Estimation Quality of Filtering Spectral Data Obtained from UAVs

Natalia Pasichnyk [a], Dmytro Komarchuk [a], Oleksiy Opryshko [a] and Nikolay Kiktev [a, b]

[a] *National University of Life and Environmental Sciences of Ukraine, Heroiv Oborony str., 15, Kyiv,03041, Ukraine*
[b] *Taras Shevchenko National Univercity of Kyiv, Volodymyrs'ka, 64/13, Kyiv, 01601, Ukraine*

Abstract

Because 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 based on wheat, using the results obtained during 2017-2020 when considering the stresses of nutrient deficiency and technological nature. For the first time, it is proposed to evaluate the quality of filtering of foreign objects by identifying plantings, based on the assessment of the intensity distribution of the pixel color components in the experimental area. It is established that the distribution for plants is described by the GaussAmp function, and therefore the presence of "foreign" pixels (soil, organic residues) is determined by comparing the existing distribution with the approximate Gaussian dependence. In addition to assessing the quality of filtration, this approach will increase the accuracy and reproducibility of the obtained data for agronomic needs. For the first time, a method of identifying areas affected by technological stress, namely crop compaction is acceptable for industrial fields on the basis of spectral monitoring data obtained using UAVs. Identification can be carried out both on separate spectral channels and on maps of the distribution of standard vegetation indices NDVI / Thus the technique can be implemented both on specialized systems such as Slantrange and with the use of universal cameras.

Keywords [1]

Unmanned aerial vehicle, spectral monitoring, crop management, data validation

1. Introduction

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

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EMAIL: n.pasichnyk@nubip.edu.ua (A. 1); dmitruyk@gmail.com (A. 2); ozon.kiev@gmail.com (A. 3) ; nkiktev@ukr.net (A. 4)
ORCID: 0000-0003-4712-3916 (A. 1); 0000-0003-3811-6183 (A. 2); 0000-0001-6433-3566 (A. 3); 0000-0001-7682-280X (A. 4)

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 about 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 peculiarity of fertilizing plants in particular with nitrogen fertilizers is the need to comply with certain phases of plant development, which causes restrictions on the implementation of these operations, namely the implementation of monitoring, decision-making, and direct application of fertilizers. In this case, a prerequisite for the implementation of technology is the reproducibility of data from the proposed systems with existing solutions for contact and contactless monitoring. Existing technologies of remote air and satellite monitoring have significant problems, primarily of a methodological nature. Thus, according to the results of studies by T.Duan and others (2017) [1] when combining data from ground equipment GreenSeeker and RedEdge camera mounted on a UAV for the NDVI index, a significant difference was recorded, which had both static and dynamic components recorded at different stages of vegetation. The need to take into account the dynamics of change of biological objects was proved in the works of T. Lendiel, I. Bolbot and others (2020) in [2] and R. A. Abdelouhahid and others (2021) in [3]. For plant monitoring in greenhouses, there are typical stresses such as water, temperature, etc. and for production, fields are characterized by additional technological stresses such as compaction of crops. Under such stresses, plants are destroyed in the final stages of the growing season. Experiments on remote monitoring of compaction using UAVs in Xiuliang Jin and others (2017) in [4] and Norman Wilke and others (2021) in [5], however, for reliable identification, the image resolution was 0.2 mm at a flight altitude of up to 7 meters which is unacceptable on an industrial scale field. 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 [6] 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 [7].

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 [8]. However, such innovative equipment for small plants, with a leaf width of several millimeters, according to Tai Guoa and others (2019) in [9].

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 [10]. 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 [11] 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 [12]. 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 increases 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 [13] 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 [14], 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 [15] 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 [16], 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.

2. Formulation of the problem

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.

3. Third level heading 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.

Research on technological stress was done on October 30, 2019, in production fields with winter wheat crops in the Boryspil district of Kyiv region with coordinates 50º16 'N, 30º58'E 50.0347. The presence of double the seeding rate was established by ground research and confirmed by evaluating data from GPS tractors of farm tractors. To take into account the influence of humidity, a lowland area was considered separately, where relatively large plant dimensions were recorded during ground monitoring (Fig. 1). Areas with stable puddles were pre-established when studying the public archive of satellite images with a resolution of 0.5 m / pixel from the Google maps service.

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 part of the production field was taken for research, where plots with the normal and doubled from a normal number of seeds were recorded within a single frame. A description of the methodology of experimental research was covered in the work of V. Lysenko and others (2018) in [17] and N. Pasichnyk and others (2020) in [18]. The application of cluster analysis methods in the study of weather conditions is described in N. Kiktev and others (2020) [19].

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 [20]. 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).

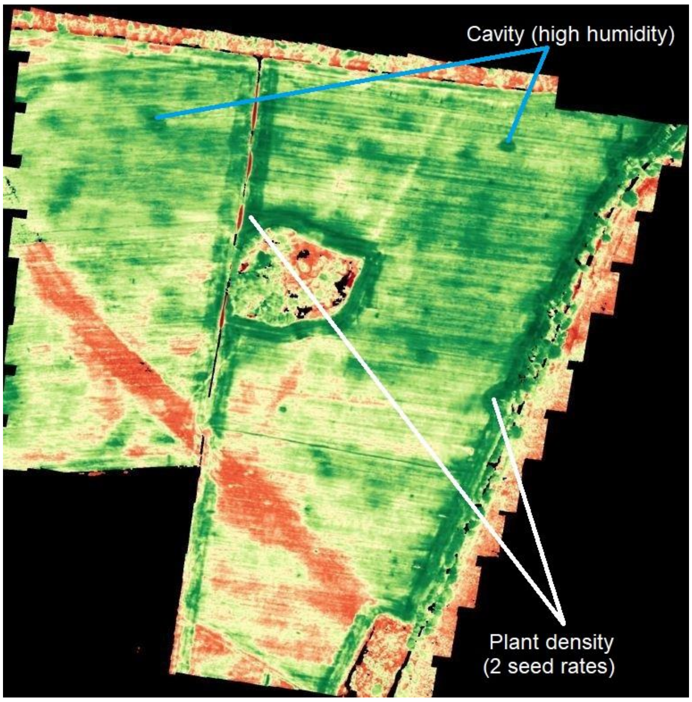

Figure 1: NDVI distribution maps are created by Slantrange software. Areas of crop compaction are shown along the edges of the field. Depressions with high humidity are marked on the field with blue arrows.

4. The results and discussions were obtained

Wheat belongs to the crops of continuous sowing, unlike row crops, so the identification of the soil will have difficulties in visual identification use the expert mode implemented in the Slantview software. Therefore, wheat was chosen for research. In fig. 2 shows the results of calculations for the red component for the experimental data obtained on 05.05.2017. The result of approximation of all data using the GaussAmp (All) equation and the sum of two equations Max1 + Max2 were considered separately. The dependence Max1 describes the plant and Max2 - the soil.

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. The plant monitoring was performed when the plants were in transition. According to the agronomy rules, the phase of growth is set by at least 75% of plants in the area. 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 presenceof 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.

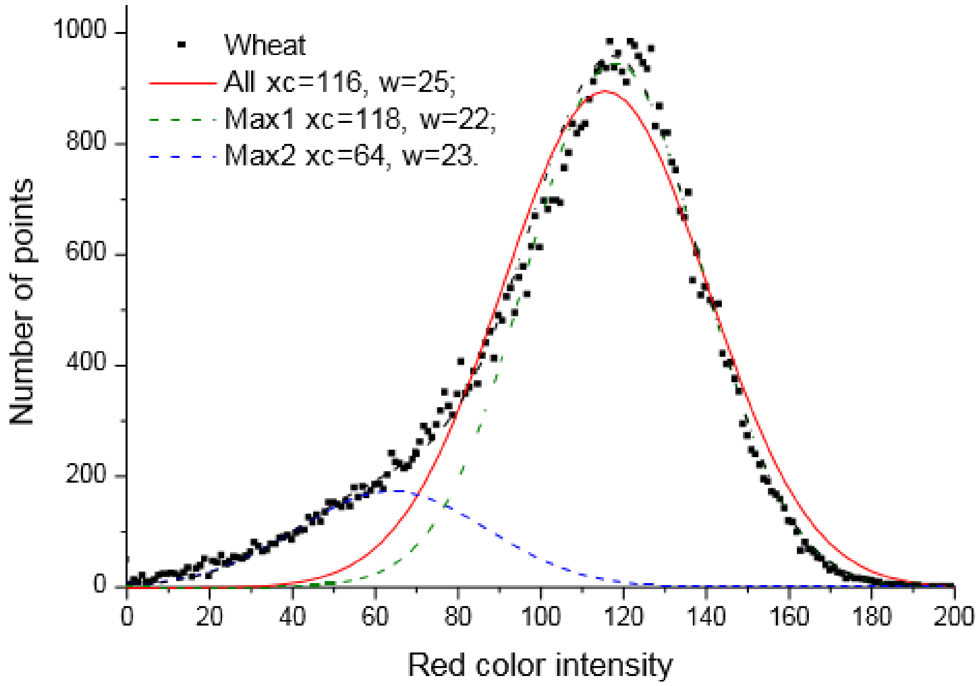

Figure 2: The results of the approximation of the dependence of the number of pixels on theintensity of the red component of color (05.05.2017)

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.

Thus the vegetation stage can be considered stable for the site and the results of spectral monitoring are suitable if, after soil filtration, the maximum distribution amplitude exceeds the nearest value more than 3 times. The results of mineral nutrition studies are presented in Fig. 4.

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 $0{,}98 \leq R^2$. 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.

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.

The results of studies of the manifestation of technological stress due to crop compaction obtained on the green spectral channel of the Slantrange system are presented in Figure 5. As can be seen from the above data, under the technological stress caused by the thickening of crops, the average value is the same as that recorded in the crops in the lowlands with the best state of water supply.

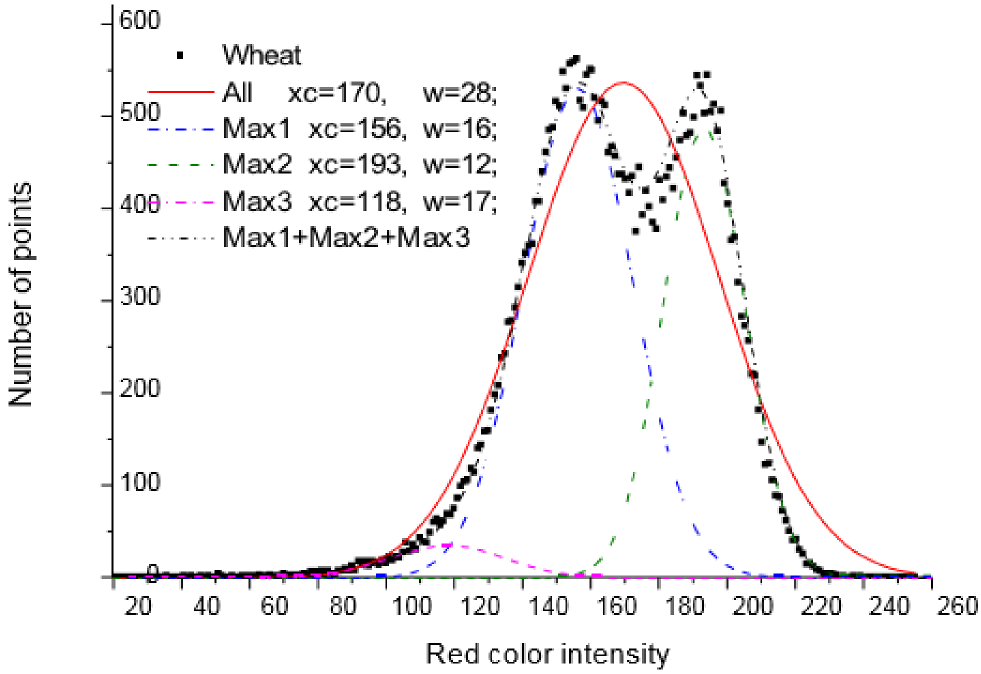

Figure 3: The results of the approximation of the dependence of the number of pixels on theintensity of the red component of color (05.05.2017)

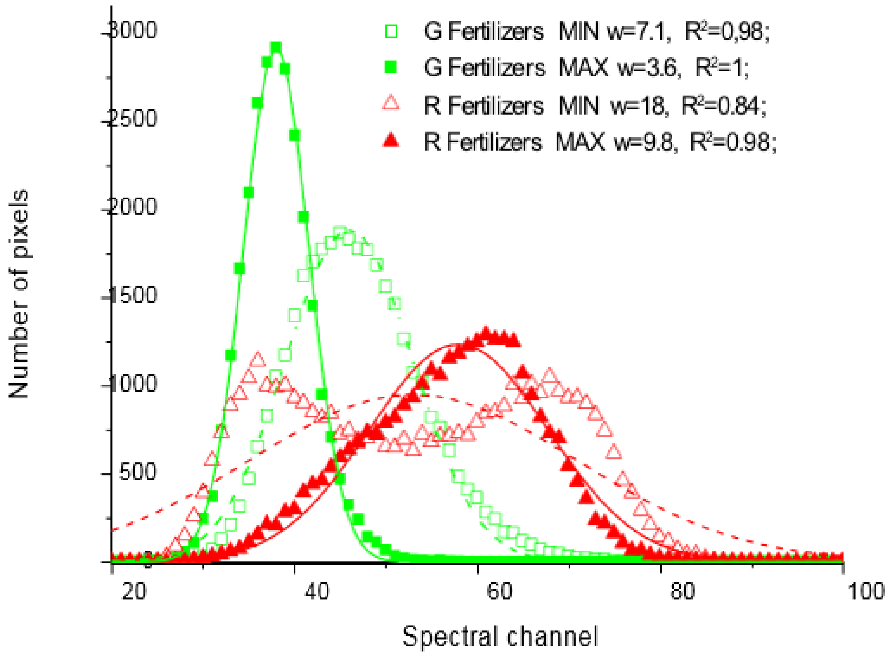

Figure 4: Dependence of the number of pixels on the value of the intensity of the green (G) and red (R) components of the color and the wall of mineral nutrition at a dose of mineral fertilizers (Fertilizers MAX) and without fertilizers (Fertilizers MAX). Date of research 2020.04.27

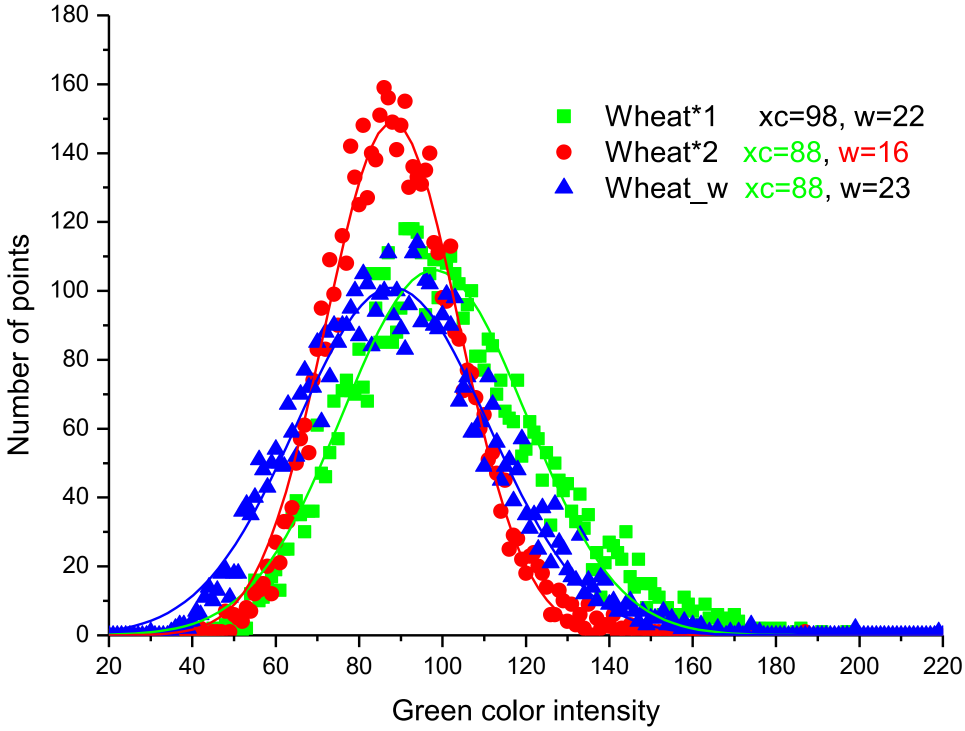

Figure 5: Dependence of the number of pixels on the value of the intensity of the green color components for normal and double the number of seeds (Wheat * 1 and Wheat * 2, respectively) and with a larger water supply (Wheat_w)

That is, the decisions made, based on the average value for the site, we're unable to distinguish these manifestations. In the case of using a promising parameter - standard deviation - identification was possible because the value was close to the reference area with a normalized number of sown seeds. The results obtained on the channels Red, RedEDGE and NIR are shown in table 1.

Table 1

The results obtained on the channels Red, RedEDGE and NIR

	Red			RedEDGE			NIR		
	Wheat 1	Wheat 2	Wheat w	Wheat 1	Wheat 2	Wheat w	Wheat 1	Wheat 2	Wheat w
xc	89	69	79	65,3	61,1	65	42	50,7	48,5
w	22,2	14	18,6	15	11,2	15,7	10,7	11,3	11,3
A	101	160	121	153	208	149	217	205	202
R2	0,95	0,98	0,97	0,99	0,99	0,99	0,99	0,99	0,98

According to the obtained results, the value of the standard deviation obtained by approximating the experimental data was suitable for detecting the presence of stress in wheat on the spectral channels Green, Red, RedEDGE. The slight difference between affected and healthy plants in terms of xc and w for the NIR channel, which is most often used to identify plantations by spectral monitoring, is probably due to the slightly larger size of the plants due to better water supply.

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

and Fig. 7 for stresses caused by the state of mineral nutrition and technological stresses, respectively.

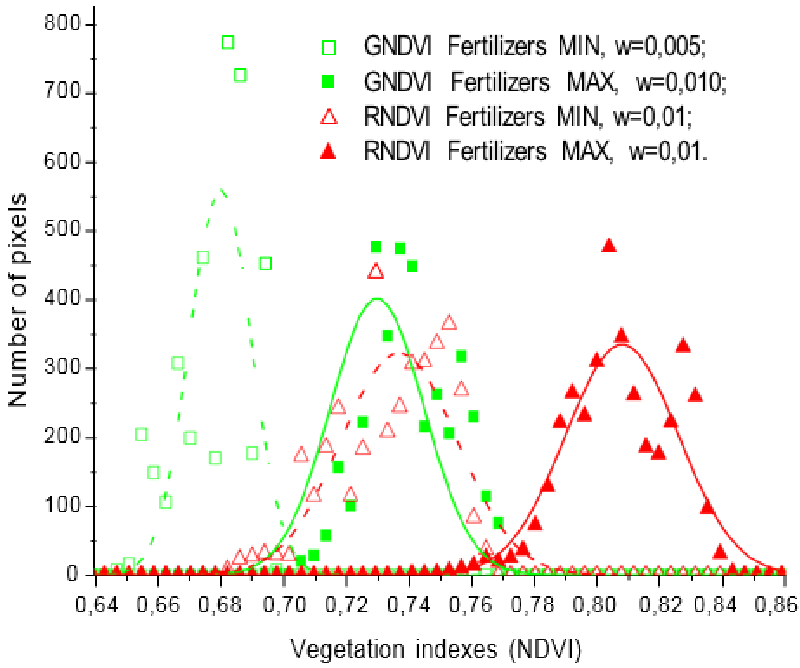

Figure 6: Dependence of the number of pixels on the value of the variant of the vegetation index GrennNDVI (GNDVI) and RedNDVI (RNDVI) at stresses caused by lack of mineral nutrition

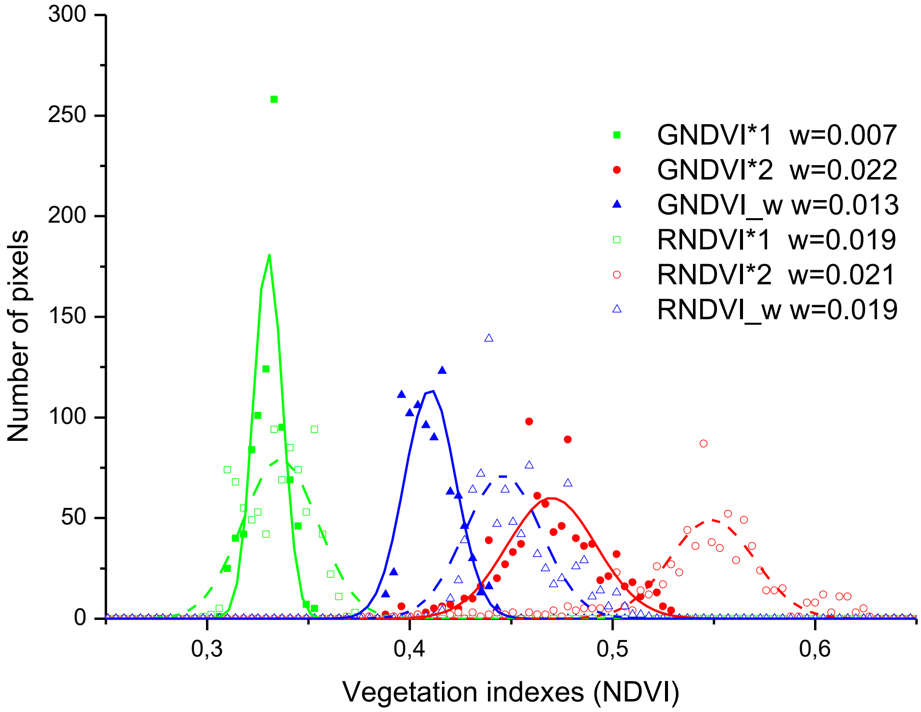

Figure 7: Dependence of the number of pixels on the value of the vegetation index GNDVI and RNDVI: stress due to thickening of crops, where * 1 and * 2, respectively, the norm and double the number of seeds, _w - increased water supply.

Thus, based on the results of the research, it can be argued that the characteristics of the Gaussian distribution for the pixels of the distribution map of the vegetation index NDVI are significantly different from those obtained directly from the spectral channels. Thus, for NDVI indices, the standard deviation of the distribution, regardless of the nature of stress in damaged plants, was equal to or even less than in healthy, in contrast to the results obtained directly from the use of spectral channels. The coefficient of determination for the distribution of NDVI indices was 0.85-0.95, which is much less than in the distribution based on the results of the use of green and red spectral channels). That is, the spectral channels Green, Red and RedEDGE proved to be more suitable for fixing and identifying stress than standard NDVI indices. Given the available serial software and hardware, the prompt receipt of distribution maps within an hour is implemented in the Slantrange complex, the software of which as of 2020 does not have a calculator of vegetation indices. It took more than 5 hours to use Agisoft's alternative geodata processing software (Tore_i5-9400F_2.90GHz _16,0GB_250SSD_2T_GeForce GTX1050Ti) to build the tiff format source data. Given the amount of output in 9GB and the bandwidth of the mobile Internet, the time to build maps is too long for production use. The advantage of the Slantrange complex is the possibility of data processing directly during the flight, so the formation of the map by the regular Slantview software took place within 40 minutes. As a feature of technological stresses is a probable conflict of interest, in practice, spectral data may require material confirmation by sampling directly from the identified areas. In view of this, it is advisable to use the GreenNDVI index for analysis, for which there was a relationship between the standard deviation for the GaussAmp distribution and the presence of stress.

6. Conclusion

For the first time, it is proposed to evaluate the quality of filtering of foreign objects by identifying plantings, based on the assessment of the intensity distribution of the pixel color components in the experimental area. It is established that the distribution for plants is described by the GaussAmp function, and therefore the presence of "foreign" pixels (soil, organic residues) is determined by comparing the existing distribution with the approximate Gaussian dependence. In addition to assessing the quality of filtration, this approach will increase the accuracy and reproducibility of the obtained data for agronomic needs. For the first time, a method of identifying areas affected by technological stress, namely crop compaction is acceptable for industrial fields based on spectral monitoring data obtained using UAVs. Identification can be performed both on individual spectral channels and on the distribution maps of standard vegetation indices NDVI / Thus, the technique can be implemented both on specialized systems such as Slantrange and using universal cameras.

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