Availability of spectral indices based on RGB image data obtained by low-cost UAV: case study

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Abstract. Spectral indices, mostly based on multispectral image data, are vital tools in remote sensing applications to extract valuable information about the surface. One modern remote sensing tool is an unmanned aerial vehicle (UAV). UAVs can provide accurate image data on demand and carry multiple camera types. However, a limitation of low-cost UAVs is that they obtain only RGB image data. The RGB image data are based on the red, green, and blue parts of the visible light. Spectral indices can enhance spectral characteristics from RGB image data obtained by a UAV. This study used RGB image data of the Baroch nature reservation obtained by a low-cost UAV. Significant values of spectral indices were found in the RGB image data. The following spectral indices were used in this study: BCC, ExG(I), DSWI4, GCC, GLI, IKAW, MGRVI, MRBVI, NDYI, NGRDI, RCC, RGBVI, RGRI, RI, and VARI. Selected spectral indices based on calculation with RGB bands are used to process the collected imagery and identify the most common types of land cover: vegetation, bare land, and water.

Keywords: Spectral index, UAV, RGB image data.

1 Introduction

Modern worlds want to have realistic, precise, and actual data. One of these aspects is to identify land cover/land use, which helps to observe changes, measure volumes, and get information about land status in the environment. Land use/land cover (LULC) identification has been based on remote sensing, particularly on satellite imagery [1][2].

Remote sensing is one of the most significant tools for capturing image data without physical interaction. The primary purpose of remote sensing is to provide fast data collection for large areas. As mentioned, remote sensing provides a noninvasive way of obtaining images even of non-accessible areas. The atmospheric influence, like cloud coverage, can be a significant cause of the unusability of obtained images.

As a remote sensing tool, a modern UAV provides high-quality local image data that is not affected by clouds. With this tool, local image data can be easily obtained. Many UAVs, mainly low-cost UAVs, provide only RGB image data [3]. The limitation of RGB is the imagery created by the reflection of visible light from the surface [4].

The paper aims at land cover identification in a small area of interest based on UAV data sensed in the visible part of the electromagnetic spectrum with a very high spatial resolution. Fifteen chosen RGB spectral indices (BCC, ExG(I), DSWI4, GCC, GLI, IKAW, MGRVI, MRBVI, NDYI, NGRDI, RCC, RGBVI, RGRI, RI, VARI) are compared from the point of view of their ability to identify most common types of land cover, which are vegetation, bare land, and water. The paper focuses on distinguishing green vegetation from water and bare land surfaces based on data collected by a low-cost UAV.

2 State of the art

2.1 Spectral indices for RGB image data obtained by a UAV

The study [5] deals with the application of low-cost remote sensing in precision agriculture, specifically in the context of emerald grass production in Brazil. The paper focuses on the use of RGB vegetation indices to identify soil and vegetation in a 58-hectare irrigated area in Bom Sucesso, Minas Gerais, Brazil. Overlapping images were captured using a remotely piloted aircraft with an RGB digital camera. The authors calculated six vegetation indices: MGRVRI, GLI, RGBVI, MPRI, VEG, and ExG. The authors report that lighting conditions influenced all indices, but MPRI and MGVRI were superior in discriminating between vegetation and soil.

The paper [6] compares the performance of the Normalised Difference Vegetation Index (NDVI) derived from multispectral cameras with four indices obtained from RGB sensors (VARI, TGI, ExG, NGRDI) in identifying soil and vegetation in images captured by an unmanned aerial vehicle. The authors note that RGB indices enable the extraction of spatial patterns similar to those observed in NDVI and can even identify areas with weed proliferation. The authors state that this capability is useful for cost-effective applications, especially when obtaining images for larger areas, and it is suitable for basic tasks such as identifying spatial variations in crop vigour.

The paper [7] compares vegetation spectral indices based on RGB bands, specifically ExGI, GCC, GLI, GLI2, NGRDI, RGBVI, TGI and VARI. The study focuses on vegetation and clear water surfaces near the shoreline of Skříň pond in Lázně Bohdaneč, Czech Republic. Data was collected using a Phantom 3 and processed using ArcGIS, ENVI, and ENVI OneButton. The pond and its shoreline were monitored several times between February 2018 and March 2019. The study concludes that monitoring land cover changes on demand is feasible using low-cost or middle-class UAVs, which provide high-resolution data at the centimeter level of detail. In this study, NGRDI, GLI2, and VARI provide the most accurate results.

The study [8] used two unmanned aerial vehicles (UAVs) to capture images of the hop gardens before the harvest. The authors calculated seven RGB vegetation indices from photogrammetrically processed RGB and multispectral images using Pix4Dmapper software. The vegetation indices used in this study include the Green Percentage Index (G%), Excess of Green Index (ExGreen), Green Leaf Index (GLI), Visible Atmospherically Resistant Index (VARI), Red Green Blue Vegetation Index (RGBVI), Normalised Green Red Difference Index (NGRDI), and Triangular Greenness Index (TGI). Binary models were created for each vegetation index, and a threshold for green vegetation was established. The study suggests that RGB vegetation indices, specifically ExG and TGI, allow effective monitoring of hop plant areas.

2.2 Spectral indices for RGB image data

The review articles [9][10][11] focus on RGB spectral indices. These indices are based on spectral characteristics of particular land cover types. Thus, they enhance the imagery and allow more straightforward interpretation and analyses.

3 Methodology

The case study is focused on comparing chosen RGB indices' suitability for detecting land cover types. The case study is carried out on nature reservation Baroch, and data are collected using low-cost UAV. The following chapters will describe the research carried out in the field of RGB spectral indices based on low-cost UAV-borne imagery and area of interest.

3.1 Area of Interest

Baroch is a nature reservation situated to the southwest of the village of Hrobice in the Pardubice Region of the Czech Republic, see **Fig. 1**. It is managed by the Czech Nature and Landscape Conservation Agency. The nature reservation is home to earthen ponds, adjacent reedbeds, forest and meadow communities, and a local ornithological site. The site covers an area of 93.58 ha, of which 62 ha are protected. The reservation is around 225 meters above sea level and comprises peat meadows with a diverse range of flora and fauna. Additionally, it serves as a significant nesting site for birds. The reason for using spectral indices is to measure vegetation [12][13]. **Fig. 2** shows the chosen researched area of interest, containing all examined land covers: water, bare land, and vegetation.

Fig. 1. Location of Nature reservation Baroch (red rectangle) [14]

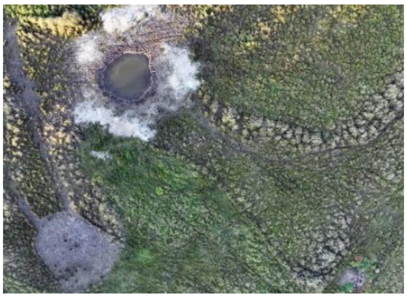


Fig. 2. Area of Interest

3.2 Spectral indices

In this study, we utilised 15 RGB indices, see **Table 1**. These include Blue Chromatic Coordinate (BCC), Excess Green (ExG(I)), Disease-Water Stress Index 4 (DSWI4), Green Chromatic Coordinate (GCC), Green Leaf Index (GLI), Kawashima Index (IKAW), Modified Red Blue Vegetation Index (MGRVI), Modified Red Blue Vegetation Index (MRBVI), Normalised Difference Yellowness Index (NDYI), Normalised Green Red Difference Index (NGRDI), Red Chromatic Coordinate (RCC), Red Green Blue Vegetation Index (RGBVI), Red-Green Ration Index (RGRI), Redness Index (RI), and Visible Atmospherically Resistant Index (VARI). The indices were chosen according to the most common indices used in the journal's articles [9][10][11]. The indices are able to enhance vegetation, bare land, and water in imagery.

Table 1. RGB indices

Index	Formula	Reference
BCC	B / (R + G + B)	[15]
ExG(I)	2 * G - (R – B)	[16]
DSWI4	G / R	[817]
GCC	G / (R + G + B)	[15]
GLI	((G - R) + (G - B)) / (2 * G + R + B)	[18]
IKAW	(R - B) / (R + B)	[19]
MGRVI	(G^2 - R^2) / (G^2 + R^2)	[20]
MRBVI	(R^2 - B^2) / (R^2 + B^2)	[21]
NDYI	(G - B) / (G + B)	[22]
NGRDI	(G - R) / (G + R)	[23]
RCC	R / (R + G + B)	[15]
RGBVI	(G^2 - (R * B)) / (G^2 + (R * B))	[20]
RGRI	R / G	[24]
RI	(R - G) / (R + G)	[25]
VARI	(G - R) / (G + R - B)	[26]

R – RED band, G – GREEN band, B – BLUE band

3.3 Used software and hardware

The planned flight was used for data collection and has been controlled and planned by Dronelink. ESRI ArcGIS PRO (version 3.2.1) was used for the calculation of RGB vegetation indices and was used for interpretation. A raster calculator from the spatial analyst tool ArcTollbox was used to calculate spectral indices using spectral indices formulas.

3.4 Data collection

DJI Mini 2 with a built-in RGB camera was used for data collection. DJI Mini 2 [27] is a low-cost small site UAV with 249 MTOW. DJI Mini 2 has a 3-axis stabilised built-in RGB camera with a 2.8 aperture and captures 12 Mpx images. The nature reservation Baroch was observed on the 27th of September 2024. The planned flight was used because it can be repeated in the future. All images were taken during one flight lasting approx. 14 min. The total length of the flight was 3 627 m, and the size of the covered area was 51 088 m2. The flight obtained images with both front and side overlap by 80 %. The altitude was 60 m. By a planned flight, 335 images were obtained. Spatial resolution was 2,77 cm per pixel. DJI drones in Czechia use the WGS 84 coordinate system, which is set to all images that have been obtained. The flight was performed at midday when the sun was in the nadir to the ground.

4 Results and discussion

The following images (**Chyba! Nenalezen zdroj odkazů.** – **Fig. 10**) show results; each image represents results provided by one spectral index.

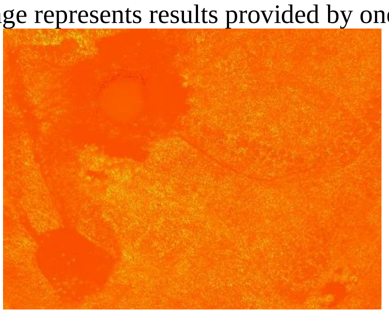


Fig. 3. GLI

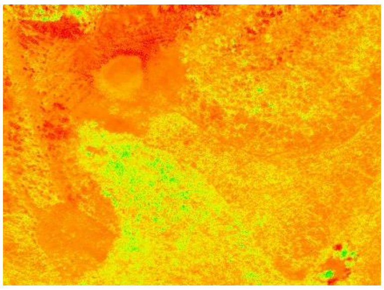
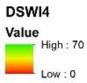


Fig. 4. DSWI4



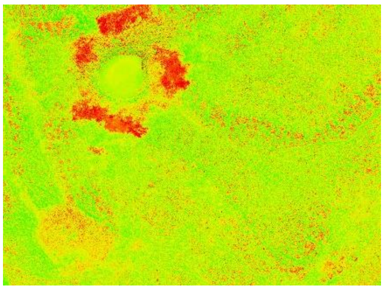


Fig. 5. ExG(I)

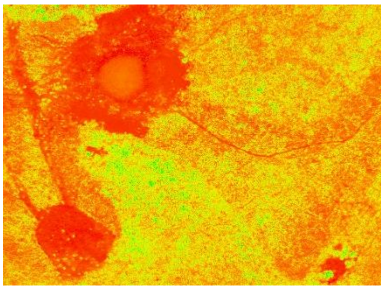


Fig. 6. GCC

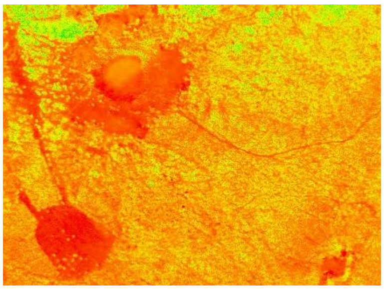


Fig. 7. IKAW

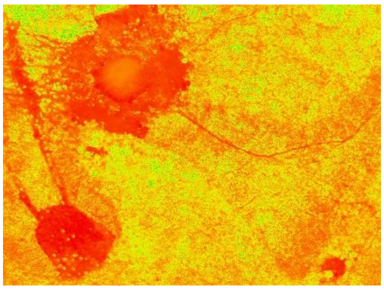


Fig. 8. NDYI

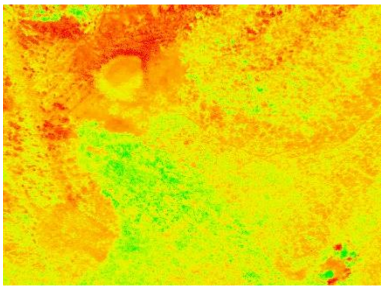


Fig. 9. VARI

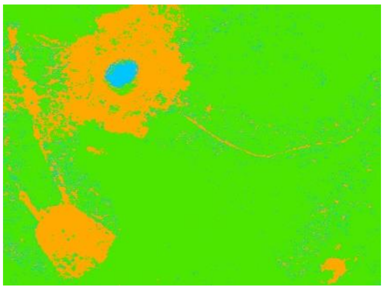


Fig. 10. Classified source data (ML)

Results provided by spectral indices (Fig. 3 – 9) can be compared to the result of image classification by Maximum Likelihood (ML, Fig. 10).

Results obtained in this case study were compared with those of a previous study by the authors [7], which used similar and identical RGB indices. For the chosen area of interest in this case study, spectral indices provide results different from those of the compared study for the GLI spectral index. VARI and NGRDI provide identical visual results, the same as those in the compared study.

GCC, NDYI, and RGBVI provide the best visual result for identifying bare land and water with the same spectral enhancement colour. ExG(I) provides the best result for identifying vegetation after modification of stretch value to an inverted colour. MRBVI, MRBVI, and NGRDI provide identical visual results. GLI spectral index provides wrong values.

Stretch value colour modification of spectral indices (ExG(I), RCC, RGRI, RI) had to be done to show correct reflective colours relative to the surface.

BCC, GLI, RCC spectral indices provides useless results to any identification of surface type, from that reason is shown only GLI spectral index as result.

MGRVI, MRBVI, NGRDI, RGRI, RI, VARI spectral indices provides identical results, from that reason is shown only VARI spectral index as result.

5 Conclusion

Spectral indices can enhance imagery and highlight chosen land cover/land use types. The purpose of each spectral index is to highlight or enhance a typical land cover based on typical spectral characteristics.
Low-cost UAVS are frequently used today to collect very high spatial resolution imagery, but they usually provide RGB data only. Data processing is based only on visible bands, i.e., only RGB spectral indices can be used. This represents a fundamental limitation of utilising low-cost UAVs because other bands are unavailable.

In this study, 15 RGB spectral indices were used and compared to the Maximum Likelihood classification. RGB spectral indices provided different results. Some of them show very conclusively bare land and water as the same value, and some of the spectral indices are useless, which can be given by the input data type.

In future work, we will apply the chosen RGB spectral indices to a different data set from a different season and area.

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