Validation of Data Obtained After Field Sensing Using UAV for Management of Future Crops

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Abstract
UAVs are innovative equipment for monitoring fields that are free from a lot of the disadvantages of satellites such as availability, low cost, and high image resolution. However, the issues of quality, reproducibility, and suitability for crop management processes remain relevant. Now, the issue of assessing the suitability of the results of spectral monitoring of plantations in relation to the condition of plants has not been resolved. Since spectral monitoring is a necessary component in the concept of crop management, the development of a methodology for assessing the suitability of remote monitoring spectral data for the calculation of agrochemical practices was the purpose of the work. According to the publications, the dependence of the number of pixels on the values of the intensity of color components for plants and soil is described by the Gaussian distribution. Deviation from such distribution is caused by the imposing of distributions from various objects fixed on a photo. The experimental test was carried out on the basis of wheat, using the results obtained during 2017-2020 when considering the stresses of nutrient deficiency and technological nature. The investigation found experimental evidence that the pixel distribution of plantations on the example of the wheat crop is described by the Gaussian distribution. It was found that the analysis of the correspondence of the nature of the distribution on the spectral channels, namely the presence of several max peaks that affects the value of the distribution maximum may indicate the presence of foreign inclusions or a transitional stage of vegetation. The suitability of the data can be assessed on the basis of the reference values of the width of the distribution on the spectral channels. Vegetation indices GNDVI and RNDVI were unsuitable for assessing the suitability of the data based on the parameters of the pixel distribution of the image in the experimental plots. This determines the feasibility of introducing in the sets of regular vegetation indices of geographic information systems additional packages that reflect the spectral channels.

Keywords
UAV, spectral monitoring, crop management, data validation

1. Introduction

UAVs are innovative equipment for monitoring fields, which are deprived of a number of fundamental shortcomings of satellites in terms of availability, cost, image resolution. However, the issues of quality, reproducibility, and suitability for crop management processes remain

ISIT 2021: II International Scientific and Practical Conference «Intellectual Systems and Information Technologies», September 13–19, 2021, Odesa, Ukraine
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relevant. More often, designers focus on the improvement of spectral equipment, but there are also methodological problems in the perception and interpretation of information from devices of technical vision. Thus, most of the vegetation indices currently used to interpret UAV data, such as NDVI, were developed for satellite platforms with their inherent low image resolution when each pixel had a group of plants. The indices developed on the basis of the soil line concept were primarily intended to assess the availability of biomass, and crop management issues require other methodological approaches to crop monitoring. It should be borne in mind that the implementation of agrochemical measures, in particular fertilization should be carried out only at certain stages of the growing season. However, the state of plant development is determined by many factors, including the state of mineral nutrition, water supply, etc., so within one field there may be a situation when the plants are at different stages of the growing season. Accordingly, in such situations, the calculation of the mean value over the site, which is inherent in satellite solutions, is erroneous. At present, the issue of assessing the suitability of the results of spectral monitoring of plantations in relation to the condition of plants has not been resolved. Since spectral monitoring is a necessary component in the concept of crop management, the development of a methodology for assessing the suitability of remote monitoring spectral data for the calculation of agrochemical practices was the purpose of our work.

2. The state of the issue

The spectral performance of objects critically depends on the state of illumination, and the reproducibility of data is tried to ensure by a combination of technical and organizational measures. The work of Helge Aasen and others (2015) in [1] considered the construction of 3D models of plants, where to ensure accuracy, they proposed a method of combining data from several flights. Despite the interesting and encouraging results, such a technique will require several flights in a row from different directions, which is unsuitable for industrial-scale in conditions of time shortages. An approach to determine the features of the dome of plants in the mass phenotyping of plants using UAVs based on a comparison of the obtained portraits with reference templates is shown in Fusang Liu and others (2021) in [2]. Information on plant dimensions is useful for determining stress conditions, but in the early stages of the growing season, accurate image resolution is required for accurate identification, which can only be obtained from low altitudes, which will not contribute to the scalability of technology on an industrial scale. An alternative technical means for estimating plant dimensions are LiDARs described in the review article by Yue Pan and others (2019) in [3]. However, such innovative equipment for small plants, with a leaf width of several millimeters, according to Tai Guoa and others (2019) in [4].

Another approach is based on the use of reference values of plant spectral indicators to identify the spread of forest pests described in Per-Ola Olsson and others (2016) in [5]. The estimate is based on recording the deviation from the seasonal changes of the NDVI index is designed for different stages of the growing season because satellite imagery is carried out at high intervals and you can select data for uniquely the same stage of the growing season. A similar approach to the selection of spectral data from an existing array of rapidly changing data is shown in the work of Ameer Shakayb Arsalaan and others (2016) in [6] on the example of forest fires. However, under normal conditions, farms in crop management should be able to decide on the basis of a single departure on the need for additional flights that require free equipment.

An original approach to the identification of plants in terms of changes in their dimensions on the example of sugar beet is shown in the work of Yang Cao Liu and others (2020) in [7]. Researchers have proposed a new wide-dynamic-range vegetation index (WDRVI) where an additional coefficient is introduced for the infrared channel. However, in production, the achieved accuracy increase of up to 5% should still recoup the cost of determining the dynamically changing coefficients for the infrared channel. That is, the most promising approach is based on the comparison of spectral indices with certain reference samples.

Spectral indicators of plants, even those that are in the same stage of the growing season have some differences. To obtain the average value for plants when fixing the soil in a photograph, Yaokai Liu et al. (2012) in [8] proposed the use of Gaussian distribution combinations where the ranges belonging separately to plants and soil were recorded. Positive results were obtained, but the resolution of images from a height of 3 m was very high, which is difficult to implement on an industrial scale. According to the data presented in the work of Guangjian Yan and others (2019) in [9], when the resolution of the images is reduced, the ability to select individual ranges corresponding to the soil and plants is lost. Improving identification by estimating the intensity distribution of color components is shown in André Coy et al. (2016) in [10] where the CIE L * a * b * space model was used instead of the RGB color model. The authors have proposed threshold values to determine the area of the dome, but this approach will be effective only in the initial stages of the growing season when in particular the shade on the lower tiers of plant leaves can be neglected. The method was improved in the work of Linyuan Li et al. (2018) in [11], when the identification of soil and plants was attempted on the basis of the Gaussian half-distribution. This approach allows you to identify 2 components, but in the case of 3 components, its efficiency is questionable.

Thus, based on the analysis of the literature, we can conclude that the dependence of the number of pixels on the values of the intensity of the color components for plants and soil is described by the Gaussian distribution. Deviation from such distribution is caused by the imposing of distributions from various objects fixed on a photo. However, experiments were performed in hospitals where the plants were in one phase of the growing season in the air-dry state of the soil, respectively, it is advisable to check the suitability of the method and in moist soil.

3. Materials and research software and hardware

The research was carried out on the basis of wheat, using the results obtained during 2017-2020. Stresses due to lack of nutrients were studied in the fields of the long-term stationary experiment of the Department of Agrochemistry and Plant Quality of NULES of Ukraine, where fertilizer application systems are studied. Technological stresses were studied on and in the production fields of farms in the Kyiv region. In fig. Green Chlorophyll index distribution maps are presented (Fig. 1).

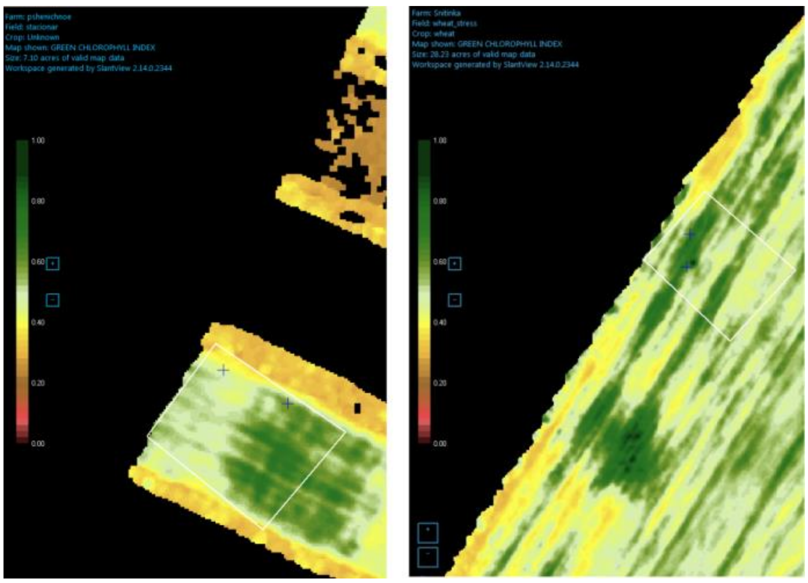

Figure 1: Green Chlorophyll index distribution maps on the research hospital on the left and production fields (on the right) are created by Slantrange software. Blue intersections highlight checkpoints for accurate positioning of pixels of different spectral channels and index distribution maps

The experiments were performed in the optical range using a standard UAV camera DJI Phantom 3+. A description of the methodology of experimental research was covered in the work of V. Lysenko and others (2017) in [12] and M. Dolia and others (2019) in [13] (2019). Multispectral studies using the infrared range were performed using the Slantrange 3p system and Slantview software (version 2.13.1.2304) designed specifically for this sensor equipment. A feature of Slantview software is the ability to quickly and autonomously create vegetation distribution maps directly in the field. Slantview software compiles a general orthophoto from images, corrects for lighting, and provides the user with ready-made maps of the distribution of vegetation indices such as various NDVI variants. Slantview software can export data to geotiff format. Areas of rapeseed with and without signs of technological stress were considered for research. Data on individual spectral channels and vegetation indices calculated by the Slantview program were considered. The research methodology is described in the work of S. Shvorov and others (2020) in [14]. Maximum detail (GSD 0.04 m / pixel) was obtained from the Slantview software image window (available NDVI index variants - Green, Red, and RedEdge). Monochrome images were used to study the results on separate spectral channels (image window), which were stored in BMP format to ensure the completeness of the information. To do this, a copy of the screen was saved in Paint (Microsoft Windows 7.0 Sp.1).

4. The results and discussions were obtained

In fig. 2 shows the results of calculations for the red component for experimental data obtained on 2017.05.05 in studies of the impact on the spectral indicators of the state of mineral nutrition using a universal camera FC200 (a standard tool for UAV DJI Phantom 3).

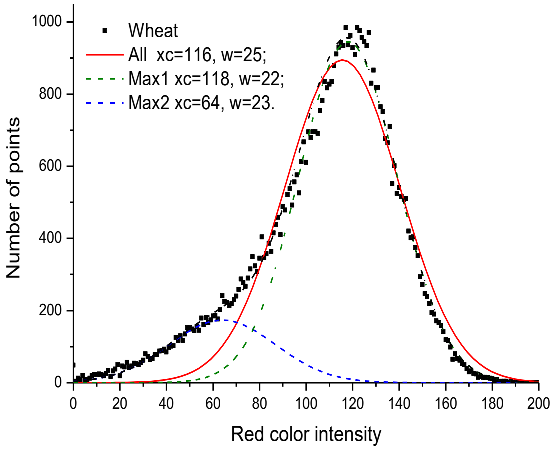

Figure 2: The results of the approximation of the dependence of the number of pixels on the intensity of the red component of color (05.05.2017)

As can be seen from the above data when using the proposed method, it was found that the value of the maximum distribution shifted by 2 units, while reducing the width w by 3 units. The presence of the Max2 distribution can be explained both by the presence of shadow on the lower and upper leaves and by the fixation of the soil.

The proposed approach to the processing of experimental results will be effective if the condition Max1≫ Max2 is satisfied. In practice, a situation is possible when plants of the same crop are in the field at the same time, but at different stages of the growing season or in a fundamentally different physiological state, such as the appearance of a flag leaf, which was recorded on 06.08.2018. According to the presented in fig. 3 data Max1≅Max2, so the approach was used when at the first stage separately determined separately 2 Gaussian distributions, after which the calculations were carried out according to the method proposed in section 3.

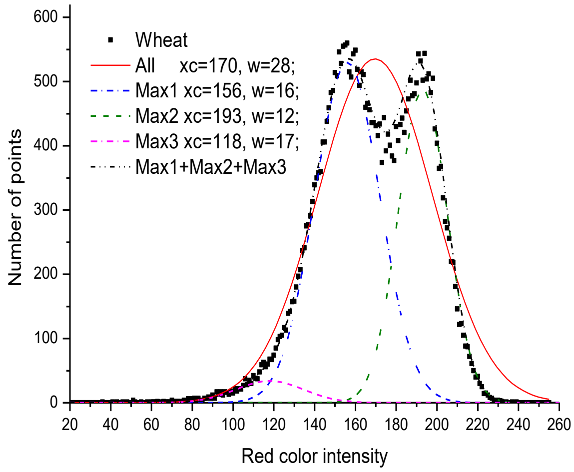

Figure 3: The results of approximation of the dependence of the number of pixels on the intensity of the red component of the color for winter wheat (2018.06.08 - there is a flag sheet)

Detection of the presence of several individual maxima can be done based on the magnitude of the distribution when using to approximate the experimental data. For the presented data, the value was 28 while in the remaining sections was 18… 23.

Based on the obtained results, the results obtained by approximating all the data by a single Gaussian dependence (All) are incorrect because they do not correspond to any of the distribution maxima. That is, monitoring was performed when the plants were in a transitional state and monitoring should be repeated after a few days when the vast majority of plants in the field are in a single stage of vegetation. For automatic processing of monitoring results, reference values for distribution parameters can be obtained in stationary experiments, etc.

For universal digital cameras in the optical range, such as FC200, strict compliance with the selectivity of light filters is not required, so to verify the results, a study was conducted using a specialized spectral complex Slantrange 3. The results of mineral nutrition studies are presented in Fig. 4.

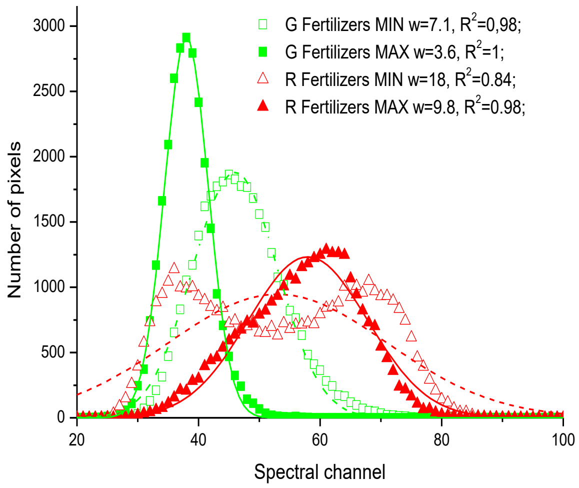

Figure 4: Dependence of the number of pixels on the value of the intensity of the green (G) and red (R) components of the color and the wall of mineral nutrition at a dose of mineral fertilizers (Fertilizers MAX) and without fertilizers (Fertilizers MAX). Date of research 2020.04.27

When approximating the experimental data by the GaussAmp dependence, the distribution width for the green channel was 7.1 for plants under stress and 3.6 for healthy plants, respectively, at 0,98≤R^2. For the red component, regardless of the state of mineral nutrition, the imposition of 2 maxima will be recorded, which were more pronounced in the absence of nutrients. Similarly to the green channel, the calculated distribution width in healthy plants was approximately twice less than in stress plants 9, 8 and 18, respectively. The coefficient of determination at 1.5 doses of mineral fertilizers was 0.98 and for affected plants 0.84.

The results of research on the technological stress caused by the action and aftereffect of herbicides from the predecessor culture were carried out in production fields near the village of Gvardiyske with the coordinates of lat. 50,0347 long. 30,0286 is presented in fig. 5.

According to the results obtained under stress conditions, the width of distribution on both the green and red channels is 1.5≤ times greater than in healthy plants. On the red channel, regardless of the presence of technological stresses, 2 pronounced maxima of distribution were not observed, in contrast to the results in Figs. 4, regardless of the channel, the coefficient of determination is 0.98≤R2. According to the authors, the difference in plant development is explained by the difference in climatic factors due to the location of the plots, so the production field is protected by dense forest strips in contrast to the used area of the experimental hospital.

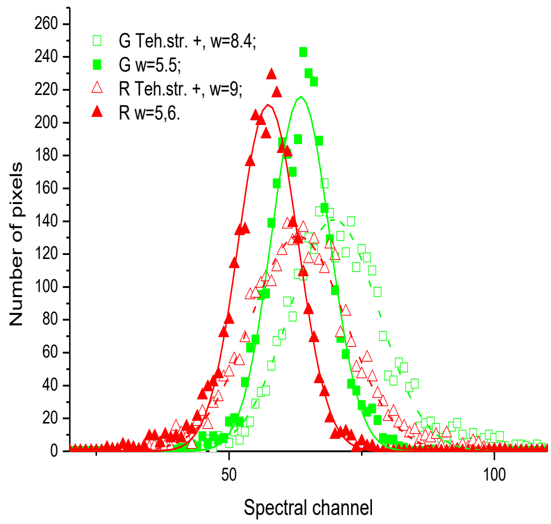

Figure 5: Dependence of the number of pixels on the intensity of the green (G) and red (R) components of color and the presence of technological stresses (The.str). Date of research 2020.04.27

5. Wheat (distribution maps of vegetation indices)

Since the experimental plots with different fertilizer contents of the stationary experiment have a relatively small width of 5 meters for remote sensing using a UAV, the results obtained from the Slantview software map window were used for the research. The obtained results are shown in Fig. 6 for stresses caused by the state of mineral nutrition and technological stresses, respectively.

Based on the data obtained for the distribution of the NDVI index, there is a difference in the distribution of spectral channels. Thus, the width of the distribution regardless of the nature of stress in stress plants was similar or even smaller than in healthy plants. The coefficient of determination was 0.85-0.95, it was much lower than in the green and red spectral channels.

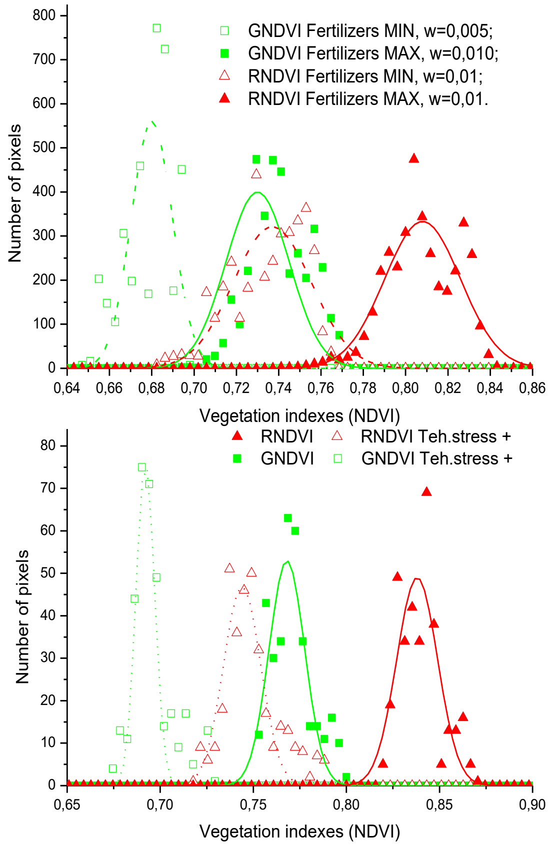

Figure 6: Dependence of the number of pixels on the value of the variant of the vegetation index GrennNDVI (GNDVI) and RedNDVI (RNDVI) at stresses caused by lack of mineral nutrition (upper) and technological nature (lower)

6. Conclusions

The study found experimental evidence that the pixel distribution of plantations on the example of wheat crops is described by the Gaussian distribution.

Analysis of the conformity of the nature of the distribution along the spectral channels, namely the presence of several maxima that affect the value of the maximum distribution may indicate the presence of foreign inclusions or a transitional stage of vegetation.

Data suitability can be assessed on the basis of spectral channel width reference values.

Vegetation indices GNDVI and RNDVI were unsuitable for assessing the suitability of data based on the parameters of the pixel distribution of the image in the experimental plots. This determines the feasibility of introducing in the sets of regular vegetation indices of geographic information systems additional packages that reflect the spectral channels.

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