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COMPARISON OF RGB AND MULTISPECTRAL CAMERAS FOR TARGETED APPLICATIONS IN AGRICULTURE

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Abstract. Agricultural machines nowadays use advanced satellite guidance systems that allow not only autonomous parallel guidance of machinery on the field but also enable the control of agriculture implements based on the geographical location of the field. By using aerial photogrammetry images, it is possible to identify the spots of land that require chemical protection. This information can be used to create prescription maps for the control of specialised implements, allowing the identification of weed outbreaks that require herbicide for their elimination. Using spot-spraying technologies, up to 80 % of the active substance can be saved compared to the current common broadcast strategy of applying it to the entire field. This technology automatically controls the sprayer nozzles on the booms only in the spots where it is needed. Using an Unmanned Aerial Vehicle (UAV) allows us to take a detailed picture of the ground. Two main possibilities exist for collecting imagery data with an RGB or multispectral camera. One of the key requirements is the appropriate resolution of the picture, which could be controlled by flying altitude. This paper focuses on comparing RGB and multispectral gathered data toward affected spot identification.

Keywords: Agriculture, QGIS, RGB camera, multispectral camera, UAV.

1. Introduction

Agriculture has been constantly evolving and adapting to new challenges and needs in recent years. An innovative approach that is gaining increasing popularity is precision farming. This modern way of farming combines traditional knowledge and technology to optimise yields while minimising negative environmental impacts. Remote sensing is becoming one of the most widely used methods for obtaining geographic information about the Earth's surface and is also usable in agriculture [1]. Image data can provide accurate and detailed images of the earth that are valuable for many research areas, including natural disasters, land use, climate monitoring, and environmental protection. Precision farming uses a range of technologies and analytical tools that allow for detailed analysis of fields and the exact needs of plants. Through the precise and targeted application of fertilisers or plant protection products, overapplication of these substances can be minimised, which positively impacts the environment while saving costs [2]. The goal of this paper is a comparison of RGB cameras, which are easy to buy for farmers, and more expensive multispectral cameras.

1.1. Field monitoring

One of the main disadvantages of Earth observations (EO) satellite monitoring systems is their orbital interval and the inability to record the Earth's surface under increased cloud cover. For some operations, the required resolution may also be a limitation. An alternative may, therefore, be Unmanned Aerial Vehicles (UAV), also known as drones, which are becoming increasingly important in agriculture. These technologies bring several benefits to modern agriculture. Drones can be used in the same way as satellite systems, but we can freely choose the sensing term, and the drone sensor offers significantly higher accuracy, around $2\,\mathrm{cm\,px^{-1}}$. In addition, drones can help detect diseases or pests at this resolution [3].

A prerequisite for imaging agricultural plots is the selection of a UAV with sufficient flight length to carry a suitably selected camera. Variants are wing-type UAVs with low weight and flight time advantages, but handling and flight path maintenance may not be completely accurate, especially in poor weather conditions. Rotorcraft UAVs are mainly characterised by their easy manoeuvrability, but the higher purchase price of professional UAVs can be a disadvantage. A common equipment requirement should be a GNSS sensor with differential RTK (Real Time Kinematic) correction. Another requirement should be the ability to fly autonomously along a predefined route [4].

The most important part of the UAV is undoubtedly the sensor system, which is subject to high demands for resolution and the ability to sense multiple spectra. In practice, this means that a classical RGB camera can be used for common analyses, such as coverage. Still, for deeper analyses, it is necessary to work with the infrared bands normally invisible to the eye using multispectral cameras. The cost of a multispectral camera can exceed the purchase price of the UAV itself. Cameras are commonly equipped with lenses that detect the GREEN (530–570 nm), RED (640–680 nm), RED EDGE (730–740 nm), and NIR (Near Infrared 770–810 nm) bands [5, 6]. Plant stress and growth progress can be monitored in these bands by spectral analysis. These recorded data are then used to calculate various indexes. Optionally, the UAV can be equipped with a so-called sunlight sensor, which records the light conditions during detection [7].

1.2. Photogrammetry

Aerial photogrammetry is an important technique in image processing and Geographic Information Systems (GIS). This method uses aerial imagery to create three-dimensional maps, terrain models, and spatial data. Photogrammetry uses the principle of parallax, meaning that a three-dimensional model can be obtained when an object is imaged from different angles. Images are usually obtained from aerial vehicles such as aircraft or unmanned aerial vehicles. Data recording is done with digital cameras, multispectral sensors, and LiDAR. During data recording, the exact geographic location is also acquired. The main advantages of this method are the speed of obtaining information with high accuracy and resolution of the data compared to, for example, 3D scanners, and the disadvantages are the high intensity of the data and the need to perform sensor calibrations in the case of longer time measurements [8].

One of the outputs of photogrammetry is a digital terrain model (DTM), which can be created using only a combination of aerial imagery, but more accurate models also use LiDAR data [9]. This model provides an accurate image of the surface of the Earth, which is crucial for use not only in agriculture but also in hydrology or urban planning. Another output is an accurate geotagged orthomosaic of the Earth's surface, both in the visible RGB spectrum used, for example, on various map portals and with multispectral data for spectral analysis using vegetation indices. In practice, photogrammetry is then used as a tool for measuring area and volume (e.g., construction), creating 3D models or positional analysis, and monitoring the state of the Earth's surface (water management, forestry, agriculture).

This paper focuses on comparing RGB and multispectral gathered data toward affected spot identification. Another comparison the article deals with is the method of data collecting using UAV and EO. For this purpose, an experiment is designed and performed under actual field conditions. It is necessary to compare real sizes of datasets and the complexity of data postprocessing. The experiments will help to reveal the suitability of the gathered data samples, used recording devices with UAV, and data sources in the case of EO.

2. Methods

2.1. The experiment

The experiment was carried out on the field of ZD Krasna Hora in the Czech Republic, in Land Registry Počepice, DPB code 3709 (6,23 ha), 3703/1 (3,64 ha), 3804/3 (6,16 ha). Field 3709 was chosen as an example for this paper (see the red-marked field in Figure 1) because of damage which was, on average, within these three examined fields. The field was sown with rape on 17 August using the strip-till method. The vegetation in the agricultural field was significantly affected by voles and grew irregularly. The local conditions of the crop were suitable for learning the technology of the targeted application of a growth regulator where spraying should be turned off in places where growth is weak or without cover. The aim should, therefore, be that strong grown-up crops would be regulated and growth slowed before winter and that weak or no-coverage sites would not. This fact has an economic impact in terms of spray savings.

The DJI Mavic 3M unmanned aerial vehicle and Sentinel 2 satellite were used to collect data. The UAV collected images in the usual RGB bands and data outside the visible spectrum, multispectral NIR and RedEdge. An autonomous UAV mission at 100 m was used to collect RGB data with a resolution of 2.42 cm px^{-1} (9 mb/frame size) and multispectral data with a resolution of 4.84 cm px^{-1} (40 mb/frame size). The Sentinel 2 satellite acquired data with a resolution of 10 m px^{-1} (data from October 2, 2023). The satellite images recorded closer to the date of the UAV measurement were unfortunately affected by cloud cover.

2.2. Data processing

The raw data recorded from the UAV (multispectral and RGB camera) was pre-processed using Pix4d Fields using the photogrammetric method. The first step in processing was the cropping of measured data along the field boundaries. For further analysis, the Sentinel 2 satellite image of the field was also processed.

Data measured with the multispectral camera were converted to the NDVI (Normalized Difference Vegetation Index) index as presented in Formula (1), and the conventional RGB data were converted to the VARI index (Visible Atmospherically Resistant Index) as presented in Formula (2) [10].

$$\text{NDVI} = (\text{NIR–RED}/\text{NIR}+\text{RED}), \quad (1)$$

$$\text{VARI} = (\text{GREEN-RED}/\text{GREEN}+\text{RED-BLUE}), \quad (2)$$

where

GREEN = pixel values from the green band,

RED = pixel values from the red band,

BLUE = pixel values from the blue band,

NIR = pixel values from the near infrared band.

The input format supported by agricultural machinery and its implements is the polygon vector maps, created based on the raster data described above. The tool used for raster data conversion was a mathematical model created in QGIS (Quantum Geographic

Figure 1. Location of the field on which the experiment was carried out.

Information System). This model optimises the resolution and performs smoothing of the extremes according to the size of the nozzle range. According to the specified breakpoint value, the software selects the pixels where the application should be made and assigns them the desired spray dose.

Analysis was made using the statistical processing tools of QGIS. For these purposes, a raster dataset with the size of the grid the same as the resolution was used, and the calculation was made under polygons overlays.

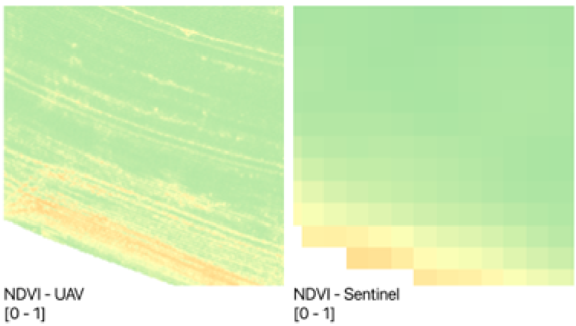
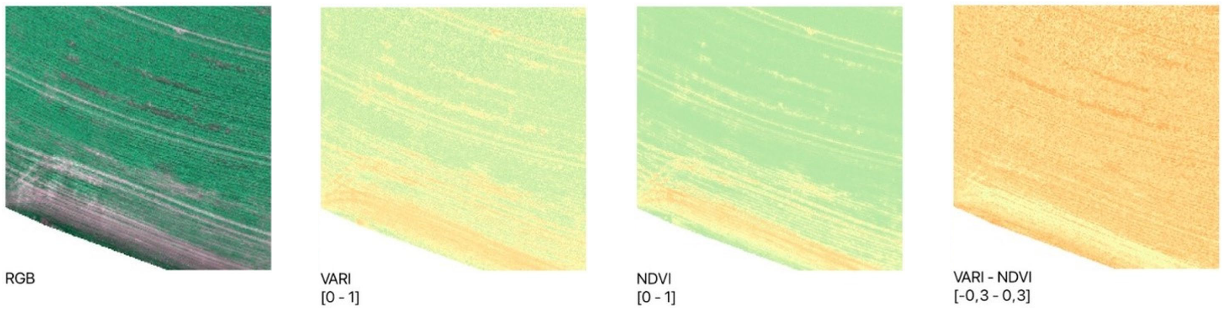


Figure 2. Comparison of the UAV and Sentinel 2 NDVI index.

3. Results

According to the available Sentinel 2 satellite data, the zonal distribution is consistent. Still, the data are not appropriate for targeted applications, as the local foci are too small and indistinguishable (see Figure 2). On the other hand, UAV data is more accurate and thus usable for targeted applications.

Based on the obtained data, it is visible that the identification of the damaged field areas is well recognisable in both NDVI and VARI indices (see Figure 3). Still, the view of the vegetation cover corresponds better to the NDVI index. For confirmation, the NDVI and VARI indices were subtracted from each other, and the result was confirmation that for targeted applications such as the identification of damaged patches, both sources are suitable. In general, the multispectral camera data can better identify the crop condition even though it is in a relatively early stage of growth. At the time of data collection (9 weeks after planting), the NDVI may not be sufficiently saturated. However, in our conditions, as presented in Figure 3d, the difference between them is not significant; from this point of view, both datasets are sufficient.



(a). (b). (c). (d).

Figure 3. Comparison of the RGB, NDVI and VARI data representation.

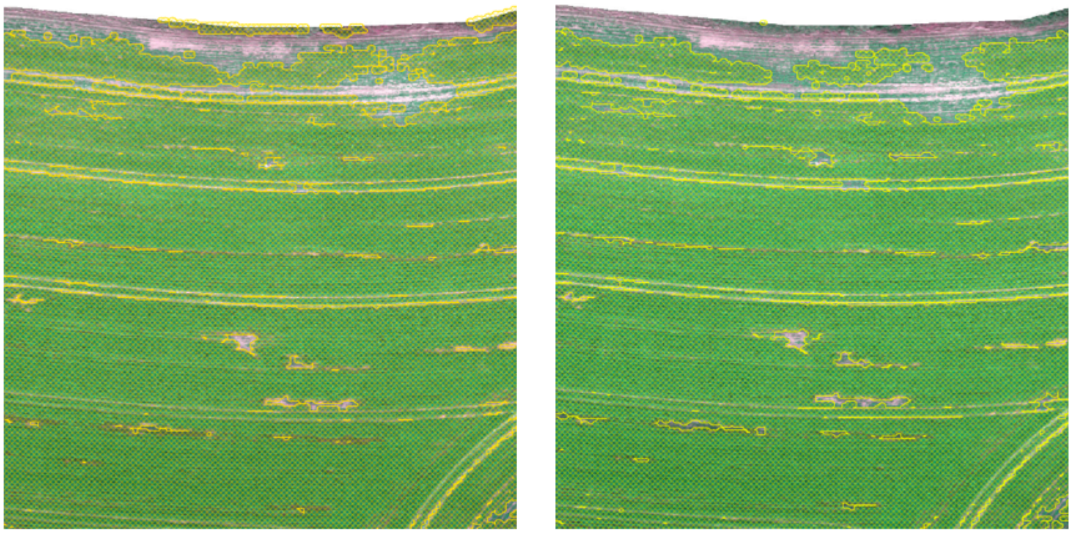


Figure 4. Comparison of difference of processed data based on NDVI (left) and VARI (right) index.

As part of the comparison, both the NDVI and VARI data were processed using the computational model created in QGIS software. The results of a so-called prescription map are presented in Figure 4. Spots marked with a light-yellow colour indicate places where the spray should be applied. The difference in the sprayed area between the approaches using NDVI and VARI is 3 %. This means that both methods for this application (green on brown) are acceptable. The threshold value was 0.60 for both (NDVI and VARI) indexes. The results of both sources were acceptable. The differences were only at the borders between weak and strong plants. This finding confirms the better sensitivity of the multispectral camera of plant stages. However, in this usage, in the detection of green on brown, the multispectral advantage is negligible (see Figure 5).

4. Discussion

Based on the results, it is evident that the processed data obtained through the Satellite System Sentinel 2 are not sufficient for the targeted application because the resolution is too low. However, the satellite EO data resolution is sufficient for VRA (variable rate applications) because the size of the pixel to change the rate is acceptable [11]. Using a UAV equipped with an RGB or multispectral camera, it is possible to reach a resolution of up to $2\,\mathrm{cm\,px^{-1}}$, which is necessary for data analysis regarding identifying specific spots in the agriculture field.

Based on multispectral data, we can compare various colour shades even in spots with similar spectral profiles. In this paper, we focus on the problem of detecting brown spots in a green field. For such an application, the RGB and multispectral data transformed into NDVI and VARI indexes per pixel were examined and found to be sufficient for target applications.

For the QGIS model, threshold values need to be identified, which is challenging, especially in detecting green shades on a green background. For example, at this moment, we identify value by creating polygons over areas of interest and calculate their average value. In future releases, it could be interesting to integrate artificial intelligence methods to determine threshold values [12, 13].

As part of the verification process, the prescription maps created in .shp (shapefile) format were

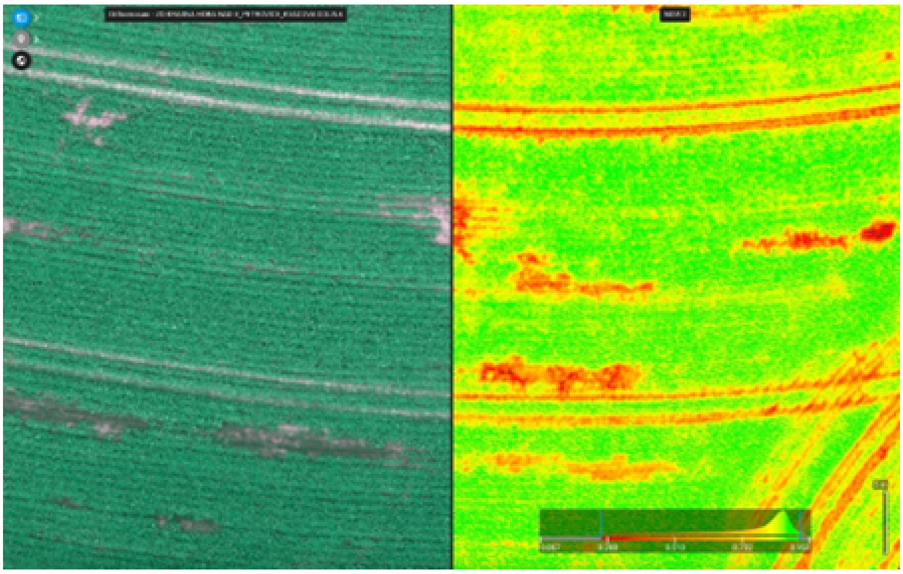


FIGURE 5. Detailed comparison of RGB and NDVI imagery.

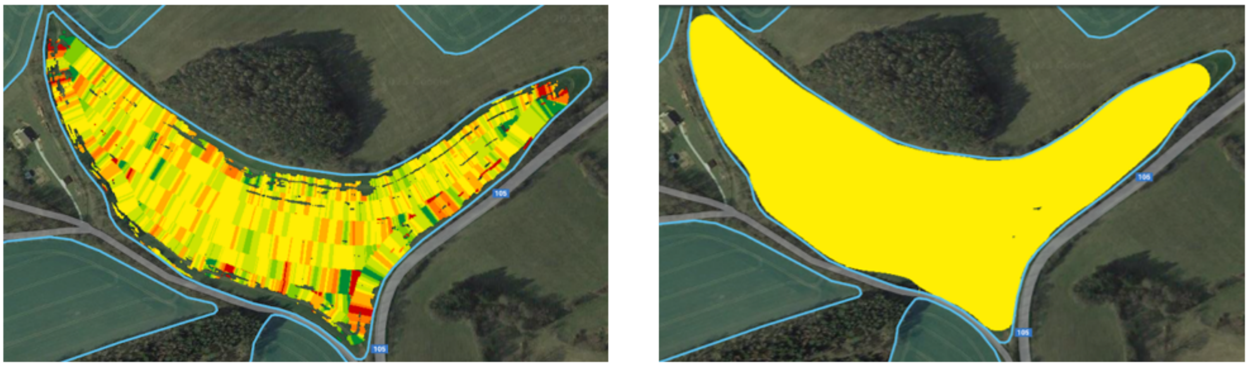


FIGURE 6. Comparison of the prescription maps – left: target operation, right: broadcast operation.

imported into the simulator of the usage implement control unit. Specifically, it was the John Deere R952i trailed sprayer. This machinery supports the control of individual nozzles, which are spaced 25 cm apart on the sprayer's shoulder. Compared to prescription maps without targeted spray application (see Figure 6), there is a 20 % savings.

5. Conclusions

Based on the evaluation of data obtained by EO satellite technology (Sentinel 2), it was found that the resolution of this technology is not suitable for targeted applications. UAV data, along with the use of NDVI and VARI indices, provide a more accurate and effective method for targeted agricultural applications.

Using multispectral images, we can achieve more accurate identification, especially on borders between weak or strong plants in affected areas, with a lower resolution compared to images from RGB cameras when choosing a suitable vegetation index. Both NDVI and VARI indices are effective in identifying damaged field areas, with the NDVI index providing a better representation of vegetation cover. Despite the crop being in a relatively early stage of growth at the time of data collection (9 weeks after planting), the multispectral camera data can identify the crop condition better than the RGB camera.

However, RGB data are needed for the initial setup of the multispectral image-based identification model. RGB cameras are cost-effective, user-friendly, and ideal for high-resolution visual tasks like crop monitoring and weed detection, especially for the recognition of green on a brown background. Data obtained by an RGB camera is also significantly less data intensive.

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