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Vegetation data processes, registered by remote sensing with a small aerial vehicle

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Abstract

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The present study aims to compare the processing methods of the data obtained by a small unmanned aerial vehicle (UAV) used to assess the vegetation processes and the forecast yields. UAVs are equipped with a 20 MP camera with a RGB spectrum and a 12 MP camera with a NIR spectrum additionally mounted on it. The shootings were carried out throughout the growing season of the crops in the economic year of 2020-21. Data was processed by several different methods and a comparison of the NDVI index obtained from the satellite data and from a UAV was accomplished. The obtained results show that, regardless different absolute values, the trends in the change remain similar.

Keywords: UAV; yield estimation; precision farming; vegetation indices; NDVI

Introduction

The vegetation monitoring of the development and the health condition of the field is extremely important for the quality of the production processes planning, as well as for the qualities of the production.

Spectral plant (vegetation) indices are widely used to monitor and analyse the plant structure changes, as well as to determine the plant health status, to depict phenological changes, to assess the green biomass and the yield potential.

Such indices also allow for the monitoring and assessment of the changes in plant biophysical properties.

Some of the most famous indices are Enhanced Vegetation Index (EVI); Normalized Difference Vegetation Index (NDVI); Leaf Area Index (LAI); etc. (Asrar et al., 1984).

Cameras able to detect reflections in the NIR spectrum close to the visible red light limit are widely used. This allows for the specific vegetation indices, obtained by the measured reflection values, to be defined (Scotford & Miller, 2005).

The most widely used NDVI index is a ratio that takes into account the amount of infrared rays reflected by the healthy plants (Rouse et al., 1974). Indices based on near-infrared light are listed in Table 1. The table describes the NDVI, SAVI (Huete, 1988), EVI2 (Jiang et al., 2008; Stevens, 2009), CVI (Vincini et al., 2008) and RDVI (Rougean et al., 1995) indices and the formula by which they are calculated.

The indices based on the visible light reflection and obtained with the RGB camera, as part of the UAV's standard equipment, are listed in Table 2. The table describes the MPRI (Yang et al., 2008), MGVRI and RGVBI (Bendig et al., 2015), GLI (Louhaichi et al., 2001), VARI (Gitelson et al., 2002) indices, and the formula by which they are calculated.

Table 1. Indices based on near-infrared reflection.

Index	Formula
NDVI	(nir-red)/(nir + red)
SAVI	(nir-red)/((nir + red)*(1 + 1/2))
EVI2	2.5*((nir-red)/(nir + 2.4*red + 1))
CVI	(nir*red)/(green^2)
RDVI	(nir-red)/(nir + red)^0.5

Table 2. Indices based on the reflection of visible light

Index	Formula
MPRI	green-red/green + red
MGVRI	(green^2-red^2)/(green^2+red^2)
RGVBI	(green-(blue*red))/(green^2 + (blue*red))
GLI	(2*green-red-blue)/(2*green + red + blue)
VARI	(green-red)/(green + red + blue)

The study aims to determine:

– the applicability of different methods for generating vegetation indices, obtained from the UAV standard equipment camera data;

– the possibilities for using a small unmanned aerial vehicle to assess the agricultural crops development for the needs of the precision agriculture.

Material and Methods

Conducting the Experiment

The survey was conducted during the agricultural season of 2020-2021. The observed areas were: (43.553366, 27.831994) – an experimental field sown with wheat in Dobrich, Bulgaria; (43.657963, 28.023110) – an experimental field sown with wheat in the village of Petleshkovo, the municipality of General Toshevo, Dobrich district, Bulgaria;

(43.548925, 27.761216) – a field sown with sunflower, owned by an agricultural producer, in the territory of the town of Dobrich, Bulgaria (Figure 1).

The UAV used is a DJI Mavic 2 Pro [dji.com (2021)] one and is equipped with a 20 MP 1" CMOS sensor Hasseblad L1D-20.

In addition to the UAV's camera, a second one was installed – a MAPIR Survey3W Camera [mapir.camera (2021)] – Red + Green + NIR (RGN, NDVI) with Sony Exmor R IMX117 sensor – 12 MegaPixel (4,000 x 3,000 px). This model is Red + Green + NIR (RGN, NDVI). Table 3 shows the parameters of the cameras used.

Flight Planning

The flight dates were planned according to the vegetation of the agricultural crops. The chosen flight days were in favourable meteorological conditions, taking into account the development phase of the agricultural cultures. The fields were photographed between 11 and 14 o'clock. In the case of the wheat fields, during the winter period, the flights took place at intervals of 14 to 20 days. At the vegetation development peak, the time span between the flights was from 5 to 7 days.

Two software programmes were used for the flight planning: Pix4Dcapture (Figure 3) and DroneDeploy (Figure 2).

Table 3. Camera channel parameters.

№	Channel name	Wavelength	Sensor weighting factor: MAPIR Survey 3W RGN 3.4 4000X3000	Sensor weighting factor: L1D-20c 10.3 5472X3648
1	Blue (B)	470 [nm]	-------	0.7152
2	Green (G)	550 [nm]	0.3152	0.2126
3	Red (R)	660 [nm]	0.2126	0.0722
4	Near Infrared (NIR)	850 [nm]	0.4722	--------

Fig. 1. Location of the experiment

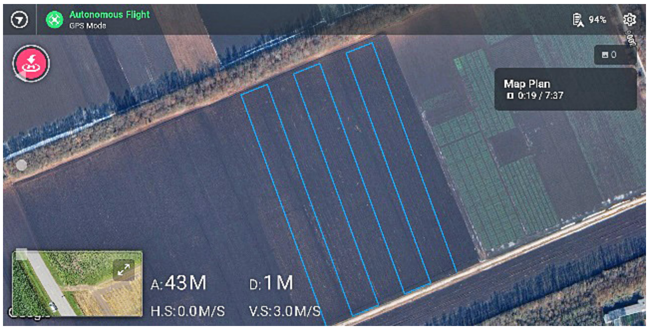


Fig. 2. Drone Deploy

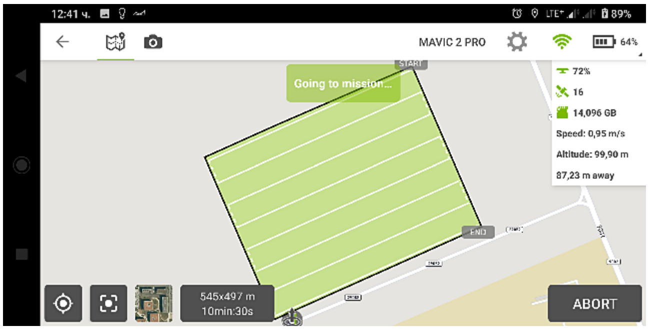


Fig. 3. Pix4D capture

Data Processing Methods

About 160 photos (with a resolution of 20MP) were obtained by the RGB camera after one flight, due to the fact that the camera operates with an 80% overlap, which is preliminary set in the flight planning phase and complies with the shooting interval, position and speed of the aircraft. The NIR camera is set to take pictures every 1 second. It is independent of the UAV systems and shoots from the beginning of the flight until its landing. During the flight, the camera (MAPIR) captures between 400 and 500 photos, with a resolution of 4000 x 3000 pixels. Each photo is taken with a focal length of 3.0 mm, 1/500 speed (the speed, at which the camera aperture opens and closes to let in a certain amount of light), a focal length of f / 2.8 and ISO 100. The planned pixel resolution is 2.34 cm, according to the spring plan. After the processing with the application program Pix4D Dmapper [pix4d.com (2021)] and the overlap of images, the obtained resolution is 3.75 cm per pixel. The image quality check after the initial processing gives an average value of 35 973 key image points. The relative difference of the image parameters between the original camera and its optimized parameters is 0.053%, which is well below the recommended variation, i.e. the parameters deviation from the ideal value is 5%. The program calculated between 12 456 and 15 206 matches of a calibrated image and determined an average RMS error of 0.093 m. The total number of image overlaps is in the range of 5+ for almost the entire target area above the field. The results show that the segmentation coefficients, (Pix4Dmapper) for NIR, and the multispectral data reach 0.92033 and 0.9531, respectively. The model is applied to the overall image obtained from the UAV and the output is the threshold for obtaining a segmented image.

Image processing time and vegetation indices generation

The program used in this experiment to process the field scan data is Pix4Dmapper. When creating a new processing, it is important to set the necessary and accurate parameters, such as the camera type and the processing type – vegetation indices depending on the camera type – GRB, NIR, Termal. An image calibrator is also available with the MAPIR Survey 3W_RGN camera (Figure 4). This image can be added in Pix4Dmapper to compensate for the differences in the sunlight on different days.

Fig. 4. Calibrator shot in NIR

The processing time is from 3 to 12 hours, depending on the number of photos processed and respectively, their size. It works completely automatically until the preliminary chosen vegetation index/indices is/are obtained. The generated indices, as random variables that change in a given range, are presented with the following values: maximum, minimum and average values, as well as their mean deviation.

When generating the NDVI, CVI, SAVI, EVI2 and NDWI indices from 338 photos, with the hardware configuration – CPU: Intel (R) Core (TM) i7-7600U CPU @ 2.80GHz; RAM: 16GB, and an Operating System Windows 10 Pro, 64-bit, the processing time is 06h: 14m: 42s.

The photos from the 2 cameras, from 3 fields take up hard drive space between 7 and 12 GB. The photos from the observation period of field 2 occupy a total volume of 133 GB and of field 3 – 97 GB. The photos for the business year, of the three fields have a size of 260GB. For the three fields, the total number of photos is 53 000.

The size of the work files for generating reflective vegetation indices varies from 12 to 50 GB per flight. The total number of flights is 99 and their working files together with the photos exceed 3 TB.

Obtaining vegetation indices using matlab

Another method studied is the data processing using Matlab software. Graphic information is extracted from the photos in the form of a histogram of the reflected radiation, as well as numerical values that are contained in each pixel of the image. They form a matrix of values, whose rows elements correspond to the reflection of a given color, according to the shooting dates and according to the wavelengths of the colors: R, G, B and NIR.

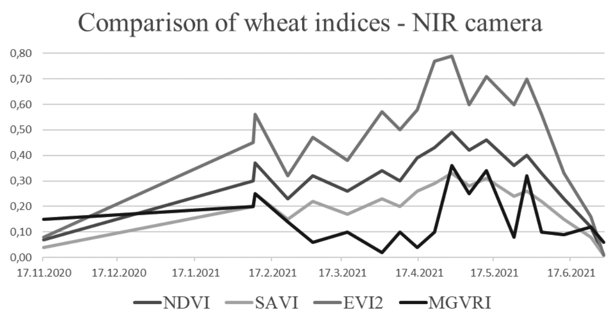
Obtaining vegetation indices from the colour values

An analysis of the obtained images was performed using the software product ImageJ (Imagej, 2022) Java-based image processing program developed at the National Institutes of Health and the Laboratory for Optical and Computational Instrumentation (LOCI, University of Wisconsin). The numerical values of the percentage contents by the individual color channels are extracted. The values of the colors vary from 0 to 255. These values can be used to calculate the vegetation indices.

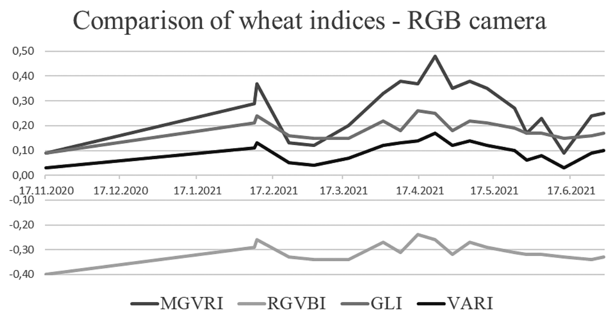
Results and Discussion

The Method Effectiveness and Applicability Check

The generation of vegetation indices from the NIR and RGB cameras for a wheat field in the agricultural year of 2020-2021, are presented in Figure 5. The comparison of the change tendencies between the two groups of indices shows that those based on the near infrared light are more sensitive to the changes in the agricultural crops.



a)



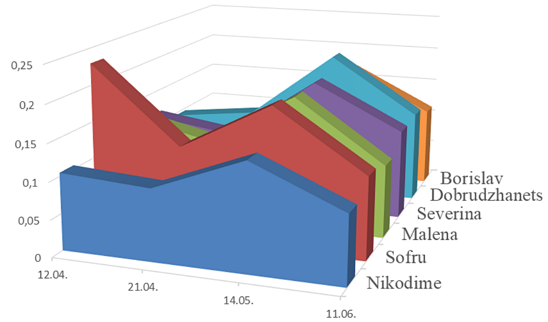
b)

Fig. 5. Vegetation indices from the NIR (*a*) and RGB (*b*) camera

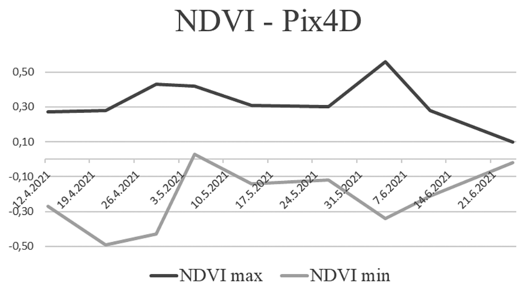
The results accuracy can be guaranteed with 2 or 3 consecutive flights per day and a following comparison of the obtained results of the vegetation indices.

Although the index is calculated by sort of agricultural crops, the general trend corresponds to the total index for the period.

In order to verify the final results, we will compare the obtained NDVI index for field 1 with the data for the same index taken from the Internet platform OneSoil [Free apps for precision farming (2021)].



a)



b)

Fig. 6. Vegetation index NDVI by dates calculated with Matlab (*a*) and Pix4D (*b*)

Figure 7 shows the change in the NDVI index for a field, from the observed areas, sown with wheat for the whole vegetation period of observation. The index is generated by Pix4D. The minimum and maximum values of the index are shown. A total of 19 shots were taken at regular intervals. Figure 8 shows the NDVI results for the same field but excerpted from OneSoil. A comparison of the two charts shows a high in mid-April, followed by a decline and an absolute high in June. There is a decline in late December, followed by a slight rise and fall in February due to a sharp cold snap during this period. Satellite data are more detailed due to the more frequent imaging.

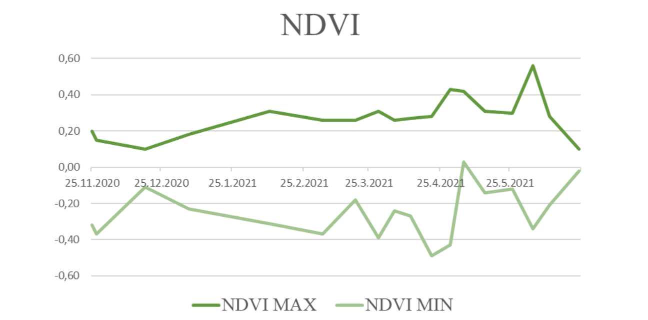


Fig. 7. The change of the NDVI index reported with UAVs

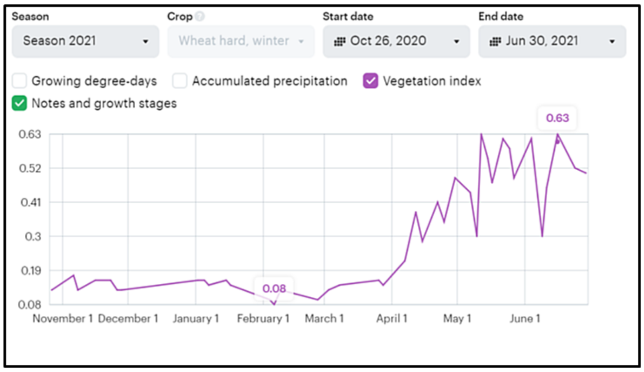


Fig. 8. The change of the NDVI index by OneSoil

In order to check the trends, obtained from NDVI, indices SAVI and EVI2 have been generated. (Figures 9 and 10). The vegetation change trend shows a similar curve of change, although the numerical values differ.

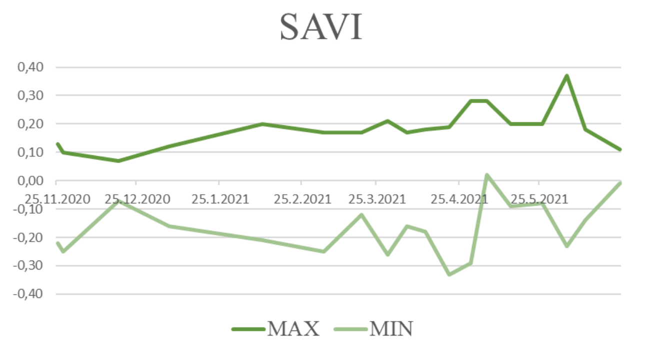


Fig. 9. SAVI

Comparison of NDVI in a field with wheat, obtained from Pix4D and calculated from the color values obtained from Figure 11.

There are differences between the two charts, but there is also similarity in the general trends of peaks and troughs of the NDVI index. Although, there are differences in the

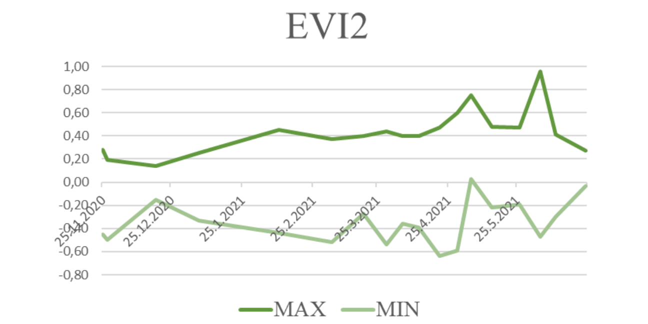


Fig. 10. EVI2

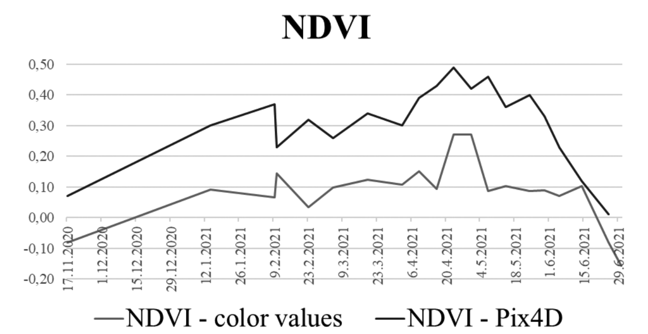


Fig. 11. Compare NDVI from Pix4D and calculated from the color value

absolute values, due to the fact that satellite images are at a shorter interval, the overall change curve is similar.

Vegetation Comparison Based on RGB and NIR Cameras

When comparing the change data of the MGVRI index (Figure 12), obtained from the two independent cameras – m MAPIR Survey 3W_RGN and Hasseblad L1D-20 – we can trace clear peaks and troughs, although the numerical values

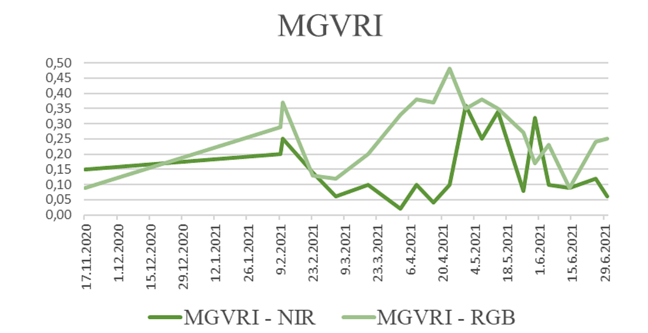


Fig. 12. Vegetation indices MGVRI of field 2 of the NIR and RGB camera

of the individual indices differ. These differences are due to the individual differences in the colour weight coefficients in the two cameras and also to the differences in their frequency bands.

Conclusions

The study on the various methods for obtaining development vegetation indices of agricultural crops using small UAV yields the following results:

• Despite the different numerical values, the general change trends in the obtained vegetation indices are similar. They can be used for treatment planning and yields forecasting.

• The obtained results correspond to the change tendencies in the vegetation processes, according to the satellites data. The close values, obtained by the different methodologies and the satellite data confirm the accuracy of the results.

• The use of NIR and RGB camera for data collection provides us with similar change trends of the vegetation process curve. This allows us to use a small UAV with its standard camera.

The obtained results will be used in conducting further experiments to observe a wheat field in the economic year of 2021-22.

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