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INTEGRATED GROUND AND AIRBORNE SAMPLING METHODS FOR MEASURING AND MODELLING THE CHANGE OF MOISTURE CONTENT VALUE IN AGRICULTURAL LANDS

ABSTRACT

The conventional sampling methods are no longer capable of satisfying the rapidly growing demand toward data and information. There has been a need for a measuring technology that provides broad opportunities of evaluating local or global processes or balances according to various aspects. Hyperspectral imaging spectroscopy, one of the most advanced technologies in optical remote sensing, but to clarify the relation between the feature-specific spectral respond of a surface or material and the studied factor large number of samples are necessary. The objective is to present the technological capabilities of remote sensing of our Institute and to show an alternative method for moisture content mapping which is adequate to collect the necessary amount of data to calibrate and validate airborne hyperspectral images for quantitative measurement of soil moisture content.

KEYWORDS: moisture content, remote sensing, thematic map

1. INTRODUCTION

In our modern civilization the growing demand for data and information is very important issue. The conventional measuring and sampling methods can no longer provide with the necessary information. These methods usually provide few or several discrete data which are relatively far from each other both in time and space. The modern imaging remote sensing technologies, however, have the potential to analyze large areas in a fast and precise way by providing thousands of simultaneously recorded data of land treatment units down to 1 m^2 scale.

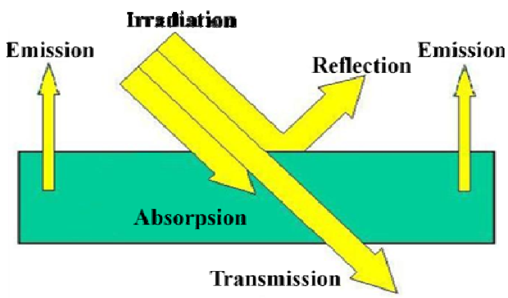

Fig 1. EM interactions (NOAA Coastal Service Center (2007) modified)

Remote sensing of Earth's surface includes several non-contact measurement techniques and evaluation methods. The only physical connection between the observer and the object is the electromagnetic radiation (EM). The incident EM interacts with the illuminated object. This interaction - based on the actual physical, chemical condition of the certain object and the energy, or rather the wavelength of the incident light - will result in the following phenomena above (Fig. 1.).

The Hungarian Institue of Agricultural Engineering (HIEA) – hereafter referred as Institute – has been working and developing wide range of remote sensing application since the early 1980's. Airborne visible (VIS) and color infra red (CIR) images were taken where signs of formal soil compaction and fungal disease/perished trees are visible (Fig. 2.).

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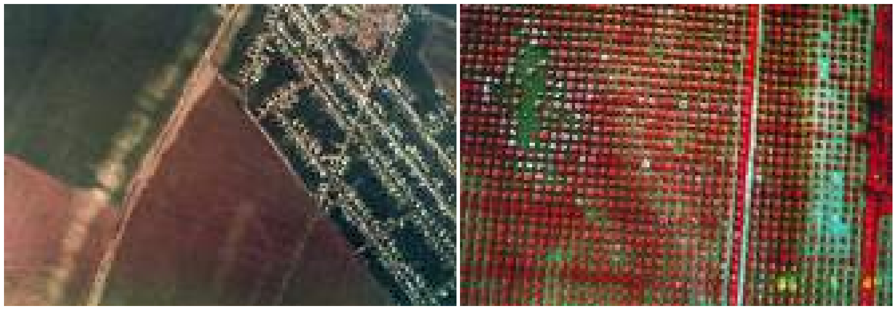

Fig 2. VIS image of a land portion and CIR image of an orchard

VIS image on Fig 2. represents those situation where purely the visible region of the electromagnetic radiation is enough to detect changes or anomalies, but only from a certain height.

In the end of the 80's our Institute started working with thermal infra red (TIR) technology.

Fig. 3. Thermal evaluation of maize and thermovision assemlby on a chopper

Fig. 4. Thermovision under laboratory circumstances

Ground-based and airborne (Fig. 3.) furthermore laboratory (Fig. 4.) applications were used and developed for examination and monitoring of various agricutural and mechanization processes.

The dynamic development of different remote sensing technologies resulted in the hyperspectral imaging spectroscopy, which is one of the most advanced technologies in optical remote sensing. Since the year of 2006, together with the University of Debrecen, Department of Water and Environmental Management our Institute have been operating an AISA DUAL airborne twin-sensor system (Specim Ltd.).

The hyperspectral technology has greatly improved the efficiency of data utilization and created new perspective for modern information management in precision agricultural production [1, 2, 3, 4]. With the use of the hyperspectral remote sensing one can record the refletced flux radiation form the studied surface on hundreds of narrow, adjacent bands. Simoultaneously, gray-scale pictures are taken of these bands and recorded separately. This data recording method results in the so called data cube [5, 6, 7]. In this high resolution of spectral information is assigned to all spatial pixel of the data cube, hence the spectral caracteristics of the surface can be mapped by high definition geometrical sampling method up to hundreds of adjacent spectral bands (Fig. 6.).

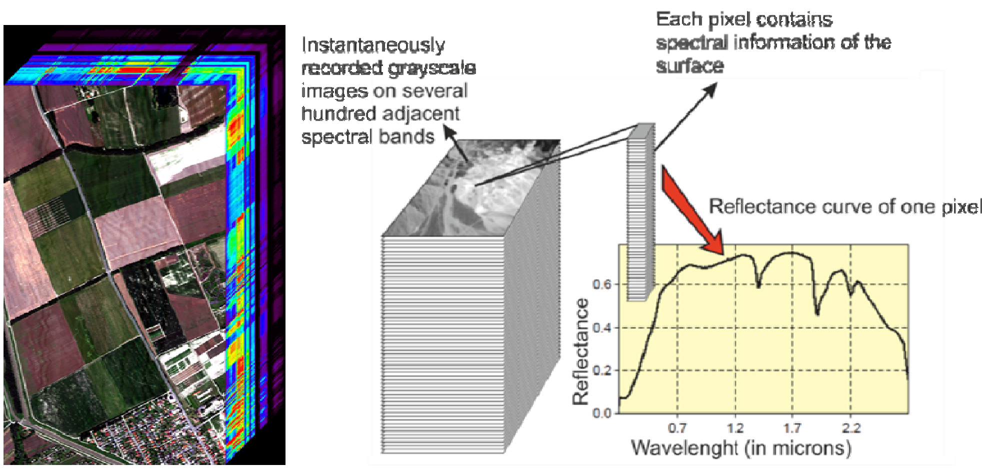

Fig. 6. Poceedure of hyperspectral imaging

We introduce a system which extends the range of the detectable (visible light) VIS [8, 9] to NIR (near infrared) and the SWIR (shortwave infrared) that are able to operate in the full optical wavelength range of 400 to 2450 nm (AISA DUAL) and 350 to 2500 nm (ASD Fieldspec®3 MAX). Characteristic near infrared wavelengths can indicate changes in moisture content of vegetables [10]. Though, the processing of these images is a very complex procedure [11]. The coordinates of in-field experiments are recorded and the soil surface spectrum can be fitted to the adequate pixel of the hyperspectral airborne image that is an important element of the subsequent evaluation processes. The number and the quality of in-field measurements determine the final accuracy of the airborne images. Using this new generation data monitoring and sampling methods we can obtain quantitative relationships between the environmental and physiological parameters of the vegetation [12, 13, 14, 15], soil quality parameters [16, 17, 18] and different sources of soil contaminations, climate attributes [19, 20, 21, 22] and the features of reflectance spectra.

The Hyperspectral group of our Institute offers new generation of data acquisition methods. Beyond the scientific application of the technology our services are available to provide the client (Research Institute, Industrial or Private Companies) with the adequate hyperspectral methodologies to meet agricultural, industrial or other scientific needs.

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2. MATERIALS AND METHODS

The AISA DUAL airborne twin-sensor system (Fig. 7.), which consist of the EAGLE and HAWK sensors, that has the potential for 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 autonomously depending on the aim of the experiment. The technical parameters of the sensor system are summarized in Table 1.

Fig. 7. Eagle sensor, AISA DUAL twin-sensor, Hawk sensor

	AISA Eagle	AISA Hawk	AISA Dual
Spectral range (nm)	**400-970**	**970-2450**	**400-2450**
Spectral sampling band (nm)	**2,3**	**5,8**	**2,3/5,8**
Spectral bands	**244**	**254**	**498**
Spatial pixels	**1024**	**320**	**320**
Spectral depth (bit)	**12**	**14**	**12**
Image rate (image/sec.)	**up to 100**	**up to 100**	**up to 100**
FOV (degree)	**37,7**	**24**	**24**
IFOV (degree)	**0,037**	**0,075**	**0,075**
Detectors	**CCD**	**MCT**	**CCD&MCT**

Table 1. Technical parameters of the sensor system

As opposed to the traditional land specific management precision agriculture makes possible the land treatment unit (LTU) based crop production. These treatment units can be reduced to tens of square meters, or even further. By providing high spatial resoulition thematic maps which can form the base of differential land treatments the imaging remote sensing technologies can greatly assist in precision agriculture.

The moisture content of soil is very decisive factor in agricultural production. Thus, obtaining information on its quantitative and spatial distribution is a vital issue. Conventional sampling methods usually provide few or several discrete data which are relatively far from each other both in time and space. In this study beside the conventional gravimetric sampling method we are measuring some indirect physical parameters which are sensitive to the change of moisture content in the soil. With integrated use of remote sensing and ground based reference data one can create high resolution soil moisture content maps that can widely be used in conventional and precision agriculture, too.

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Test area was assigned in the Hungarian Institute of Agricultural Engineering. Moisture content was mesured by three different methods: Electric conductivity (EC), Time domain reflectometry (TDR), Conventional sampling method.

The Veris-3100 equipment (Fig. 8.) measures the EC at 0 to 30 cm and 0 to 90 cm depth ranges. Coordinates of every measurement are also recorded with 1 Hz. During the measurment the GPS signal is provided by Trimble AgGPS 114. Work speed is 9 to 18 km/h and usually 5 m line width is used.

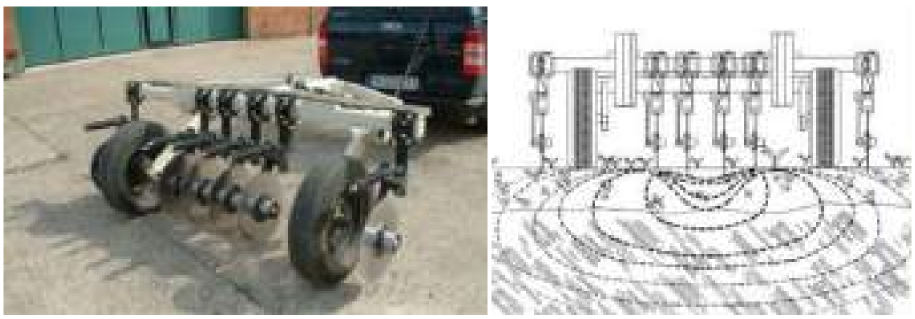

Fig. 8. Veris-3100 EC measuring device and its working principle

In the common practice the GPS antenna of the system was placed on the top of the tractor's cabin and the distance between antenna and measuring disks were measured and compensated by "Boom offset" value – in this case it was 3.42 m. Precision was validated on an assigned trajectory by cruising back and forward several times, on various travel speed. Trajectories were analyzed on map (Fig. 9.).

Fig. 9. Distance between the GPS antenna and measuring disks of Veris-3100 and the validation method

The Spectrum TDR-300 device works with time domain reflectometry principle and measures volumetric moisture content. Resolution is 1 %, precision is < 3 % and the measuring range is 0 to 50 %. Beside the measured moisture content the equipment also records the coordinates of the sampling position (Fig. 10.).

Fig. 10. The Spectrum TDR-300 soil moisture meter and its utilization

During the conventional sampling process an Eijkelkamp soil sampler was used. After the sampling coordinates were logged by Mobilemapper CE GPS receiver and TDR-300 device was used to measure the soil moisture on four positions nearby (Fig. 11.).

Soil samples were dried – based on paragraph 12 of MSZ 08 0205-78 standard - in dryer at 105 °C temperature until reaching a constant weight. Gravimetric moisture contents were converted into volumetric moisture content.

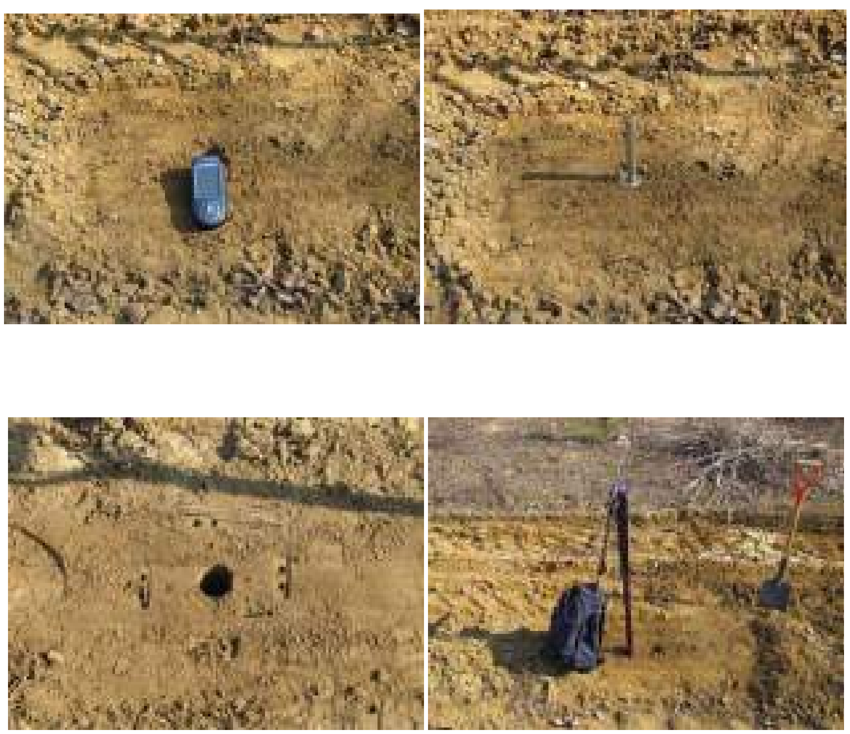

Fig. 11. Collection of soil sample, logging coordinates, measuring with volumetric moisture content with TDR-300

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3. RESULTS AND DISCUSSIONS

Using the data gathered by Veris-3100 and TDR-300 and the reference moisture content measured in laboratory after drying we made an interpolated map of EC and volumetric soil moisture content of the area (Fig. 12.).

Fig. 12. Interpolated EC map with sampling points of Veris-3100 – left – and Interpolated volumetric moisture content map with TDR-300 sampling points –right –

Evaluation showed that the GPS receiver calculates the position where the antenna is placed and “Boom offset” function has no effect. Therefore to reduce this position error we designed and manufactured a frame which makes possible to fix the GPS antenna just above the measuring discs of Veris-3100 device. Further measurements were carried out by using this frame which has decisively improved the positioning accuracy (Fig. 13.).

Fig. 13. Veris-3100 device upgraded with antenna holder frame

4. CONCLUSIONS

The hyperspectral imaging spectroscopy is a promising future tool in the field of optical remote sensing and it creates new perspective for modern information management in site specific agricultural production. One can determine quantitative relationships between the environmental and physiological parameters of vegetation cover and the soil quality parameters as well as the features of the reflectance spectra by the new-generation data monitoring and sampling method. These reflectance spectra have characteristics of different crops and provide with the possibility of accurate classification and detection. Study confirms the significance of alternative soil sampling instruments which can provide with the necessary number of samples to calibrate and validate airborne hyperspectral images. By combining the laboratory spectroscopy and hyperspectral imaging with Veris-3100 system and TDR-300 device even

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limited number of labour-intensive ground sampling and laboratory analysis will be sufficient to perform detailed evaluation of the scanned area.

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