SPECTORADIOMETRIC AND HYPERSPECTRAL SAMPLING AND DATA PROCESSING METHODOLOGIES IN MODERN AGRICULTURAL PRODUCTION

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Abstract

The field- and laboratory spectroradiometry are indispensable components of airborne hyperspectral remote sensing by giving reference information for image processing. At the same time, 'in' and 'ex situ' ground spectroradiometric measurements can be used for analysis in various application fields in a self-contained manner, too. In this paper, we present the ASD Field Spec®3 MAX portable spectroradiometer together with its role in airborne remote sensing and the main methodological details of the field- and laboratory spectroscopy.

Keywords

spectroradiometric and hyperspectral sampling, data processing

Introduction

The dynamic development of the different remote sensing technologies resulted in the hyperspectral imaging spectroscopy, which is one of the most advanced technologies in optical remote sensing.The hyperspectral technological capabilities of the Hungarian Institute of Agricultural Engineering provides wide opportunity for obtaining quantitative relationships between the environmental or physiological parameters of vegetation cover or the soil quality parameters and those spectral characteristics. The AISA DUAL hyperspectral airborne twin-sensor system has the advantage of being able to operate in the full optical wavelength range of 400 nm to 2450 nm and, thus, providing several times more information as sensors operating in the visible range alone, by revealing phenomena which exhibit diagnostic absorption features in the shortwave infrared bands. Remote sensing of Earth's surface involves all evaluation methods which work without touching the object. The only physical connection between the observer and the object is the electromagnetic radiation. With the use of the hyperspectral remote sensing we record the refletced flux radiation form the studied surface on hundreds of narrow, adjacent bands. Simoultaneously, on these bands gray-scale pictures are made and recorded separately. The technology provides broad opportunities of evaluating local or global processes or balances according to the various aspects. It has also greatly improved the efficiency of data utilization and created new perspective for modern information management in precision agricultural production by satisfying the growing demand toward data and information. This data recording method resulting in the so called data cube (see Fig. 1) where high resolution of spectral information is assigned to all spatial pixel of data cube and spectral characteristics of the surface can be mapped by high definition geometrical sampling method on up to hundreds of adjacent spectral bands.

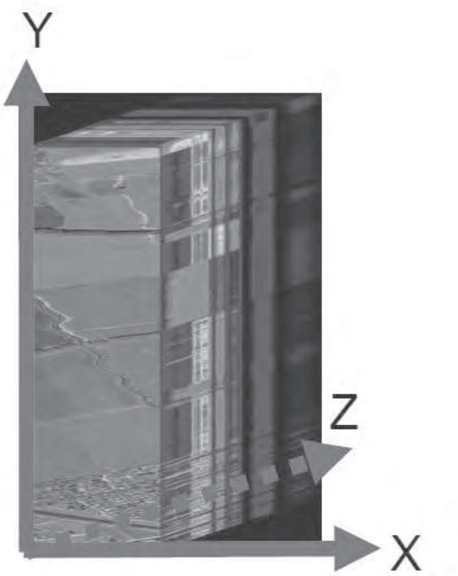

Figure 1. Hyperspectral data cube

The integration of in-field and laboratory spectroradiometric measurements is adequate for analyse large areas in a fast, precise and economic way (Milics et al. 2010, Milics et al. 2011a, Késmárki-Gally et al. 2009). Unlike airborne imaging data in-field or laboratory spectral sampling results in one pixel, which contains the mean reflectance of the instantaneously scanned surface. In this study we are introducing two sensors which extend the detectable visible light (Lágymányosi and Szabó 2009, 2011) to NIR – near infrared – and the SWIR – shortwave infrared – and able to operate in the full optical wavelength range of 400-2450 nm (AISA DUAL) and 350-2500 nm (ASD Fieldspec®3 MAX). The coordinates of in-field examinations are recorded so the ground spectrum can be fitted to the adequate pixel of the hyperspectral airborne image that is an important element of subsequent evaluation processes. The number and the quality of in-field measurements determine the final accuracy of the airborne images. This technology is adequate to analyse vegetation in a fast, precise way (Fenyvesi 2008, Yang et al. 2009, Milics et al. 2011b, Virág and Szőke 2011). Using this new-generation data monitoring and sampling methodology, we can obtain quantitative relationships between the environmental or physiological parameters of vegetation cover (Tolner et al. 2010, Szalay et al. 2011, Balla et al. 2011), soil quality parameters (Máthé et al. 2010, Tolner 2011) and different source of soil contaminations (Csorba and Jordán 2010), or climate attributes (Erdélyi 2009, Tarnawa et al. 2011) and the features of reflectance spectra (Csorba 2011). The Department of Water and Environmental Management of the University of Debrecen, Centre For Agricultural and Applied Economic Sciences, (Burai and Tamás 2005, Kőmíves et al. 2006) and the Institute of Agricultural Engineering of the Hungarian Ministry of Agriculture and Rural Development (hereafter referred as Institute) operate the AISA DUAL sensor system of the Finnish Specim Spectral Imaging Ltd., a unique remote sensing system in all Europe, collectively (Szalay et al 2010). In the year of 2010, the Institute of Agricultural Engineering bought an ASD Fieldspec®3 MAX field spectroradiometer expanding the available data acquisition systems. The Hyperspectral Working Group established in the Institute offers new generation of data acquisition methods. Beyond the scientific application of the technology we offer our service to work out the adequate hyperspectral methodologies according to the requested agricultural, industrial or other scientific projects.

Materials and methods

The AISA DUAL airborne twin-sensor has the potential of detecting the electromagnetic radiation in the wavelength range of 400 to 2450 nm with sub-meter level of spatial precision. During the flight the geographical coordinates and the position of the plane are recorded by Oxford RT-3000 GPS/INS system. Beside the DUAL mode both sensor can be operated solely depending on the aim of examination.

The ASD Field Spec®3 MAX portable spectroradiometer (see Fig. 2) can widely be used for both in-field and laboratory measurements, too. The specification of the instrument is presented in Table 2.

Figure 2. Az ASD Field Spec®3 MAX

Table 2. System parameters

	ASD Field Spec®3 MAX
Spectral range (nm)	350-2500
Spectral resolution (nm)	3-10
Sampling interval (nm)	1,4-2
Scanning time (milliseconds)	100
FOV (degree)	1, 8, 25
Detectors	Si, InGaAs

By using the spectroradiometer – beside it's solely application, without airborne measurements – it is possible to correct and validate the airborne data with in-field and laboratory measurements. For laboratory examinations we constructed a unique light-isolated cabinet (see Fig 3.) which makes possible to achieve outstanding precision, since the disturbing environmental light is shielded and the undesirable reflexions from the interior of the measuring cabinet are minimized by the appropriate arrangements of the implements (see Fig 4.). The special material of the sample stage and the cabinet's interior result in minimal reflectance over the whole electromagnetic spectrum detected by the spectroradiometer (350-2500 nm).

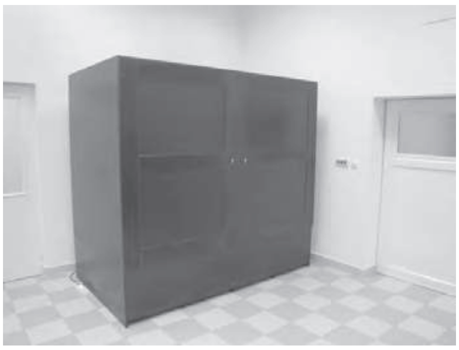

Figure 3. Light-isolated cabinet

Figure 4. Experimental arrangement

The proper geometrical arrangement during the in-field measuring process – the measuring process should be taken outside of and perpendicularly to the principal plain – and the appropriate number of white reference highly improve the precision. Both for airborne and field data acquisition fair sky and high angle of incidence are optimal.

Based on the application of hyperspectral technology ex situ measurements were carried out to identify the spectral differences of winter wheat treated with various nutrient dozes. 'Alföld 90' winter wheat variety was studied in agronomic replicated blocks. The half of the plots received 80 kg ha^{-1} nitrogen fertilizer in form of ammonium nitrate (0-0-36), the others did not received any mineral fertilizer. Wheat ears and kernels from all plots were gathered and analysed in laboratory according to its spectral characteristic with spectroradiometer in the wavelength of 350 to 2500 nm.

While wheat ears were illuminated by and studied with the use of Pro Lamp (Fig 5.) kernel samples were studied with the use of Plant Probe sensor-head (Fig 6.).

Figure 5. Pro Lamp

Figure 6. Plant Probe

The pre-procession of data were made with ViewSpecPro software. Further process steps were carried out with ENVI image analyser software.

We used continuum removal to normalize reflectance spectra in order to compare individual absorption features from a common baseline.

Results and discussion

During the evaluation of the wheat ears with spectroradiometry, we worked with computed mean reflectance spectra of the treatments. Red colour represents the nitrogen fertilized, while green the unfertilized parallel. According to these curves the spectral characteristic of the different treatments are diverge (see Fig 5.), but the deviation of those seems independent according to the differences generated by the mineral fertilizer.

By removing the continuum of the curves we found a characteristic interval between 1650 nm and 1800 nm (see Fig 6.).

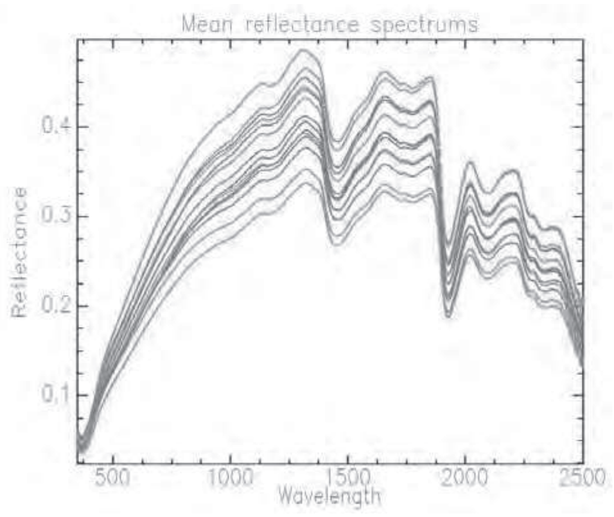

Figure 4. Mean curves

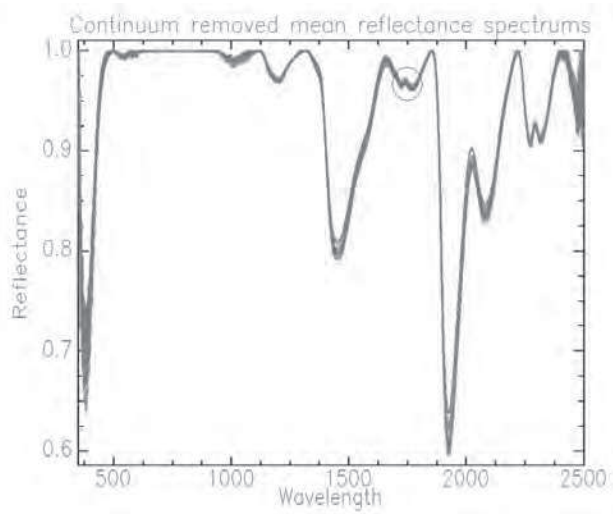

Figure 5. Continuum removed mean curves

After removing the continuum we performed Principal Component Analysis on the dataset of the relevant interval to find the hidden information in the dataset (Fig 6.).

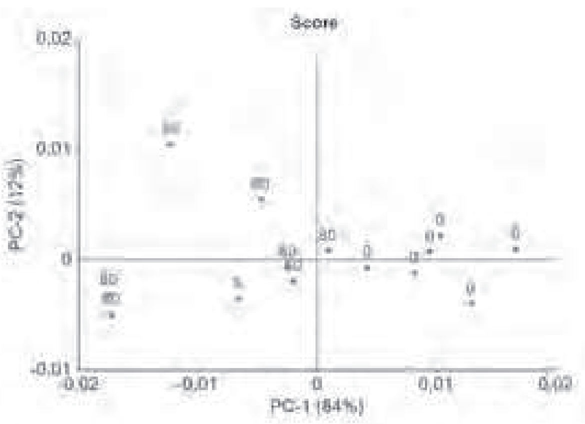

Figure 6. Principal Component analysis

The analysis indicated the presence of one decisive factor based on which the different treatments can be separated. The 84 % of the variability is explained by the first Principal Component.

The evaluation of wheat kernels – with the above described method – resulted in the same correlation in the wavelength interval of 500 to 800 nm. In this case the kernels 98 % of the variability is explained by the first Principal Component.

Conclusion

Since beside the different nitrogen treatment all factors were constant during the experiment we do accept the hypothesis that the decisive factor is the differing quantity and quality parameters of the wheat variety generated by the diverse nitrogen fertilizer treatment. These changes resulted in such spectral differences as well which were detectable with spectroradiometer in form of wheat ears and kernels as well. Among the analyzed reflectance curves after removing the continuum of the spectra we found two characteristic intervals at the wavelength range of 500 to 800 nm (wheat kernel samples) and 1650 nm to 1800 nm (wheat ear samples) at which the treatments became distinguishable. By evaluating the most important parameters of the winter wheat such as yield, protein, wet gluten content and farinographic value with conventional laboratory technology the interrelation between spectra and nutrition application can be clarified. After the appropriate calibration and validation process the spectral methodology can greatly assist in describing and tracking the current dynamics of nutrient supply and plant up-take in a fast and economic way. The defined correlations based on laboratory 'ex-situ' measurements can be greatly implemented in the 'in situ' in-field and airborne hyperspectral imaginary resulting in time and cost effective, precise sampling method which can exquisitely be applied in the modern agriculture.

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