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An inexpensive process for 350–1100 nm wavelength aerial photography for agro-environmental studies

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Abstract. The aim of this work was to present the possibilities of obtaining four-channels of aerial photographs (blue, green, red, infrared) and their use in agriculture research. Two synchronised and gyro-stabilised digital cameras FujiFilm IS-1 sets installed on a Cessna airplane were used. The digital cameras used in the study were factory set and adapted to perform photos in the 350–1100 nm wavelength. To separate the photographs content into spectral channels, selective filters were used and installed on the lens as well as photographs from two cameras were combined in a GIS computer program. High-resolution multispectral photographs were the source material for the spatial analyses. For example, the analysis can be used in field monitoring – e.g. vegetation index (NDVI, VARI) map drawing. In this work, an evaluation of the cost involved in obtaining this type of data was presented.

Keywords: remote sensing, image processing, computer vision, NDVI, VARI

INTRODUCTION

Low altitude digital photography allows for a quick and cheap acquisition of spatial data. This data, processed by the methods available in geographic information systems (GIS) take on cartometric characteristics. Additionally, their processing allows vegetation index maps to be drawn, one of the main sources of information used for agro-environmental studies (Nieróbca et al., 2008; Pudełko et al., 2008a, 2008b, 2009; Borzęcka-Walker, 2007).

The advantages of using low altitude digital photography are in its low cost of obtaining photographs (the price of a flight) and in timing the date of the flight according to the state of the plant vegetation in the researched area. These opportunities are not always given by either high-resolution satellite images (clouds and flights periodicity) or high altitude aerial photography (clouds at low and middle altitudes). In many cases, there is a need to evaluate the implementation of a spatial variability for a smaller area. Therefore, bearing in mind the financial factor, the use of a cheaper solution rather than professional remote sensing methods is necessary. For this reason, alternative ways of obtaining low altitude digital photos are increasingly used in scientific research and practice. In the literature, there are many examples of methods used such as light aircraft (Bauer at al., 1997; Nieróbca at al., 2007; Pudełko and Igras, 2008), unmanned aerial vehicles (Igras and Pudełko, 2008; Hunt et al., 2005; Rydberg at al., 2007; Sugiura et al., 2005), balloons (Inoue et al., 2000) and kites (Jensen et al., 2007). Another advantage of digital photography is the possibility of taking infrared photographs. Commonly available cameras have built-in filters that eliminate registrations in the channel over 750 nm (near infrared). However, some companies offer cameras to record the full range (350–1100 nm) registered by the CCD (charged couple device) matrix. Such cameras include IS-1 produced by the Fujifilm Inc.

The aim of this work was to present possibilities of obtaining four-channels of aerial photographs (blue, green, red, infrared) based on a Cessna plane and self-made gyro-stabilised platform for Fujifilm IS-1 cameras.

MATERIALS AND METHODS

This project deployed a self-constructed multispectral sensor system for low-altitude remote sensing (MSS-LA-RS) that consisted of two synchronised and gyro-stabilised digital cameras FujiFilm 9MP IS-1 set, which was installed on a Cessna airplane (Figure 1). The images done in Red (600–700 nm), Green (500–600) and Blue (400–500 nm) and IR (700–1100 nm) were captured at the same time by using a radio controlled trigger. The system allows an operator

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Fig. 1. Multispectral sensor system for low-altitude remote sensing (MSS-LA-RS) mounted on a Cessna plane.

to preview the area to be photographed in real time. For RGB photography the B+W No. 58 filter was used, and for NIR the B+W 52 UV-IR CUT CHROM. An image processing package ERDAS IMAGINE® 8.4 (Erdas, Inc.) was used for drawing up maps of vegetation indices. NDVI (Normalised Difference Vegetation Index) maps were obtained based on jointly taken Red, Green, Blue and NIR photos. VARI (Visible Atmospherically Resistant Index) map can be used as an equivalent of NDVI maps in the case of only RGB photography (Golzarian et al., 2007; Stark et al., 2000).

The possibilities of obtaining four channels of high-resolution aerial photographs were presented based on the analysis of a chosen RGB-NIR combined photos. The photos were taken on 30.08.2008 from an altitude of 500 m, when the system was tested on IUNG's experimental fields (51°28'N, 22°04'E, western Poland).

RESULTS AND DISCUSSION

The MSS-LA-RS test has demonstrated its functionality. Thanks to the possibility of a preview in real time of the image seen by the cameras, the operator has an opportunity to choose the appropriate moment for taking the photographs. Figure 2 shows aerial photos, obtained with the stabilisation mode of cameras, which provides sufficient precision in the vertical direction of the photograph axis and parallel axis according to the direction of the two cameras. This allows the geometrization of the photographs into orthophotomaps and connection of RGB and NIR channels into the 4-channel photography, which was the basis to draw up the NDVI and VARI index maps (Figure 3).

Table 1. A statistical description of the NDVI and VARI maps.

Index	Mean	Median	Std. Dev.	Max	Min
NDVI	-0.02	-0.01	0.37	1.00	-1.00
VARI	0.02	0.02	0.17	0.96	-0.37

The pictures below represent the following forms of land use: ploughed fields, fields with developed vegetation, abandoned area, fields with no developed vegetation, fields with medium developed vegetation, water, artificial area (buildings).

A comparison between the NDVI map and the VARI map shows a high correlation between selected indices on both maps. This suggests a possibility of applying the VARI index as an equivalent of the NDVI index, where the images were made solely in the RGB channels. VARI mostly correlates with NDVI in areas used for agriculture: ploughed fields, fields with developed vegetation, fields with not developed vegetation, fields with medium development of vegetation (Figure 3 and 4 – zones: A, B, D, E). Compared with VARI index, NDVI much better illustrates the areas occupied by buildings or by water (Figure 3 and 4 – zones: G and F). A comparison between the descriptive statistics of both images shows that the NDVI index is more spectrally sensitive. The NDVI image is characterised by a greater value of standard deviation along with more extreme values (Table 1). Therefore, the image classification process is more efficient.

The CCD matrix used in popular digital photography is characterised by a lower sensitivity of infrared registration (Pudełko et al., 2008b). Therefore, the ratio of registered values in the NIR and R channels will differ from the real ratio. It caused the NDVI index figures to be undervalued, which is shown on the presented map (Fig. 3). In contrast, the CCD matrix is especially sensitised to the green and red with blue. Consequently, both analysed indexes presented a large correlation in the registration of the vegetation intensity. An even better contrast can be observed between the vegetation and soil on the VARI maps than on the NDVI maps (B vs. zones A and D on the Figure 3). Only the NDVI index showed a capability of detecting water. In the case of detecting buildings, it seems most appropriate to compare the information with maps of both indices.

Low altitude aerial photography compared with other methods of remote data acquisition seems to be the most economical. The cost of a flight in a Cessna aircraft, which was used to obtain data presented in the work amounted to 130 Euro. In 2008, Fujifilm IS-1 cameras in the United States cost $900.

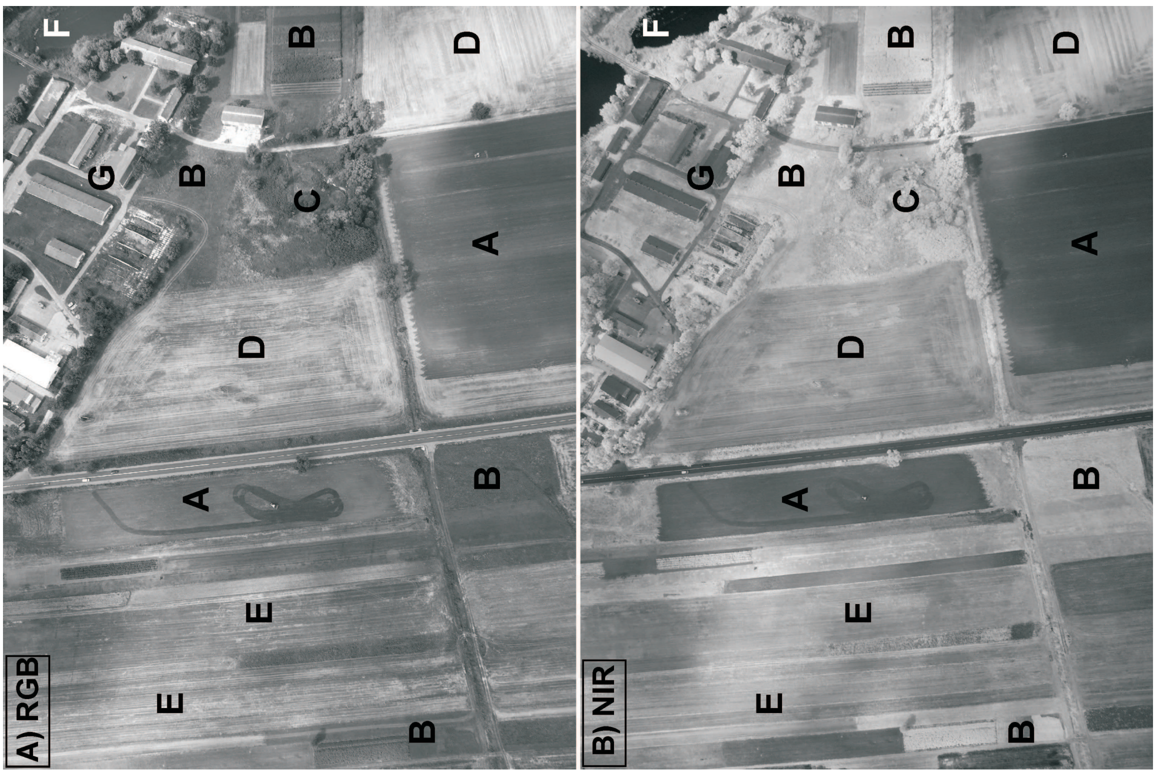

Fig. 2. RGB and NIR aerial photos taken on 30-08-2008.
Description of sites: A – ploughed fields, B – fields with developed vegetation, C – abandoned area, D – fields with no developed vegetation, E – fields with medium developed vegetation, F – water, G – buildings.

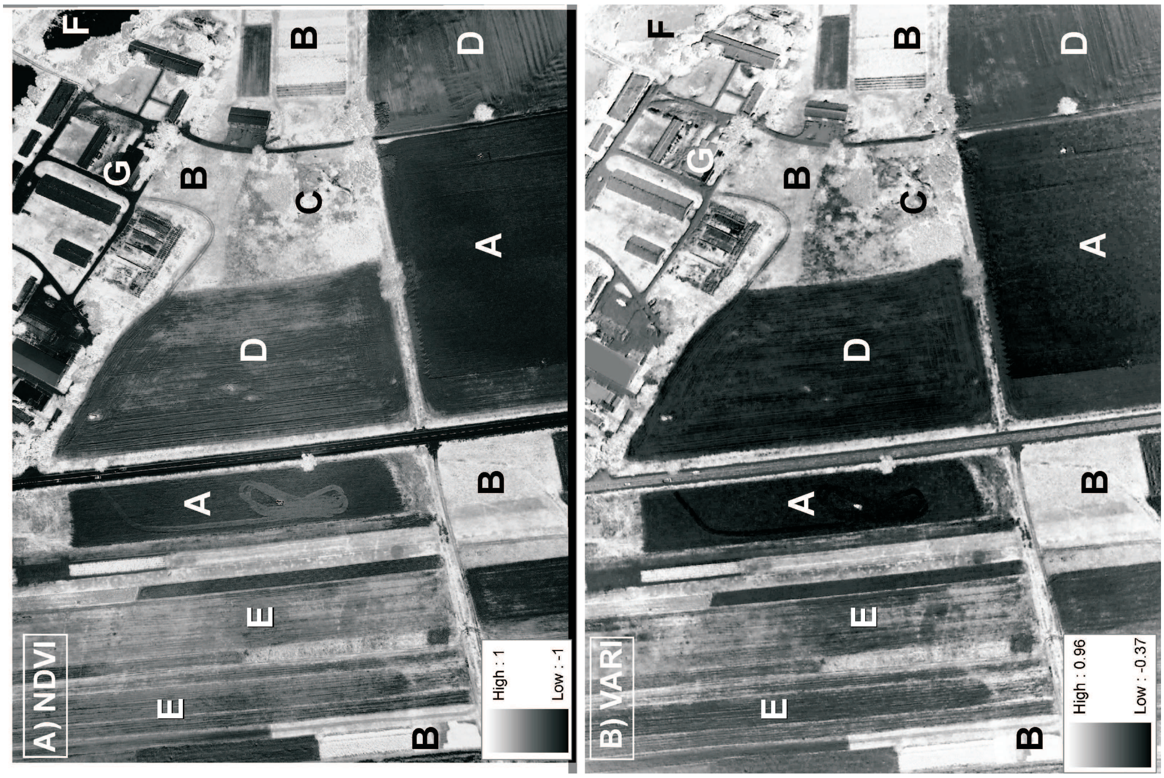

Fig. 3. NDVI and VARI maps based on the photos shown in Figure 2. The sites A,B...G have characteristics according to their descriptions in Figure 2.

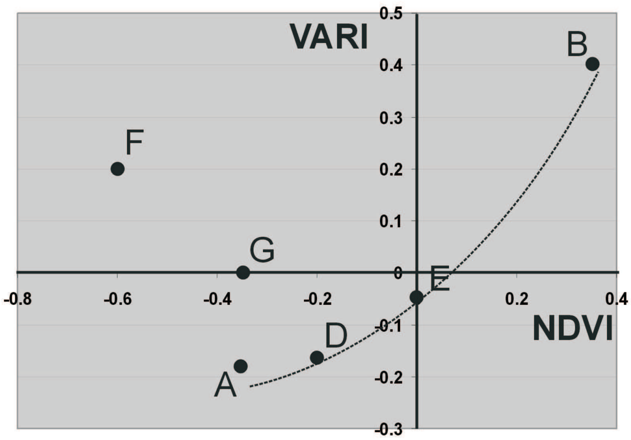

Fig. 4. The relation between NDVI and VARI for the mean (representative) values of chosen zones (see Figure 2 and 3). The dashed line on the diagram shows a positive correlation for A, D, E, B.

The low cost of obtaining high-resolution spatial data constitutes a major advantage of the presented method when applied to assess the diversity of land use structure in surveyed areas. The ability to make the rapid analysis of crop conditions during the growing season is crucial when it is necessary to draw up maps of varied applications of three doses of nitrogen fertilizer and plant protection products. The doses may be established on the bases of NDVI and VARI distribution.

CONCLUSION

1. Digital photography based on the popular CCD matrix offers the opportunity to interpret the image registered in blue, green, red, and near infrared.
2. Analysis of the recorded value of individual RGB and NIR channels allows obtaining indices that characterise the development of vegetation and the land use.
3. Low altitude aerial photography is an efficient way of obtaining remotely sensed data. The main advantages of this method is the possibility to study the vegetation status within short time of acquisition and low cost of obtaining the image.

REFERENCES

Bauer M. (ed.), **1997.** The first North American symposium on small format aerial photographs, technical papers. ASPRS, Minnesota, USA.

Borzęcka-Walker M., Pudełko R., 2007. Wstępne badania nad możliwością zastosowania zdjęć lotniczych do oceny przezimowania miskanta. Sesja naukowa z. 93. Zesz. nauk.AR Kraków, 444: 99-104.

Golzarian M., Desbiolles J.M.A., Lee M.K., 2007. Colour index evaluation method for plant segmentation from a soil background. In: Precision agriculture 07' (ed. J.V. Stafford). Wageningen Academic Publishers, The Netherlands, pp. 325-332.

Hunt E.R. et al., 2005. Evaluation of digital photography from model aircraft for remote sensing of crop biomass and nitrogen status. Precis. Agric., 6(4): 369-378.

Igras J., Pudełko R., 2008. UAV monitoring of experimental fields. Ital. J. Agron./Riv. Agron., 2008, 3 Suppl.: 687-688.

Inoue Y. et al., 2000. A blimp-based remote sensing system for low-altitude monitoring of plant variables: a preliminary experiment for agricultural and ecological applications. Int. J. Remote Sens., 21: 379-385.

Jensen T. et al., 2007. Detecting the attributes of a wheat crop using digital imagery acquired from a low-altitude platform. Comput. Electron. Agr., 59: 66-77.

Nieróbca A., Pudełko R., Kozyra J., Smagacz J., Mizak K., 2007. Wykorzystanie pomiarów zdalnych do oceny wiosennego porażenia roślin przez choroby. Prog. Plant Protect./Post. Ochr. Rośl., 2007, 48(2).

Nieróbca A., Pudełko R., Kozyra J., 2008. The use of remote sensing methods in assessing cereal condition after winter. Ital. J. Agron./Riv. Agron., 2008, 3 Suppl.: 687-688.

Pudełko R., Igras J., 2008. Ocena zmienności przestrzennej cech pola na podstawie metod zdalnych. Fragm. Agron., 4(100): 128-140.

Pudełko R., Kozyra J., Nieróbca P., 2008a. Identification of the intensity of weeds in maize plantations based on aerial photographs. Zemdirbyste-Agriculture, 95(3): 130-134.

Pudełko R., Kozyra J., Mizak K., 2008b. Zastosowanie fotografii CIR w badaniach rolno-środowiskowych. Fragm. Agron., 2(98): 119-127.

Pudełko R., Nieróbca A., Kozyra J., 2009. Zaawansowane analizy zdjęć lotniczych do wyznaczania zasięgu stref zagrożonych chorobami podstawy źdźbła. Probl. Inż. Rol., 4: 103-108.

Rydberg A. et al., 2007. Field specific overview of crops using UAV (Unmanned Aerial Vehicle). In: Precision Agriculture '07 (ed. J.V. Stafford), Wageningen Academic Publishers, The Netherlands, pp. 357-364.

Stark R., Gitelson G.A., Grits U., Rundquist D, Kaufman Y., 2000. New technique for remote estimation of vegetation fraction: Principles, algorithms and validation. Asp. Appl. Biol., 60: 241-246.

Sugiura R. et al., 2005. Remote-sensing technology for vegetation monitoring using an unmanned helicopter. Biosyst. Eng., 90(4): 369-379.