Evaluation of soybean condition under various fertilizer application by the relationship of the red and near-infrared bands reflectance in scatter plot

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Abstract. This study aims to determine the dependence of the red band reflectance and near-infrared band reflectance in the evaluation of crops. The experiment using various fertilizers on soybean crops was analyzed to show the difference in reflections of red and near-infrared wavelengths. We used a multispectral camera attached to a UAV to obtain reflectance data of the surface. In this study, we used the normalized difference vegetation index, calculated based on red and near-infrared bands. The lower the value of red reflectance and the higher of near-infrared reflectance, the more chlorophyll, healthy vegetation, and the higher the crop condition. The decreasing photosynthesis rates and changes in leaf mesophyll are usually associated with decreasing reflectance of wavelengths within the near-infrared spectral range. We processed the obtained images and data from the camera and analyzed the reflectance separately for each plot of the surveyed field and each pixel of the image. The results showed in this paper that, according to a scatter plot analysis, different pixel concentrations were noted, which indicated by different information on the test field plot.

1. Introduction
Given current forecasts of the expected growth of the world's population and the subsequent reduction in arable land and natural resources, there will be a need for cheaper, more efficient, and environmentally friendly agricultural production [1]. The need to improve the quality and profitability of agricultural production encourages farmers to adopt new technologies, such as remote sensing. In recent years, unmanned aerial vehicle (UAV) technology has become a standard farm management tool. For example, UAV monitoring can be used to obtain cartographic data for soil analysis at the beginning of the season, which is useful when planning seed planting. This is a useful step in the evolution of agricultural management systems towards improving land-use efficiency [2].

Remote sensing is limited to regional and national scales due to the limited spatial and temporal resolution in optical images, considering the great potential for use in agriculture [3]. Optical satellite imagery always has problems with revision time and cloud cover during crop monitoring [4]. Therefore, existing methods based on multispectral and hyperspectral data, even capable of providing information on crops on a regional and national scale, are difficult to apply in real-time and on-field crop
management [5]. The main idea of nitrogen monitoring and the final assessment of yield is to measure the energy of perennial vegetation, represented by multiple temporary vegetation indicators. Vegetation indices, as products obtained after satellite image enhancement, were developed and applied to assess the vegetation canopy or chlorophyll content. An alternative solution for remote sensings, such as the use of UAVs, is necessary to provide flexible and accurate monitoring of field crops [6,7].

The multispectral camera provides spectral data (red 668 nm, green 560 nm, blue 475 nm, near-infrared 840 nm, and red edge 717 nm) for in-depth crop monitoring. Leaves predominantly absorb visible lights, and a healthy green vegetation canopy reflects about 2% percent blue light, 5% percent green light, and 3% red light. Thus, vegetation appears green because slightly more green light is reflected [8].

In this study, we used red and near-infrared (nir) bands, which are commonly used to calculate the vegetation index (VI). As a result, we presented the reflections of each pixel in two bands to display and understand the identification of the state of vegetation by scatter plots. Thus, with the help of the shown graphs, we can compare the state of vegetation and soil concentration in each plot to evaluate the experimental plots with different cultivation conditions.

2. Materials and methods

2.1. Study site
The experiment was carried out on a soybean varieties number 1 and number 2, cultivated on the experimental field of the All-Russian Scientific Research Institute of Soybean, Sadovoe village in the Amur Region (figure 1). The flight was made on 30 July 2018 year. The growing stages of soybean were V3 and V4 of vegetative stages.

Figure 1. Map of the study site location of All-Russian Scientific Research Institute of Soybean in the Sadovoe village, Blagoveschensk, Amur Region, Russia. The survey was conducted in 2019.

2.2. Equipment
We used the UAV model Matrice-100 (rotary wing drone), manufactured by DJI, China. Rotary wing drones allow for vertical take-off, hovering, and closer crop inspection. The map of the field with the use of the Micasense Red Edge multispectral camera was captured. Flight altitude was 30 meters from the ground. The pixel size was 2.05 cm. The better the quality of the photo and video data, the faster
and more accurately, we can analyze certain areas. The resolution of images is possible in centimeters per point, due to the low altitude of the flight.

2.3. Experimental scheme.
The repetition of tests was threefold. Controlled release fertilizer (CRF) containing nitrogen was applied as a basal nitrogen dressing on the fourth and fifth repetitions. CRFs are fertilizer granules intercalated within carrier molecules. The use of such fertilizers is a novelty in the region, and one of the requirements is the temperature of the soil at which the fertilizer begins to work. At this stage, we analyzed the state of crop vegetation and compared it with local fertilizers.

Figure 2 shows the visualised scheme. Experimental scheme is as follow: 1. Control - N5P18K20, 2. Control + Ammonium nitrate (N5), 3. Control + Ammonium nitrate (N10), 4. Control + CRF 5 kg of nitrogen / 10 acres, 5. Control + CRF 10 kg of nitrogen / 10 acres.

3. Results and discussion
In figures 3-5 are shown the relationships between red and infrared bands in scatter plots for two soybean varieties number 1 and number 2. In this article, we selected three figures that showed praxis of differences in the dependencies of the reflections of red and infrared wavelengths. Different varieties were selected to provide variability in the analysis. The maturity group of soybean variety number 1 is MG000, and number 2 is MG0. Variety number 1 has very-early ripening, and the development of its vegetation was better than variety number 2 on the day of the survey.

Each point is a single pixel of the image with reflectance data captured by the multispectral camera (2.05 pix/cm). Analysis of band reflectance values showed the highest concentration of pixels in the variants where CRFs were applied, fourth and fifth plots (figure 3-5, d, e)). Due to the better uptake of nitrogen when using CRFs that are activated after 40 days in plots 4 and 5, the positive dependence is traced in all replications [9,10]. The lower the value of red reflectance (0.01-0.06 nm) and the higher of nir reflectance (0.40-0.90 nm), the more chlorophyll can be observed, which indicated crop as healthy and developed well. The concentration of pixels in the area of high reflection of the red band (0.08-0.12) and low reflection of the near-infrared band (0.20-0.40) characterizes the location of the soil, which indicates lower development of the plant on the plot.

Figure 3 showed a good example when the greenness of the experiment options is the same when compared to each other. Soybean varieties number 1 is a very-early ripening variety (MG000), which at the time of the survey was in reproductive stage R4. Scatter plots a) and b) of figure 3 indicated a noticeable concentration of points in the area of 0.08-0.11 nm reflection of the red wavelength and 0.25-0.30 nm in infrared reflection. The ratio of these values indicated the location of soil pixels on the surveyed plot. Thus, the density of vegetation has not reached the maximum possible value in comparison with plot e). Plots e) and d) showed the best result here, as long-acting fertilizers were
applied, which affected the result.

**Figure 3.** Scatter plots relationships of each pixel among red and near-infrared bands of soybean variety number 1 (MG000), repeat number 1 were processed. Fertilizer application scheme represented as following: a) plot 1 (N18P18K20); b) plot 2 (N3); c) plot 3 (N10); d) plot 4 (CRF5); e) plot 5 (CRF10).

In figure 4, plot c) was found with a significant presence of soil in the accounting zone. This also indicated the location of pixels in the lower right area of the scatter plot (red 0.08-0.14 nm, nir 0.25-0.40 nm). However, the reflection of wavelengths (red 0.02 nm, nir 0.45-0.90 nm) showed that the development of greenness on plot e) was higher than those plots where we could not detect soil area. This is a good indicator that when analyzing plots, an average indicator is usually calculated, which includes soil values and affects the result. Therefore, if we compare the averaged normalized difference vegetation index (NDVI) values, we get the low value of the plot e) due to the area with the soil. In this test, plot d) showed a high result, which visually showed a highly concentrated shape of pixels in a narrow range of the red wave and high infrared. The vegetation of a very-early ripening variety (MG000) was analyzed in this test, where high density and vegetation have been achieved.
Figure 4. Scatter plots of each pixel in red and near-infrared bands of soybean variety number 1 (MG000), repeat number 3 were processed. Fertilizer application scheme represented as following: a) plot 1 (N₅P₁₈K₂₀); b) plot 2 (N₅); c) plot 3 (N₁₀); d) plot 4 (CRF₅); e) plot 5 (CRF₁₀).

Figure 5 showed a survey of soybean varieties number 2 (MG0), where at the time of monitoring, the development stage was R2. In this test, soybeans did not reach the maximum development of their biomass, which is easily confirmed in figure 5. Plots d) and e) showed a high value of the vegetation index since prolonged fertilizer was applied, which began to act at 40th days after application. In this example, we showed how well CRFs worked from the beginning of the reproductive stage. Very rapid accumulation of nitrogen began from the beginning of the reproductive stage and continues to stage R6. Primary lateral roots turned downward in the soil, and nitrogen fixation by root nodules increased rapidly [11]. During the period of stage R2, this was very noticeable in contrast to stage R4. Plots a), b) and c) showed an equally weak dependence of the reflection of red and infrared wavelengths. Despite the low density, greenness did not show the maximum value. Infrared reflection remained below 0.80 nm, which indicates insufficient accumulation of nitrogen.
Figure 5. Scatter plots of each pixel in red and near-infrared bands of soybean variety number 2 (MG0), repeat number 1 were processed. Fertilizer application scheme represented as following: a) plot 1 (N<sub>5</sub>P<sub>18</sub>K<sub>20</sub>); b) plot 2 (N<sub>5</sub>); c) plot 3 (N<sub>10</sub>); d) plot 4 (CRF<sub>5</sub>); e) plot 5 (CRF<sub>10</sub>).

NIR light, which can transmit through the leaf layers, then transmitted back through the canopy to the camera, shows the reflectance more than 50 percent. Soil reflectance has fewer reflectance values. The reflection coefficient in the near-infrared range is mainly controlled by the structure of mesophyll and has a positive correlation with the health of crop and yield [8]. Thus, the near-infrared band is very useful for crop assessment and yield prediction. Using the different bands in the analysis allows us to make the picture of developing crops much clearer. Analysis of vegetation by various spectra is the right direction in the development of methods for forecasting productivity. Unfortunately, despite widespread use, it is not always possible to accurately predict the possible yield, and insufficient weather data is needed to ensure the reliable determination of vegetation indicators.

The analysis of the yield of different varieties of crops in different regions, northern and southern, does not always have a positive correlation with indices and reflectance. Moreover, weather data is a necessary data tool to predict yield. Therefore, we aimed to create a model for forecasting yield in Russian regions such as Amur Region and Primorskiy Krai with the using newly established climate stations in the regions.
4. Conclusion
We analyzed the reflectance separately for each plot and each pixel to evaluate the condition of soybean growth under various fertilizers, including CRFs. Obtained figures had shown two active areas of pixels. The area of high red reflectance (0.08-0.15 nm) and low nir reflectance (0.20-0.40 nm) was shown as soil. The area of high nir reflectance (0.45-0.95 nm) and low red reflectance (0.01-0.04 nm) was represented as vegetation activity. Based on the shape of the pixel arrangement, we can judge the vegetation, excluding the presence of soil in the calculated values.

In this study, we compared CRF to show the effectiveness of their application compared to other fertilizers. Thus, the following concentration of vegetation was very different at stage R2.

Based on the obtained data, we can develop a model that can be used in predicting soybean yield by pixels excluding pixels of soil and other crop vegetation. In future experiments, we plan to analyze soil conditions and plant photosynthetic activity along with band reflectance to ensure the better clearness of the results.

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