Red Edge allows better studying later rapeseed harvests because it is more sensitive to leaf chlorophyll content, nitrogen uptake, reflecting changes in other mineral fertilizers, and provides a better estimate of vegetation state than the Normalized Difference Vegetation Index [5].

Fig. 4. Land use zoning for rapeseed cultivation according to the NDRE data on July 1, 2019
Source: on the basis of data [5].

The automated character of the data processing of the space image, the use of the mathematical and statistical zoning apparatus improves the accuracy of determining the vegetation zones of cultivation of a certain agricultural crop in comparison with the traditional method of large-scale soil survey and their mapping. Fig. 4 shows the zoning of land use for the cultivation of rapeseed according to the MSAVI vegetation index on July 1, 2019. Unlike other vegetation indices, it considers atmospheric natural phenomena during long-term monitoring [3].

Fig. 4. Land use zoning for rapeseed cultivation according to the MSAVI data on July 1, 2019
Source: on the basis of data [6].

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The cartogram of the brightness of the land use zoning image carries direct information on the values of the RECI vegetation index in each pixel in Fig. 5, which determines the content of chlorophyll in plants in a stress state and indicates whether the plant is healthy [3].

Fig. 5. Land use zoning for rapeseed cultivation according to the RECI data on July 1, 2019
Source: on the basis of data [2].

One has pointed out three zones with high, medium and low vegetation of plants in accordance with the zoning results of land use in the cultivation of rapeseed using remote sensing data in the geo-information system Crop Monitoring [2]. However, their area is diverse according to the vegetation index NDVI, NDRE, MSAVI, and RECI. Close in structure is the area of land use zoning by NDRE and MSAVI values, and similar is the NDVI and RECI indices (Table 1). It indicates the peculiarities of their application to optimize crop cultivation.

Table 1. Land use zoning for rapeseed cultivation according to the NDVI Vegetation Index on July 1, 2019

Vegetation Index	Area					
	High vegetation		Medium vegetation Zone 2		Low vegetation	
	ha	%	ha	%	ha	%
NDVI	33.3	47.7	17.6	25.2	18.8	27.0
NDRE	4.7	6.6	33.1	47.5	32.0	45.9
MSAVI	2.7	3.8	24.6	35.3	42.4	60.9
RECI	28.6	41.0	18.9	27.1	22.2	31.9

Source: on the basis of data [2].

Based on the obtained values of the vegetative index NDVI, NDRE, MSAVI, and RECI according to the data of remote sensing in each land use area on July 1, 2019, the estimated rapeseed yielding capacity which is lower than the statistical one 34.2 c/ha for the location area of the research object [4]. One can observe from Table 2 that the yielding capacity from the whole land area will be 1.7 times lower compared to the agricultural one in the amount of 2,383.7 c in the area of 69.7 ha. Taking into consideration the analysis of rapeseed cultivation in the studied area of the field (69.7 hectares), we observe that the maximum biological (predicted) yielding capacity can be 1,382.1 according to the results of the vegetative index NDVI, and the minimum one – 965.0 t based on MSAVI data. It is definitely that the sparse vegetation of low-yielding rapeseed sowing is on the land plot, and accordingly, it requires the application of additional organic and mineral fertilizers in the low vegetation area [8] with an average of 41 hectares per the research object.

Table 2. The predicted yielding capacity of rapeseed according to vegetation index data for land use on July 1, 2019.

Area	Vegetation index value				The predicted yielding capacity of rapeseed according to vegetation index data, c/ha				The statistical yielding capacity of rapeseed in the research area, c/ha	The yielding capacity of rapeseed for sowing area of the researched land use, c				
										predicted				statistical
	NDVI	NDRE	MSAVI	RECI	NDVI	NDRE	MSAVI	RECI		NDVI	NDRE	MSAVI	RECI	without taking into account the vegetation index data
High vegetation	0.74	0.58	0.63	0.63	25.31	19.8	21.5	21.5	34.2	842.8	93.1	58.1	614.9	
Medium vegetation Zone 2	0.58	0.53	0.53	0.53	17.1	18.1	18.1	18.1		300.3	598.4	445.1	341.5	
Low vegetation	0.37	0.37	0.32	0.26	12.7	12.7	10.9	8.9		239.0	406.0	461.8	197.5	
For sowing area of land use 69.7 ha										1,382.1	1,097.5	965.0	1,153.9	2,383.7

Source: on the basis of data [2, 4].

CONCLUSIONS

As a result of the conducted research, an algorithm of modern soil zoning was formed due to the transition to quantitative estimation of the cultivation state of crops, using the creation of electronic soil maps based on thematic raster vegetation index applying geo-information technologies. The developed crop cultivation zoning model will significantly reduce the time spent on fieldwork by diagnosing and mapping soils, which presents qualitative information for the purposes of soil monitoring, effective land use, soil protection, and fertility enhancement.

Zoning using geo-information systems based on multispectral space scanning data allows the creation of electronic mapping of crop growth and development indices, as well as their yielding capacity on certain fields within space imagery with accurate geographical reference.

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