Application of NDVI and NDRE indices in the assessment of soybean productivity under controlled-release fertilizer

B. Boiarskii
All-Russia Scientific Research Institute of Soybean
Blagoveschensk, Russia
haomoris@gmail.com

***Abstract*—UAVs are becoming widespread in modern agriculture for data collection and measuring instruments for solving agriculture tasks such as field surveys and crop monitoring. Multispectral sensors and obtained spectral images make it possible to conduct an in-depth and high-precision analysis of the crops and fields. This study used vegetation indices to determine vegetation status and chlorophyll activity in soybean plants. Thereby finding out the difference in soybean vegetation between standard fertilizer and controlled-release fertilizer (CRF) applications. This study aimed to make a correlation between soybean productivity (yield, grain mass, and plant height) of two soybean varieties and two indices normalized difference vegetation index (NDVI) and normalized difference red edge (NDRE), depending on the applied fertilizers ratio. The research was carried out in an experimental field of the All-Russia Scientific Research Institute of Soybean, Amur Region, Russia. The analysis showed a significant increase in yield and a positive relation with vegetation indices on plots using CRF.**

Keywords— control-released fertilizer, NDRE, NDVI, Russia, soybean, UAV.

1. Introduction

The first UAV (unmanned aerial vehicles) was created in 1916 by Americans [1]. UAVs for a long time were mainly used for military and civilian purposes. At the beginning of the 90s, drones were used for surface optical surveys and research [2]. Nowadays, in the world, UAVs and multispectral sensors are widely used in agriculture due to the continuous development of food quality and safety [3].

VIs (vegetation indices) applications are the most reliable instruments in agriculture across the world. VIs can provide data for use in field surveys, crop monitoring, yield predictions, crop status mapping, and detecting weeds, diseases, and nutrient deficiency (for example, nitrogen shortage in soybean plants) [3], [4]. Change in leaf mesophyll content of the healthy crop shows increasing the reflectance of wavelengths within the infrared channel and decreasing the red channel's reflectance. Thus, the ratio of different channels can be used in crop health assessment [5].

Precision agriculture in Russia was started to develop rapidly in recent years. The government, scientists, and farmers are increasingly aware of the importance of precision agriculture and the need for development in this direction as agriculture development expands significantly. In 2017, the government program "Digitalizing of Agriculture" of the Russian Federation Program was approved, which aimed to transform agriculture by introducing intelligent and precious agriculture and platform solutions to ensure a technological breakthrough in the country's agricultural sector [6].

2. Materials and methods

The tests were carried out in the southern zone of the Amur region, on the experimental field of the All-Russia Scientific Research Institute of Soybean. The zone belongs to a warm, relatively humid agro-climatic region of the Region. The crop Heat Units (CHU) indicator, the sum of temperatures accumulated above a base of 10 °C mean air temperature, is 2471 °C.

This study used the UAV model DJI Mavic Air 2, manufactured by the DJI company located in China. This UAV is a rotary-wing drone used for vertical take-off, hovering, and closer crop inspection. The survey was carried out at the height of 30 meters above the ground. The study used a multispectral camera, RedEdge-3, manufactured by Micasense, USA. The camera captured five spectral bands (red 668 nm, green 560 nm, blue 475 nm, NIR (infrared) 840 nm, and red-edge 717 nm). It provided NDVI, which is defined as a ratio of the difference between infrared and red channel bands to the sum of two bands. The camera provided NDRE, which was defined as a ratio of the difference between an infrared band and red-edge band to the sum of two bands instead of red.

3. Results

This study used NDVI and NDRE to analyze vegetation's greenness, with the greenness of plant leaves determined by chlorophyll's concentration and plants' green pigment. Analysis of NDVI and NDRE values showed the highest index in the plots where the pigment concentration was high [4].

The plant density of the Zakat variety was more developed than that of the Nega-1 variety. However, the maximum greenness values were higher in the Nega-1 soybean variety. This remark indicated the different characteristics of each of the varieties. Therefore, in this experiment, the author calculated and compared the state of vegetation separately for each variety.

In this experiment, the author made correlations between soybean productivity (yield, grain mass, and plant height) of two soybean varieties and two indices, NDVI and NDRE. Fig. 1 shows the soybean variety of Zakat's productivity structure, which significantly increased plants' height by 10 cm and crop yield by 0.6 t/ha under CRF10. However, the soybean variety Zakat showed an adverse coefficient determination in terms of the mass of 1000 grains. The seed weight varied from 140 grams to 160 grams of 1000 grains. This gap is relatively small in this experiment and very sensitive to calculation. Therefore, in this case, the author pointed out the error in the calculations within the normal range. As a result, the correlation coefficient for plant height to indices was 0.74 for NDRE, 0.72 for NDVI, seed weight was 0.53 for NDRE, 0.59 for NDVI, and yield 0.75 for NDRE, 0.77 for NDVI.

Fig. 2 represents the productivity structure for soybean variety Nega-1. The height of soybean plants increased slightly, by 2 cm and 5 cm for CRF5 and CRF10, respectively, compared to the control. The grain mass showed an increase of 10 grams for CRF5 and 20 grams for CRF10 compared to the control. The increase in yield was insignificant, with a rate of 0.48 t/ha and 0.16 t/ha for CRF5 and CRF10, respectively.

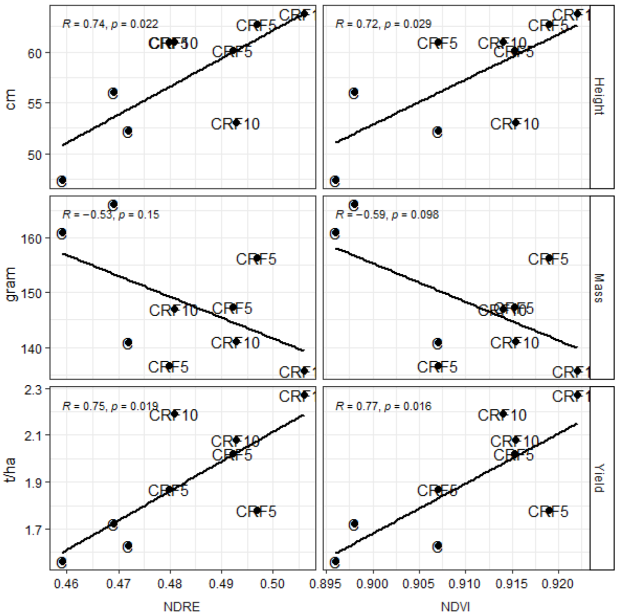

Рис. 1. Correlation analysis of vegetation indices, NDVI, NDRE vs. crop height, grain mass (1000 seeds) and crop yield for soybean variety Zakat

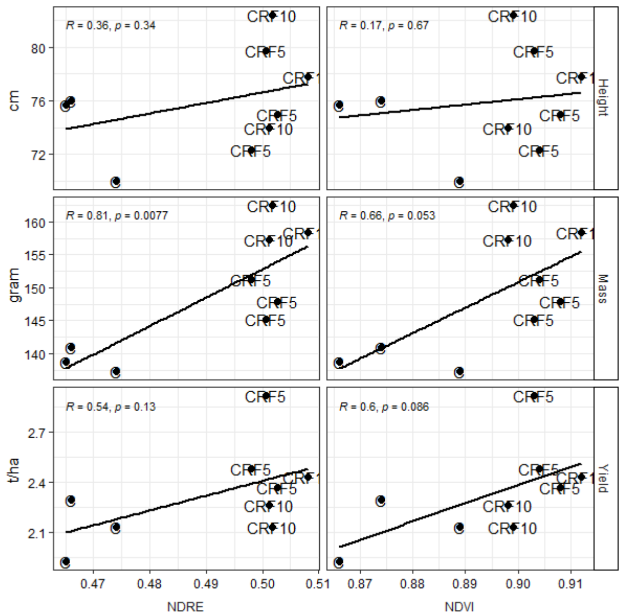

Fig. 2. Correlation analysis of vegetation indices, NDVI, NDRE vs. crop height, grain mass (1000 seeds) and crop yield for soybean variety Nega-1

4. Conclusion

This article described and demonstrated the application of two vegetation indices, NDVI and NDRE, on the experiment of soybean productivity assessment under different fertilizers, as a part of remote sensing tests. The result showed the distribution of index values depending on the applied fertilizers on the map obtained from the UAV based on multispectral images. The study observed that CRF did not significantly affect the soybean grain's quality during the yield analysis. However, there was a tendency to increase the fat content and decrease protein in soybean seeds of Zakat variety with CRF dose increasing. Conversely, there was an increase in protein and decrease fat in Nega-1 variety.

The study showed that CRF has a beneficial effect on the productivity of soybeans. Moreover, the author showed that the indices reflected chlorophyll activity plants since the release of nitrogen in the soil occurred at its active uptake by soybeans.

Acknowledgment

The author would like to thank the Academician of the Russian Academy of Sciences, Sinegovskaia Valentina Timofeevna, for the provided materials for this paper. The author declare that they have no conflict of interest.

References

[1] Nonami, K. Prospect and Recent Research & Development for Civil Use Autonomous Unmanned Aircraft as UAV and MAV / K. Nonami // J. Syst. Des. Dyn. – 2007. – Vol. 1(2). – P. 120-128. DOI: 10.1299/jsdd.1.120.

[2] Baek, H. Design of Future UAV-Relay Tactical Data Link for Reliable UAV Control and Situational Awareness / H. Baek, J. Lim // IEEE Commun. Mag. – 2018. – Vol. 56(10). – P. 144-150. DOI: 10.1109/MCOM.2018.1700259.

[3] Whelan, B.M. Downscaling for site-specific crop management needs? / B.M. Whelan, A.B. McBratney // Digital Soil Assessments and Beyond - Proceedings of the Fifth Global Workshop on Digital Soil Mapping. – 2012. – P. 353-356. DOI: 10.1201/b12728-69.

[4] Berni, J.A.J. Thermal and narrowband multispectral remote sensing for vegetation monitoring from an unmanned aerial vehicle / J.A.J. Berni, P.J. Zarco-Tejada, L. Suárez, E. Fereres // IEEE Trans. Geosci. Remote Sens. – 2009 – Vol. 47(3). P. 722-738. DOI: 10.1109/ TGRS.2008.2010457.

[5] Carter, G.A. Leaf optical properties in higher plants: linking spectral characteristics to stress and chlorophyll concentration / G.A. Carter, A.K. Knapp // Am. J. Bot. – 2001. – Vol. 88(4). – P. 677-684. DOI: 10.2307/2657068.

[6] Drobot, E. Prospects for digitalization of agriculture as a priority direction of import substitution / E. Drobot, M. Vartanova // J. Int. Econ. Aff. – 2018. – Vol. 8(1). – P. 1-18 (in Russian).