Design of adaptive measures in crop production based on remote monitoring of crops

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SUMMARY

The paper presents the results of studies of the possibility of using the data of operational remote monitoring as a basis for the design of adaptive measures in case of adverse weather phenomena on spring crops (sunflower, corn). Dji Phantom 4 drone and Sentinel 2a satellite information were used as test equipment,, the technology tested on the example of a field that suffered from spring flooding. Based on the obtained data maps of differentiated use of herbicides and nitrogen fertilizers were constructed. The study of the results of the application showed the significant economic efficiency of differentiated use of materials, and the economic advantage of the technology compared with the traditional solid system of introduction. It is established that UAV data can serve as a reliable information base for planning adaptive measures, and in general for the introduction of elements of precision agriculture in the Polissya region of Ukraine.

Introduction

Satellite monitoring data are accessible and easy to process, which has led to their widespread adoption in agricultural production. Currently, the Sentinel 2a, 2b, Landsat satellite information is effectively used in crop monitoring to determine vegetation type and conditions, crop development status and dynamics, productivity estimates and yield forecasting (Kokhan, 2012; Sharma et al., 2008; Trofymenko et al., 2019). Photographic plans and cartograms of the vegetative indices NDVI, RVI, NRVI, which are based on satellite data, are widely used for operational management in field crops growing (Antonenko et al., 2005, Furmanets et al., 2019). Despite the many advantages, satellite monitoring data have significant drawbacks, which include, first of all, the discretion and time constraints of data acquisition, depending on the meteorological conditions of a particular area. These drawbacks do not allow for an on-site analysis of the situation on the field and apply appropriate adaptive measures fast, which is required by intensive plant growing. The decision in this case may be to use as a primary source of UAV information. The use of UAVs in agriculture has enormous potential, and every year interest in their use is increasing (Duveiller et al., 2012). Unmanned monitoring data in combination with appropriate image processing (Bianconi et al., 2011) can effectively solve the problems of obtaining operational information about the status of crops, in particular in the region of Ukrainian Polissya (Trofimenko et al., 2017). In this case, the obtained information can be used as a base for constructing images of vegetation indices (Kolesnik, Kolesnik, 2003; Savin, Vern'yk, 2015, etc.), which allows to onduct an operational analysis of the state of the field, in particular to detect the manifestation of adverse phenomena (flooding, drought) and to apply appropriate corrective measures in a timely manner.

Methods

The main purpose of the study was to establish the practical possibility of using the air monitoring data to design of adaptive measures in case of adverse weather phenomena on spring crops. The source of the images was Dji Phantom 4 with a spectral camera (550, 660, 735 and 790 nm imaging channels).The flight is made automatically under the control of the DroneDeploy software. Flight altitude 200 m, total number of field images 112. Task-maps planning was performed using SMS Agleader software. As a test for analysis, were used the field of LLC West Agroprom with a total area of 31 hectares, located in the Berezne district of Rivne region, in the zone of Western Polissya. The predominant type of soil is sod-podzolic sandy soil with the impregnation of sand and peat soils and the presence of reliefs with excessive periodic moistening. The studies were carried out on the example of sunflower field (sowing date 14-15.04.19, predecessor - corn).

Results of investigations

More than 200 mm of precipitation fell on the test field during the period 28.04-15.05.19, which resulted in partial flooding of the existing sunflower crop during the ladder stage. The meteorological conditions restricted access to the field for the sprayers for a long time, which caused a secondary problem - over-development of weeds.

Figure 1 *Test field image 15.05.19, Phantom Dji*

Both phenomena were unevenly developed in the field and required immediate application of corrective action.
At the same time, on the areas of sustainable flooding (about 5% of the area) sunflower plants were lost, and the corresponding areas of the field had to be excluded from further cultivation to save resources. Weed overdevelopment sites (about 30% of the area) required increased doses of herbicides. The rest of the field area required regular doses of herbicide application to attenuate the phytotoxic effect on the attenuated sunflower culture (Figure 1).
To accomplish these tasks, a UAV field flight was planned, which resulted in the construction of a field photoplan and NDVI index map (Fig. 2).

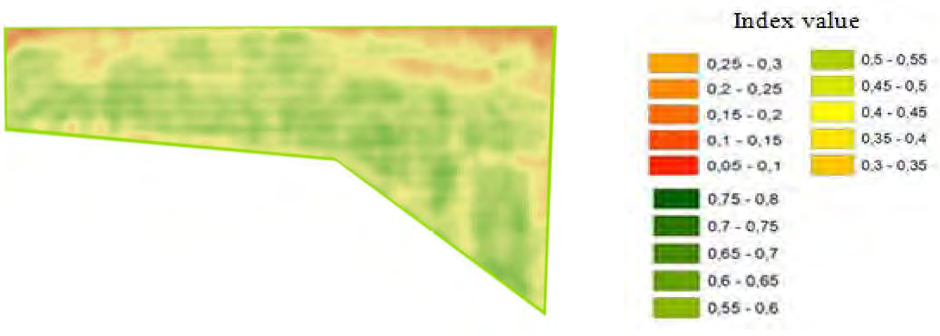

***Figure 2** Map of the NDVI index values in the test field according to UAV data*

The plot shows clearly visible areas affected by flooding and areas requiring increased doses of herbicides.
In order to plan specific measures for the crops cultivation, it is necessary to build on the base of obtained image task-maps for herbicide treatment, with the aim of eliminating undesirable vegetation as soon as possible, and for the application of fertilizers, in order to stimulate the sunflower growth. It is important in both cases to avoid the introduction of funds to the fragments of the field that were killed by the flooding.
At the first stage of implementation of adaptive measures, the task of conducting herbicide treatment was created (Fig. 3).

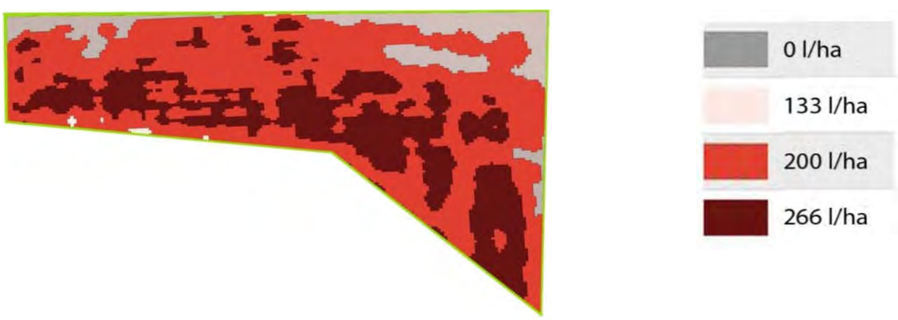

***Figure 3** Task-map for conducting herbicide treatment of the test field*

As the herbicide used the Express Gold pesticide, the basic rate of application - 30 g / ha. Sprayer Case Patriot 3330 with Trimble RTX RangePoint-adjusted navigation system. Variable rate of herbicide application in individual areas of the field were achieved due to the variable rate of pouring of the pesticide solution. At the concentration of the active substance in the pesticide solution - 0,015%, the basic rate of application of the drug is achieved by pouring 200 liters of working solution per ha. With a further increase of discharge to 266 l / ha, the rate of application of Express is increased to 40 g / ha. Further increasing of the dose of application threatens phytotoxic effect on the culture. The average weighted planned quantity of the preparation per unit area of the field is 31 g / ha, which is almost indistinguishable from the usual continuous treatment. The same time, planed application significantly increases the overall performance of the drug on the field due to selective introduction. The next stage was the construction of a task for the differential application of nitrogen fertilizers (Fig. 4).

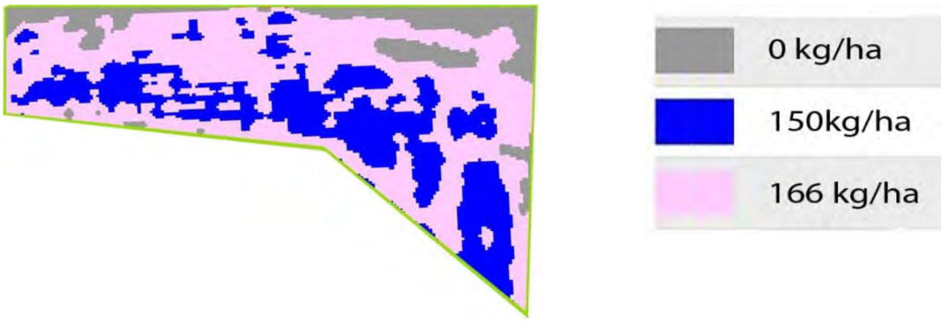

Figure 4 *Task-map for conducting fertilizer application of the test field*

The planning of further application of nitrogen fertilizers was carried out in accordance with the following objectives:
- do not use fertilizers in flooded areas;
- to apply an increased rate of fertilizer in areas that are not affected by excessive contamination and thus have a higher productivity potential.

Working unit Case Magnum 310 + Kuhn Axis 40.2., Trimble copilot with RTX CenterPoint correction.

Baseline application rate is 150 kg / ha of granulated ammonium sulfate; higher application rate - 166 kg / ha, have been applied in areas of higher productivity. In this case, due to the exclusion from the cultivation of flooded areas in accordance with the map-task, the total need for fertilizer on the field is 4380 kg. In this case, the average dose per hectare is 141 kg, which is even less than it would be with normal continuous application with the basic rate. Subsequent field monitoring showed a gradual normalization of crop development with minimal deviations in sunflower development (Fig. 5).

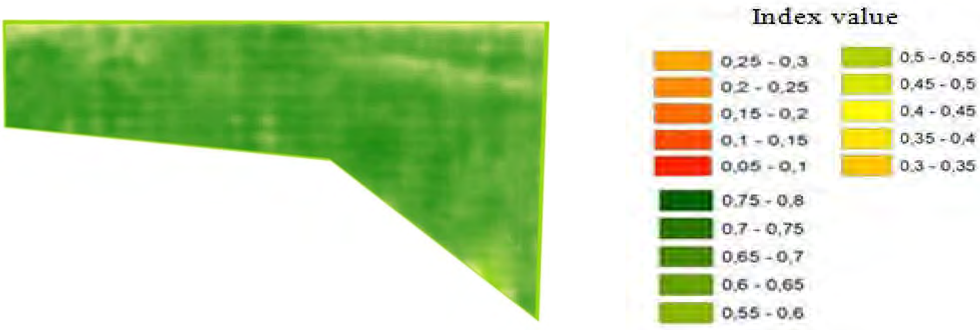

Figure 5 *Sunflower vegetation on the test field, 13.07.19*

The flooded areas of the field began to intensively overgrown with weeds after sunrise, so the NDVI contrast is visible only on their perimeter, which has been treated with herbicide. In the rest of the field, the main culture was developing fairly evenly. Planned costs for the introduction options are summarized in Table. 1.

Thus, even at direct costs per hectare of cultivated field, differential application technology has an economic advantage over the traditional technology. But the main positive effect of the differentiated application technology is to increase the gross harvest from the cultivated area due to more efficient economic use of resources that are spent in the field.

***Table 1** Calculation of costs per 1 ha of field for continuous and differentiated application of materials*

Variant	Herbicide treatment			Fertilizer application			Total value, uah/ha
	Dose g/ha	Value to 1 ha, uah	Execution costs, uah/ha	Dose g/ha	Value to 1 ha, uah	Execution costs, uah/ha	
Continuous	30	162,0	54,5	150	1020	49,5	**1286,0**
Differentiated	31	167,4	54,5	141	959	43,6	**1224,5**

Conclusions

In conditions which requiring rapid response, UAV data take precedence over similar satellite monitoring data due to speed of their receipt, availability for processing and less dependence on meteorological factors. However, depending on the specific tasks, there is an opportunity to vary the detail and fragmentation, which extends the scope of potential applications. The using of small drones like Dji Phantom 4 in crop production has considerable prospects, in particular for the accurate assessment of the manifestation of adverse meteorological phenomena. UAV data can serve as a reliable information base for planning adaptive activities and, in general, for the introduction of precision farming elements at the zone of Ukrainian Polissya. The cost-effectiveness of introducing of differentiated field treatments has been experimentally proven, through direct cost savings and through improved cost-effectiveness of drugs.

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