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Monitoring wheat NDVI variation using a small UAV in Southern Dobrudja

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Abstract

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For the needs of precision agriculture, it is important to create a database on the trends of changes in vegetation indices. The correct interpretation of the data for a specific region is useful for reading and planning subsequent treatments. The research was conducted with a small UAV equipped with a NIR camera in the period 2019–2022, in three fields in southern Dobrudja. The aim is to track the dynamics of NDVI changes in wheat. To create a database on the trends of change in NDVI in the specific agrarian climatic conditions of southern Dobrudja. The dynamics of the index during the period of extreme drought 2019–2020 have been tracked. Maximum values are recorded in the spindle phase – grading at the beginning of May. Returning frosts at the beginning of March lower the value sharply. The dynamics of NDVI during the phenological development of wheat was tracked, as a maximum of 0.5 was reached during the grading period. Humidity analysis gives a direct link to NDVI change trends with a week lag of the changes that occurred.

Keywords: Normalized Difference Vegetation Index (NDVI); Unmanned Aerial Vehicle (UAV); common wheat; spectral vegetation indices

Introduction

Direct observation of wheat varieties provides important information about the condition of the crop. Unmanned aerial vehicle (UAV) provides raw information on the condition of crops. After processing, we can obtain maps with different vegetation indices. These indices are key to precision agriculture. It is important to create a database with the relevant indices and their features and trends of changes in the specific agrarian climatic features of the studied regions. By means of cameras registering the reflected infrared light from agricultural crops.

Electromagnetic waves with a length of 0.7–1.3 μm are not absorbed by leaf pigments. Energy passes through the leaf or is reflected, which is related to the leaf structure. Although vegetation generally has high reflectance levels in the near-infrared range of red and green values, these can vary significantly among species. This can give us accurate information about the vegetation processes and the stage of development in agricultural crops. Tracking the difference between infrared and red radiation gives us the state of the vegetation cover.

NDVI serves as a quantitative assessment of the leaf cover, it is a signal of occurring changes (Alvaro et al., 2007; Cabrera-Bosquet et al., 2011) but is not a way to diagnose a specific condition.

At the beginning of the wheat vegetation, the reflection with a wavelength of 700 nm close to the red (660 nm) zone of the spectrum drops sharply. Near infrared reflectance is highest in the middle of the growing season, stabilizes for a short time, and then steadily decreases to about 35% of its maximum (Sanjiv et al., 2017).

The objectives of the study are 1) to track the dynamics of changes in the NDVI vegetation index during the phenological development of winter common wheat under the conditions of Dobruja; 2) generation of data to be used for comparison across developmental phases and trends in future observations.

Material and Methods

The research was conducted during the period 2019–2022 using a DJI Mavic 2 pro UAV (dji, 2022) equipped with a Mapir Survey3W RGN (Red+Green+Infrared) camera (mapir, 2022). The shooting took place at 100 m above the terrain with an overlap in both directions of 80% resulting in a resolution of 3.75 sm/pix. 193 UAV flights were conducted. The locations of the experiment are shown in Figure 1.

Field 1 is an experimental field of the Dobrudja Technological College. City. Dobrich with coordinates (43.553181, 27.830570).

Field 2 is an experimental field of the Dobrudzha Agricultural Institute, Petleshkovo village, General Toshevo municipality with coordinates (43.657832, 28.022780).

Field 3 of a farmer is located in the land of the town of Dobrich with coordinates (43.548686, 27.759369)

Characterizes vegetation density, growth, presence of weeds or diseases, yield prediction. The indices are generated by taking pictures of green vegetation that absorbs electromagnetic waves in the visible red range and reflects them in the near infrared range. The red region of the spectrum (0.62–0.75 µm) accounts for the maximum absorption of solar radiation by chlorophyll, and the near infrared region (0.75–1.3 µm) (Rouse et al., 1974).

$$NDVI = (Rn - Rr)/(Rn + Rr) \quad (1)$$

The NDVI index is an indicator of the condition of plants and does not explain the reasons for their level and variation. At the beginning of the season, it is an indicator of how the plants overwintered:

• At values below 0.15 there is a probability of a high percentage of frost;

• Values of 0.15–0.20 are low, different degrees of damage are possible or the plants have not matured well enough when entering the winter months.;

• Values of 0.20–0.30 are relatively good and indicate a normal state of the crop for the development phase;

• Values of 0.30–0.50 are typical for a highly bratyl crop or advanced phenological development (onesoil, 2022).

Results and Discussion

As a result of the recordings in the red and infrared range, reflectance maps of the NDVI vegetation index were generated for the three years of the study.

Climatic characteristics for the Dobruja region show a significant deviation of the main meteorological factors during the economic year 2019–2020. The year is unfavorable for agricultural crops. Compared with the meteorological data for previous years, it was found that the precipitation is insufficient during the autumn-winter period. As a result, the drought deepens throughout the period until economic maturity. High temperatures in the winter months followed by return frosts in the spring. The graph of change in NDVI (Figure 2) vegetation index corresponds to the state of wheat during the period.

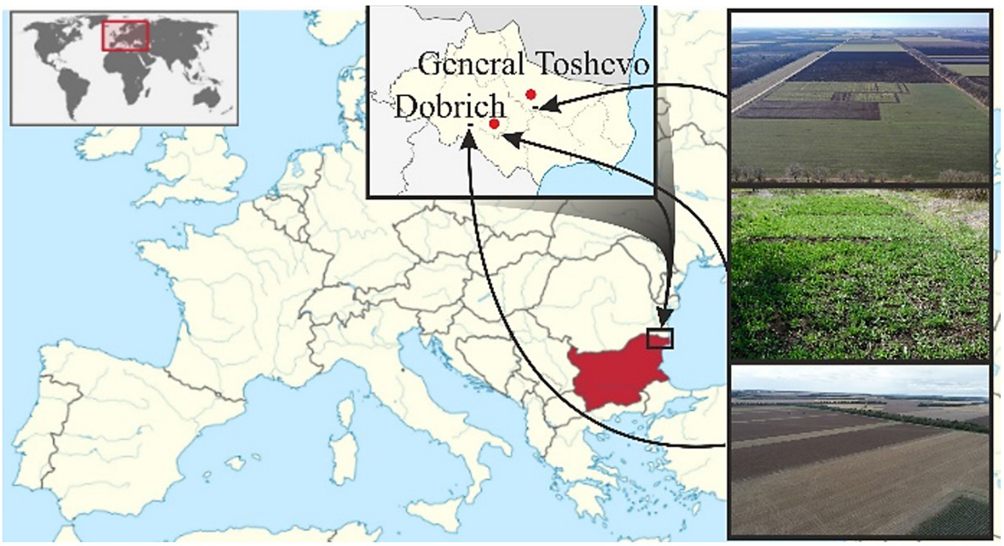

Fig. 1. Place where the experiment was conducted

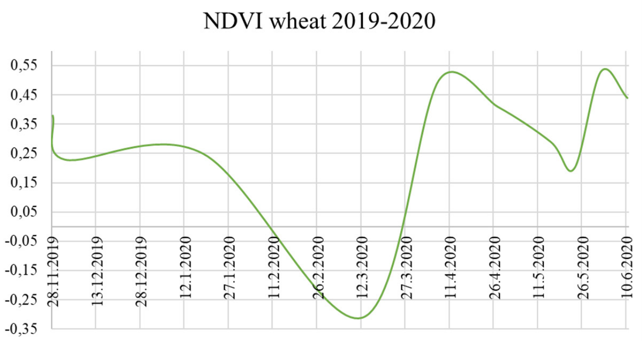

Fig. 2. NDVI of field 1 wheat during the 2019–2020 economic year

Conditions during the 2020–2021 agricultural year, were favorable for the development of wheat. Sowing was carried out in a period suitable for the region. High temperatures during the autumn-winter period favor fraternization. At the end of February, damage from return frosts was reported.

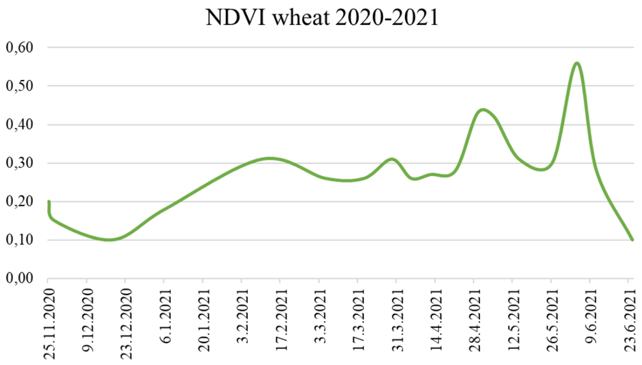

Fig. 3. Field 1 wheat during the 2020–2021 economic year

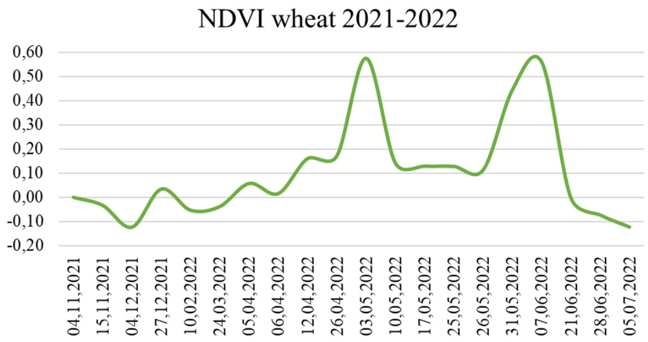

Fig. 4. Field 1 wheat during the 2021–2022 economic year

In the middle of the month, daytime temperatures exceeded 12°C, while night and morning temperatures reached -10°C. Direct frost is not observed. Compared to the average multi-year data, the growing season lasted longer, the main reason for this being lower average temperatures in April and early May. The trend is shown in Figure 3.

The winter of 2021–2022 has less precipitation than last winter. January is relatively dry as is February. December 2021 has a large amount of precipitation. The three winter months were relatively warm, which allowed the vegetation to continue. Return frosts in early March did not have a significant impact. During the growing season, there were no permanent droughts, and probably for this reason, temperature is the main factor that influenced the changes in the index (Figure 4).

Figure 5 shows the change trends in NDVI against the background of air temperature and precipitation. During the 2020–21 period for Field 2, NDVI increased from the first reading to mid-February. The index is directly related to the specific conditions of the period – warm winter months with

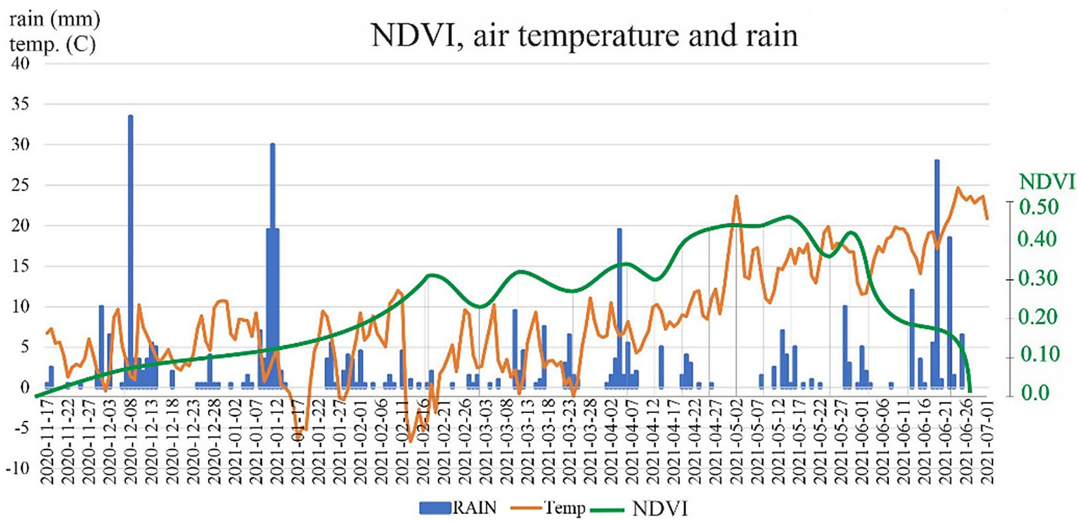

Fig. 5. NDVI of field 2 with wheat in 2020–2021

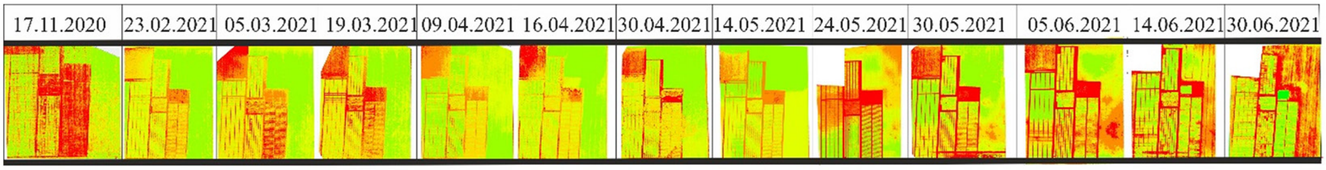

Fig. 6. Maps of the field with generated NDVI index for the entire growing season 2020–2021

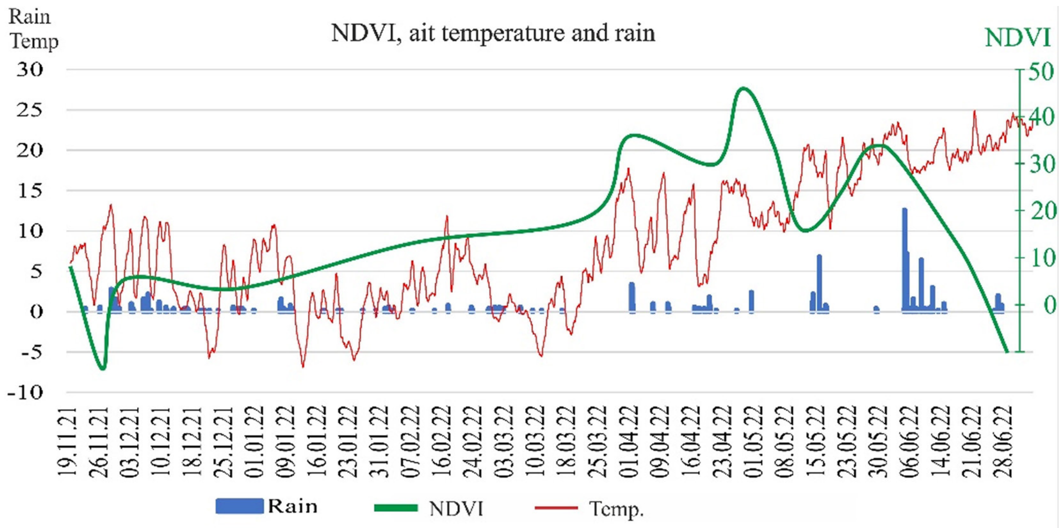

Fig. 7. NDVI of field 2 with wheat in 2021–2022

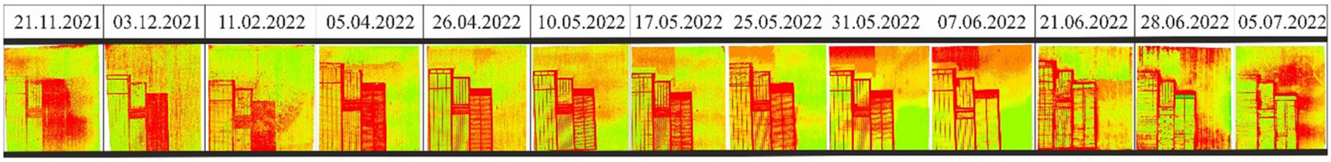

Fig. 8. Maps of the field with generated NDVI index for the entire growing season 2021–2022

high average daily temperatures, intensive wheat threshing and subsequent sharp cold with negative temperatures. When photographing the observed area immediately after a period of temperature amplitudes and periods with frosts in the hours until noon, the index is significantly lower – 0.22, the value rises until mass entry into the spindle phase reaches 0.33. The highest NDVI found is at the end of the spindle-grading phase – 0.5, after which it starts to decrease. The result is directly related to the health status of the wheat and agro-climatic conditions. In Figure 6 graphically presents the NDVI index of the field.

Figure 7 shows the change trends for field 2 season 2021–2022 for NDVI against the background of air temperature and amount of precipitation. The dynamics of NDVI is also directly related to the phenological development of wheat. The highest NDVI values are reported during the grading period – milky to waxy maturity, and in some cases they exceed 0.5 with the methodology used in the conditions of southern Dobrudja. In Figure 8 graphically presents the NDVI index of the field.

Figure 9 shows the NDVI for a wheat field sown with the Falado variety in the 2021–2022 season. The trend of change is similar to Figure 6, in which the Enola variety is presented. The differences are due to the characteristics of the varieties and the distance between the two fields.

Figure 10 shows the trend of change of NDVI vegetation index with the meteorological features during shooting. In regression analysis, Multiple R = 0.36 is the ratio of humidity to NDVI, but in reality the relationship is stronger. A decrease/increase in humidity is found to cause a decrease/increase in NDVI after a week. When considering this dynamic, the Multiple R = 0.67.

The processed results yielded Mean Reprojection Error [pixels] = 0.39; RMS Error [m / %] X = 1.43; RMS

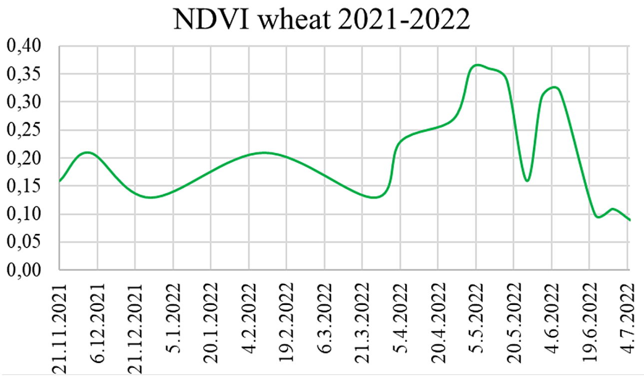

Fig. 9. NDVI of field 2 with wheat in 2021–2022 variety Falado

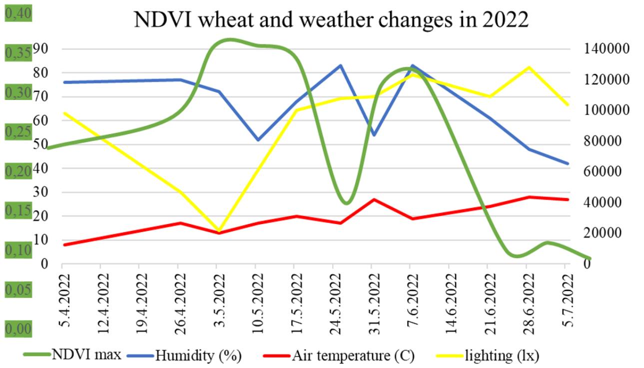

Fig. 10. NDVI of field 2 with wheat for the period April 2022 to July 2022 with meteorological data from the measurements

Error [m / %] Y = 1.25; RMS Error [m / %] Z = 1.86; Average Density (per m^3) = 23.98. Accordingly Number of 2D Keypoint Observations for Bundle Block Adjustment – 662105, Number of 3D Points for Bundle Block Adjustment – 247591,9.

Conclusion

The UAV survey using an infrared camera created a database of NDVI variation trends under the conditions of southern Dobrudja for the purpose of precision agriculture.

Results of the dynamics of NDVI change in the year 2019–2020, which is characterized by extreme drought and unusually high temperatures for the region, have been obtained.

The dynamics of NDVI during the phenological development of wheat was tracked for a period of 3 years, with a maximum of 0.5 being reached during the grading period. Maximum values are recorded in the spindle phase – grading at the beginning of May. Returning frosts at the beginning of March lower the value sharply.

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