Evaluation of applicability of airborne AISA DUAL hyperspectral imaging system to map environmental conditions in orchards

János Tamás[(1)],Csaba Lénárt[(1)], Péter Burai[(1)]
[(1)] UNIDEB - University of Debrecen, Faculty of Agronomy, Department of Water and Environmental Management, H-4032 Debrecen, Böszörményi 138, Hungary. Tel: 36-52-508456, e-mail: tamas@gisserver1.date.hu

ABSTRACT

Airborne remote sensing data are increasingly used in precision agriculture. Applicability of RS data is mostly depending on the spatial and spectral resolution. Nowadays, a new generation of airborne hyperspectral imaging systems is available and applicable to map the environment. Since effects caused by soil or climatic stress are well-detectable in the plants, vegetation is a promising indicator of water and nutrient supply, as well as degradation processes occurred in soils. Biophysical properties of the leaf show photosynthetic activity, mutations, stress, and the state of plant nutrient content, which has particularly high significance in precision agriculture. In our study, hyperspectral data were collected by an AISA DUAL hyperspectral imaging system, in the wavelength range of 398-973 nm, in 63 channels, with 0.5m ground resolution. The radiometric and geometric calibrations were processed by Caligeo and ITT ENVI software. Band selection method was developed to reduce the noise, which allowed to collect the most reliable bands for plant properties, while, hyperspectral indices were calculated to evaluate the narrow waveband properties of hyperspectral reflectance spectra. Indices designed to detect different physical and chemical properties related to nutrient and water contents were in focus (NDVI, SIPI, PRI, etc.). Dry, senescent or damaged plants not using nitrogen and light efficiently, indicate agricultural stress, whereas a crop showing healthy, productive vegetation indicates (VI) low stress. Indices from canopy-scale hyperspectral reflectance data taken under field conditions were used to derive the spatial patterns of stressed damage of peach varieties in orchards. More than 150 VIs have been published in literature, but only a small subset has substantial biophysical basis or have been systematically tested under field conditions. In addition, based on the evaluated indices, it is possible to map the properties at individual tree's level, which can provide important information for precision agriculture.

Keywords: hyperspectral, vegetation indices, image processing, plant stress, Hungary

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János Tamás, Csaba Lénárt , Péter Burai. "Evaluation of applicability of airborne AISA DUAL hyperspectral imaging system to map environment conditions in orchards". International Commission of Agricultural and Biological Engineers, Section V. Conference "Technology and Management to Increase the Efficiency in Sustainable Agricultural Systems", Rosario, Argentina, 1-4 September, 2009.

1. INTRODUCTION

Remote sensing technologies provide an important tool to aid site-specific management of crops. Remote sensing has the potential to provide real-time analysis of the attributes of a growing crop that can assist in making timely management decisions that affect the outcome of the current crop. Based on remote sensing images the farmers are effectively able to measure and visualize the reflectance values of numerous wavelength ranges, from which statements can be made concerning the normal (healthy) and stressful status of soil and vegetation. This paper briefly summarizes the preparatory, planning and implementation phases of the first Hungarian airborne hyperspectral data acquisition project and a practical example of the new precision agricultural service.

In Hungary, the investigation of high resolution spectral characteristics of rocks, soils and vegetation cover began in 1980 in cooperation frameworks, such as the Russian coordinated INTERCOSMOS program (Kardeván et al., 1998). In the last decade, the development of advanced remote sensing methods in Hungary connected partly to space research but mainly to the application of satellite images of medium or low spatial and spectral resolution. At that time, remote sensing related projects were carried out in several institutes focusing on different application fields like soil science (Soil Sciences and Agrochemical Research Institute of Hungarian Scientific Academy, University of Debrecen) or hydrology (Water Resources Research Institute).

The application of hyperspectral remote sensing technology is quite a new one in the field of remote sensing. The Hungarian project of the HYSENS 2002 hyperspectral flight campaign was carried out by the German DLR to detect agricultural secondary salinization, and heavy metal polluted mining sites. In that case, the main factors of difficulties could result from the need for expertise in spatial statistics, image processing and the interdisciplinary character of this new scientific branch (Kardeván et al., 2003). After the first hyperspectral flight campaign, several papers were published on the introduction of remote sensing methods to the agricultural sciences in Hungary (water and environmental management, soil classification, precision farming), where target regions included a mixed area of commercial farm and natural protected area, and the Látókép – University Experimental Farm with multifactorial long-term plant cultivation experiments.

From 2007, hyperspectral images were taken by an AISA DUAL (Eagle and Hawk) airborne hyperspectral camera system installed and operated in joint venture by Mechanization Institute of Agricultural Ministry and the University of Debrecen. The Eagle camera takes images in the visible and near infrared range (400- 970 nm), while Hawk operates in the middle infrared range (970-2500 nm) with 498 spectral channels. AISA is a dual sensor system, which provides seamless hyperspectral data in the full range of 400 - 2500nm. Airborne hyperspectral imagery provides the potential for more accurate and detailed information extraction than it is possible with any other types of broad band, remotely sensed data. The "hyper" in hyperspectral refers to the large number (>498) of measured wavelength bands. Field and laboratory spectrometers usually measure reflectance at many narrow, closely spaced wavelength bands, so that the resulting spectra appear to be continuous curves. When a spectrometer is used in an imaging sensor, the resulting images record a reflectance and intensity spectrum for each pixel in the image. Precision agriculture requires spatially correct image data to control different field technologies. In this case, an important point was to develop the effective flight campaign to produce highly accurate high ground and spectral resolution data. For first, photogrammetric and spectral accuracies were evaluated by different GPS/Inertia systems in different flight condition in Europe (Germany, Finland, Switzerland and Hungary).

Beyond these general aims, our specific goal was to determine indices that could characterize spatial heterogeneity of different orchards on the basis of a hyperspectral data cube and related field sensors data. Hyperspectral narrowband indexes are more sophisticated measures of general quantity than the traditional satellite broadband indexes. Many of these indices are currently unknown in agricultural practice or under-used. In our study, the potential of AISA DUAL airborne hyperspectral sensor data to create a narrowband vegetation indexes distribution map of agricultural fields was evaluated. Test field was a peach orchard that is a sensitive plant in Central-Europe, and is expected to indicate different stress (water, frost and herbicide) within short period of time. The world peach production is about 10 million tons a year, and the highest concentration of peach orchards is located in the Mediterranean countries, in Europe. While peach production has been decreasing in the U.S.A. and is stable in the EU, it is increasing in China and in South America, particularly in Chile. In numerous countries, the main problems of the peach industry are as follows: low fruit yield and quality, high production costs, and international overproduction. Regarding fruit species, the production of the white flesh nectarines are increasing while peaches for food industry are decreasing. In Hungary, an important task is to be able to develop an advanced horticultural technology to reduce peach growing risks for farmers (Soltész et al., 2004).

2. MATERIALS AND METHODS

The schematic steps of the hyperspectral image processing were the following: 1) Aerial and land image taking. 2) Radiometrical and geometrical corrections. 3) Noise filtering and data decrease. 4) Choosing the objective spectrum. 5) Classification. 6) Interpretation. 7) Checking (Burai and Tamás, 2004). steps 1 and 2 were made with the CaliGeo (radiometric and geometric corrections), while for steps 3 to 6, ENVI 4.6 raster based remote sensing software and 7th in ESRI ArcGIS 9.3 GIS environment were applied. Below, steps 2, 5 and 6 as the most crucial ones of the whole process will be reported.

The identification and mapping of materials and material properties can be best accomplished by deriving the fundamental properties of the surface, and its reflectance, while removing the interfering effects of atmospheric absorption and scattering, solar spectrum, and instrumental biases (Clark et al., 1990).

The objectives of calibrating remote sensing data are to remove the effects of the atmosphere (scattering and absorption) and to convert radiance values received at the sensor to reflectance values of the land surface.

The peach orchard studied is situated in the western part of the Hungarian Great Plan, 10km south of Lake Balaton. Field measurements to frost damage or other stress investigations were performed before the flight and simultaneously with it (Figure 1).

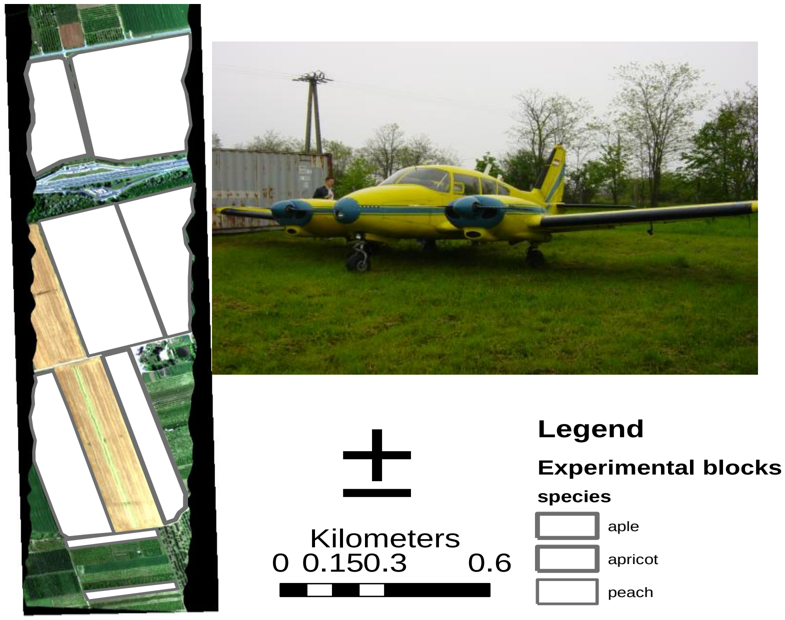

Figure 1. The location of analyzed peach orchards and the airplane used for airborne data acquisition

The image swath width was 500m, and the total area was 3.8km^2. The orchards are intercepted by a highway, the parcels south from it provided the reference study areas. The hyperspectral data were collected by AISA DUAL hyperspectral imaging system, 398-973nm wavelength, in 63 channels and 0.5m ground resolution, while the transmissive imaging spectrograph was nearly independent of the polarization in the incoming light, and provided high diffraction efficiency and uniform spectral resolution of 10nm band within every channel, in full spectral range. All the optics (fore optics and imaging spectrograph) and the detector assembly are temperature-stabilized. The AISA system included push broom imaging sensors, consisting of a hyperspectral and high-performance GPS/INS sensor and a data acquisition unit housed in a rugged PC. Figure 2 represents the operator site of hyperspectral remote sensing instrument.

Figure 2. The installed spectral camera with red color OxTS RT3003 GPS/INS unit

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A real-time fiber optic down welling irradiance sensor (FODIS) on top of pilot cabin was integrated into the sensors to monitor the illumination conditions. Auxiliary components included a mount to connect the sensor to the GPS/INS unit, and regulated the power supply. The technical parameters of the AISA DUAL camera system is summarized in Table 1.

Table 1. Technical specification of AISA DUAL hyperspectral camera

Specification	**VNIR (EAGLE)**				**SWIR (HAWK)**
Sensors characteristics					
Spectral range	400-970nm				970-2450nm
Spectral resolution	2.9nm				8.5nm
Spectral binning options	none	2x	4×	8×	none
Spectral sampling	1.25nm	2.5nm	5nm	10nm	6nm
Fore optics					
#spatial pixels	320		1024		320
FOV	24		37,7		24
IFOV	0.075 degrees		0.075 degrees		0.075 degrees
Swath with	0.65×altitude		0.65×altitude		0.39×altitude
Electrical characteristics					
Radiometric resolution	12 bits (CCD)				14 bits (MCT)
SNR	350:1 (peak)				800:1 (peak)
Image rate	Up to 100images/s				

EAGLE can detect reflected spectral data (VNIR) in visible (400 - 700nm) to near infrared (700 - 1300nm), and HAWK can be used to analyze in shortwave infrared, with spectral ranges of 1300nm to 1900nm (SWIR-1) and 1900nm to 2500 nm (SWIR-2).

Photosynthetically active leaf pigments affect only the visible portion of the shortwave spectrum (400nm to 700nm), though the effect depends on the type of pigment; this is the main reason why VNIR range is especially important for vegetation analysis. At the time of data acquisition, the calibration site was also characterized with a field spectrometer, which is very important (Clark et al., 2002).

Our data base also contained topographic maps, true-color airborne images and field surveys, and supporting data for fruit tree sub-species, irrigated and non irrigated areas, different fertilizer doses to distinguish between impacts of different fruit trees and peach varieties.

For our frost damage investigations, at least 10 fruiting lateral species were collected and their lengths were measured. Flower bud density was calculated at every 10 cm, and cutting in half the number of damaged bud was also determined. The bud density of species is a very important factor, since the higher bud density index can accommodate the degree of the frost damage (Nagy, 2009).

Leaf area of fruit trees was measured by ADC AM 100 typed leaf are scanner, continuously tracking the flight campaign, to get information about the transpiration surface, which is important for the determination of the amount of daily transpiration (Burai and Tamás, 2004). In line with this, the water demand in the area was mapped, based on sampling by using GPS registered points in every 0.2m layer till 1.5m depth to get acquainted with the actual water content of the soil. Near the surface, TDR method was applied to measure the actual water content of soil (W/V %), and the samples collected from deeper layers were analyzed with gravimetric methods, in laboratory. Sample points were selected by geostatistical evaluation, based on a 1:10000 scale digital elevation TIN model and digital soil maps (Tamás, 2001). All collected data were prepared in ArcGIS environment. In the reference point, leaf sample were collected from top young part of tree and mid-lover part as suggested by a Hungarian agro-chemistry reference book. The chlorophyll A contents of leaf were measured according to the ISO 10260:1993 patent, using hot ethanol (90%) for the extraction. The chlorophyll A absorbance was detected by Anthelie UV-VIS spectrophotometer at 665nm and 750nm wavelengths. The reflectance spectra of leaf and fruits were measured by a field portable, ALTA II type spectrometer at 470, 525, 560, 585, 600, 645, 700, 735, 810, 880, and 940 nm. This provided a suitable basis for our investigations.

3. RESULTS

The photogrammetric accuracy is as an important border condition that can give high influence for error propagation process and the absolute value of the overall total root mean square. It was a high-performance, integrated 3-axial inertial navigation sensor for monitoring the aircraft position and attitude. The systems include a CaliGeo control and operation software, which allows data acquisition settings to be tailored for individual flight mission requirements. Calibrating imaging spectroscopy data to surface reflectance is an integral part of the data analysis process, and is vital if accurate results are to be obtained (Green et al., 1998).
In the first 10 months long test period of our service, 2 different GPS systems were compared. The C-MIGITS III and OxTS – RT 3003 GPS/INS systems were applied for collecting navigation data for direct geometric correction. External DGPS data were used for controlling the GPS/INS system. Several images were taken to monitor the direct georeferencing of push-broom scanner data with or without external DGPS using ground control points (GCP’s). OxTS – RT 3003 was showed pixel sized accuracy of 1m without external DGPS data while the C-MIGITS III provided about 6m RMS position error, when the average flight altitude was 800-1000m and the average speed was 200-250 km/h, with minimum swath width of 500m (Table 2).
During the hyperspectral test term, 127 hyperspectral images were prepared at different places. In case of larger areas images having high resolution (0,5-1,5 m), should have been taken, where the correct geometry of the bands were very important elements because of the right mosaics. Ground Control Point (GCP) was supplied to the controlling of the direct geometry.

Table 2. Geometric accuracy of the test images

GPS/IMU system	# of images	GCP points	max. RMSE	min. RMSE	RMSE
C-migits-III	6	28	14,01	4,81	6,10
OxTS RT3003	6	28	4,44	0,31	3,03

An OxTS RT3003 GPS/IMU system was applied with high punctuality in the course of the airborn survey of the examined test area near the town Siófok. The CaliGeo and ENVI software were applied for post-processing and transforming the raw AISA data into radiometric corrected and georeferenced images. The FODIS data were scattered, too, where the roll or pitch value were more than zero. After dropping out the inadequate values, trend line was calculated for processing FODIS ratio of all bands.

After the geometric and radiometric correction the hyperspectral n-dimensional data cube was made, which was then ready for classification. This data cube contains all geographical and spectral data changing pixel by pixel (Figure 3).

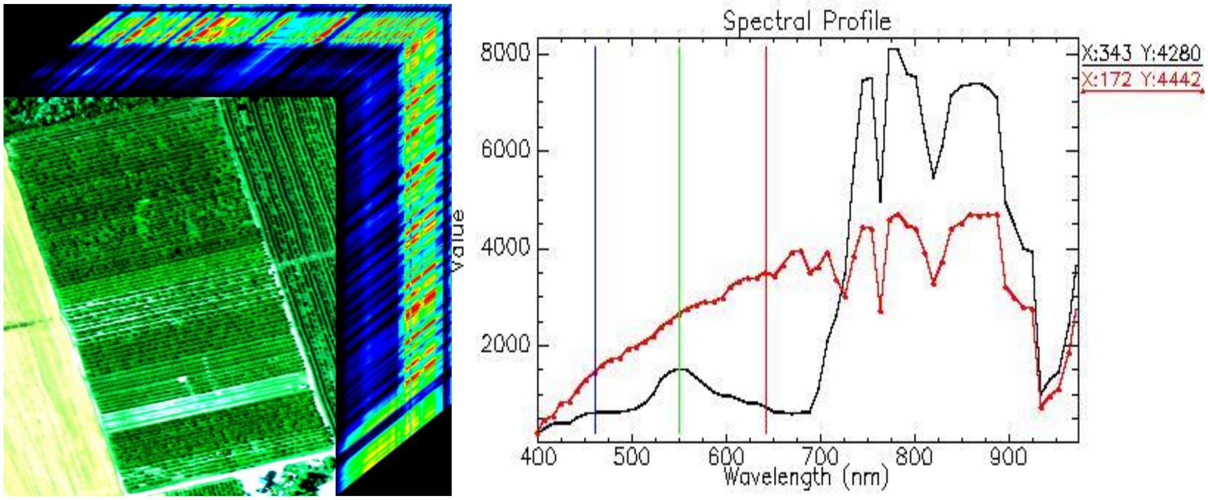

Figure 3. The 3D data cube made from 69 VIS-NIR channels and spectral reflectance curves of pixels

Spectral reflectance curve is typical for every object, but in mixed surface, the spectral data are also mixed. Before classifications, spectrally clean, not mixed pixels of the objects should be found. These are the spectrally not correlated pixels called endmembers that are spectrally matched to similar spectral curves in the spectral space. In Figure 3, right site presents two typical endmembers, one of them is a peach tree in 343 x, 4280 y; while, the left side shows a spare light clay soil in 172 x, 4442 y pixel position. The curves show relatively high differences in red channels around 650nm and NIR channels close to 740nm, and this is why these ranges are intensively used for interpretations.

The leaf area index (LAI) is the green leaf area per unit ground area, which represents the total amount of green vegetation present in the canopy. The LAI is an important property of vegetation, and has the strongest effect on overall canopy reflectance resulted from leaf pigment activities. The calculated Pearson correlation between LAI and NDVI values was strong positive (0.8-0.9). LAIs of peach tree were between 3-8, in the 1^{st} week of June. The trees with higher LAI value presented higher standard deviation in the NIR range as the visible range (Figure 4).

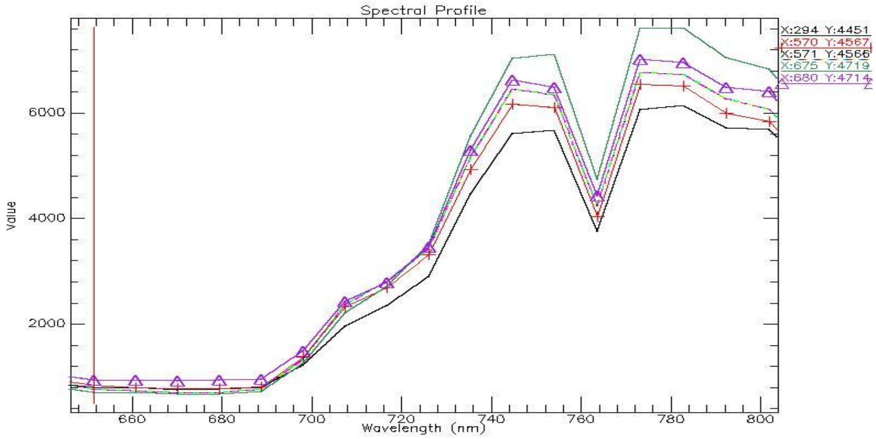

Figure 4. Increasing LAIs of peach tree give higher reflectance values in 740-800 nm range

Hyperspectral data cube can give huge dataset and it is important to find effective data mining techniques; to reduce evaluation time, classification accuracy was improved by masking sample areas. Before the spectral analysis a mask was used to choose the green biomass area in the investigation field on the basis of the histogram of the NDVI index map. Segmentation of NDVI image was the following: no vegetation (≤ 0.3), sparse vegetation (0.3 – 0.7), moderate vegetation (0.7-0.82), dense vegetation ($\geq$0.82). Further, areas covered by biomass only were evaluated, which included spacing of the peach rows where crops detected.

To reduce dimensionality and compress the real information about spectral endmembers, the Minimum Noise Fraction –cascade analyses and Pixel Purity methods were applied based on Green et al. (1988), and Boardman and Kruse (1994). The spectral curves of endmembers show the spectral values of each object in every band without auto correction, which are bases of the SAM classification. Spectral Angle Mapper (SAM) is a physically-based spectral classification that uses an n-D angle to match pixels to reference spectra. The algorithm determines the spectral similarity between two spectra by calculating the angle between the spectra and treating them as vectors in a space with dimensionality equal to the number of bands.

The following classes were sampled in the spectral study area, between brackets the number of the examined pixel and the value of the spatial accuracy were indicated: Spare vegetation (7011 – 83%); Dry grass (1386 – 79.4%); Green grass (6257- 68.2%); Weed (7659 – 72.3%); Yellow canopy (8480 – 89.6%), Stressed canopy (9142 – 69.7%) Green canopy (24683 92.4%) Greenest canopy (15890 95.2%).

The classification was performed independently from species. Within classes the identification of species were carried out with the help of field work, field GIS software and GPS. In the course of classification, the spectrum of the green grass and stressed canopy can be detected with higher mistake because of greater number of spectral mixing pixel. Foliages of the trees of the stressed canopy class have shown some kind of pigmentation or tugor pressure aberrations compared to healthy. The greenest canopy is the foliage of the trees consisting of middle aged leaves containing higher chlorophyll content.

The largest green parts of peach trees were frozen by cold air in this level (close to soil surface) every 2-3 year. The age, the cultivation method and shape of the crown of species examined were consistent in every row. In our experiments 10-10 fruit shoots were analyzed at 1m height from 4 varieties to evaluate early spring frost damages. In our case of "Cresthaven" variety, at 1 meter height the frost damage was 74.6%, at 2 meter height 44.7%, and 25.2% at 3 meter. The

frost damage of "Suncrest" variety was 7.6% at , the "Maystar" variety was 17.6% , "Redhaven" variety was 16.8% at 1 meter height. The minimum and the maximum frost damage values (%) at the different growing places were 7.6-38.7 at Siófok test site. 87 percent of the frost damaged foliage was classified to the Yellow canopy spectral class on the basis of remote sensing analysis.
Spectral extracts were prepared from every spectral class and indexes under mentioned were calculated:

- Broadband Greenness indexes: Normalized Difference (NDVI); Atmospherically Resistant (ARVI); Simple Ratio (SR),
- Narrowband Greenness indexes: Red Edge Normalized Difference ($NDVI_{705}$); Modified Red Edge Normalized ($mNDVI_{705}$); Vogelmann Red Edge Difference (VOG1),
- Light Use Efficiency: Photochemical Reflectance (PRI); Structure Intensive Pigment (SIPI); Red Green Ratio (RG)
- Leaf Pigments: Carotenoid Reflectance 1 (CR1) Carotenoid Reflectance 2 (CR2) Anthocyanin Reflectance 1 (ARI1); Anthocyanin Reflectance 2 (ARI2)
- Canopy Water Content index: Water Band

A Broadband Greenness index group is widely used to evaluate Landsat, SPOT remote sensing satellite data sources, where red and NIR channels data ratio analyzed.
Narrowband greenness VIs more sophisticated measures of general and vigor of green biomass than the broadband VIs. Light Use Efficiency VIs use reflectance measurements in the visible spectrum to take advantage of relationships between different pigments types to assess efficiency of photosynthesis. Leaf Pigments VIs are stress related leaf pigments, which are higher concentration in weakened vegetation. The equations of calculated vegetation indexes are summarized in Table 3.

Table 3. The applied spectral vegetation indexes of fruit trees

$NDVI = \frac{\rho_{705} - \rho_{650}}{\rho_{705} + \rho_{650}}$	$ARVI = \frac{\rho_{705} - (2\rho_{650} - \rho_{450})}{\rho_{705} + (2\rho_{650} - \rho_{450})}$	$SR = \frac{\rho_{705}}{\rho_{650}}$	$NDVI_{705} = \frac{\rho_{750} - \rho_{705}}{\rho_{750} + \rho_{705}}$
$mNDVI_{705} = \frac{\rho_{750} - \rho_{705}}{\rho_{750} - \rho_{705} - 2\rho_{445}}$	$VOG1 = \frac{\rho_{740}}{\rho_{720}}$		$PRI = \frac{\rho_{531} - \rho_{570}}{\rho_{531} + \rho_{570}}$
$CR1 = \left(\frac{1}{\rho_{510}}\right) - \left(\frac{1}{\rho_{550}}\right)$	$SIPI = \frac{\rho_{800} - \rho_{445}}{\rho_{800} - \rho_{680}}$	$RG = \frac{\rho_{650}}{\rho_{550}}$	
$CR2 = \left(\frac{1}{\rho_{510}}\right) - \left(\frac{1}{\rho_{700}}\right)$	$ARI1 = \left[\left(\frac{1}{\rho_{550}}\right) - \left(\frac{1}{\rho_{700}}\right)\right]$	$WBI = \frac{\rho_{900}}{\rho_{970}}$	$ARI2 = \rho_{800}\left[\left(\frac{1}{\rho_{550}}\right) - \left(\frac{1}{\rho_{700}}\right)\right]$

The characteristics of the reflectance curves of each fruit tree species result from the large amount of absorption of chlorophyll A content at 450 – 670nm wavelength intervals. On the other hand, reaching the near infra-red (NIR) interval, the reflectance of the healthy fruit tree leaves are raising markedly at 700nm. Besides, the reflectance value of the vegetation without any stress is high at NIR intervals, but low at red wavelength interval. The chlorophyll content is one of the indicators of the state of health before ripening term. The biomass samples taken in the study area were collected and analyzed on the basis of spectral class. Around fruit tree the µg/g mean and standard deviation of the average chlorophyll values are as follows: Dry grass (512, 190); Spare vegetation (1285, 549); Weed (975, 298); Green grass (1117, 210), Yellow grass (674, 261). The µg/g mean and standard deviation of the average chlorophyll values of foliage of fruit tree are follows: Stressed canopy (1072 340), Yellow canopy (814, 496), Green canopy (1302, 231), Greenest canopy (1689, 272). The 4-5. tables show the mean VIs values of surrounding and foliage of the peach tree.

Table 4. VIs parameters of the peach orchard ambient

	Dry grass	Spare vegetation	Weed	Green grass	Yellow grass
NDVI	0.66	0.81	0.73	0.71	0.72
SR	4.92	9.48	6.61	5.97	6.64
ARVI	0.61	0.80	0.70	0.68	0.70
$NDVI_{705}$	0.40	0.49	0.44	0.43	0.45
mSR	3.10	3.53	3.32	3.28	3.50
$mNDVI_{705}$	0.51	0.56	0.54	0.53	0.55
VOG1	1.77	1.95	1.86	1.84	1.88
PRI	-0.022666	-0.027627	-0.022361	-0.021173	-0.01719
SIPI	1.07	1.02	1.04	1.05	1.05
RG	0.84	0.68	0.77	0.79	0.77
CRI1	0.000345	0.000529	0.000413	0.000388	0.000413
CR2	0.000495	0.000686	0.000566	0.000539	0.00057
ARI1	0.00015	0.000157	0.000153	0.000152	0.000158
ARI2	0.431994	1.067612	0.68491	0.600131	0.74357

Table 5. VIs parameters of the canopy spectral classes in peach orchard

	Stressed canopy	Yellow canopy	Green canopy	Greenest canopy
NDVI	0.79	0.65	0.72	0.82
SR	8.40	5.36	6.64	10.30
ARVI	0.77	0.60	0.70	0.83
$NDVI_{705}$	0.45	0.40	0.45	0.54
mSR	3.19	3.06	3.50	4.36
$mNDVI_{705}$	0.52	0.50	0.55	0.62
VOG1	1.87	1.76	1.88	2.09
PRI	-0.03155	-0.02149	-0.01719	-0.0087
SIPI	1.03	1.08	1.05	1.01
RG	0.69	0.82	0.77	0.67
CRI1	0.000491	0.000349	0.000413	0.000535
CR2	0.000622	0.000478	0.00057	0.000705
ARI1	0.000131	0.00013	0.000158	0.000171
ARI2	0.96849	0.58799	0.74357	1.40979

In the next step, indexes among the mean values of the VIs above mentioned were introduced, which are more important in terms of the examination, however, less known in practice.

The Modified Red Edge Simple Ratio (mSR $_{705}$) index is a modification of the traditional broadband SR index. It differs from the standard SR because it uses bands in the red edge and incorporates a correction for leaf specular reflection. Applications include precision agriculture, forest monitoring, and vegetation stress detection. The value of this index ranges from 0 to 30. The common range for green vegetation is 2 to 8 (Datt, 1990).

The Red Edge Normalized Difference Vegetation Index (NDVI $_{705}$) is intended for use with very high spectral resolution reflectance data. Applications include precision agriculture (an information- and technology-based agricultural management system to identify, analyze, and manage site-soil spatial and temporal variability), forest monitoring, and vegetation stress detection (Gitelson et al., 1994). This VI differs from the NDVI by using bands along the red edge, instead of the main absorption and reflectance peaks. The NDVI 705 capitalizes on the sensitivity of the vegetation red edge to small changes in canopy foliage content, gap fraction, and senescence. The value of this index ranges from -1 to 1. The common range for green vegetation is 0.2 to 0.9 (Smith et al., 2004; Sims et al., 2002).

The Vogelmann Red Edge Index (VOG1) is a narrowband reflectance measurement that is sensitive to the combined effects of foliage chlorophyll A concentration, canopy leaf area, and water content. Applications include vegetation phenology (growth) studies, precision agriculture, and vegetation productivity modeling (Vogelmann et al., 1993). The value of this index ranges from 0 to 20. The common range for green vegetation is 4 to 8.

The Photochemical Reflectance Index (PRI) is a reflectance measurement that is sensitive to changes in carotenoid pigments (particularly xanthophyll pigments) in live foliage (Gamon et al., 1992).

Carotenoid pigments are indicative of photosynthetic light use efficiency, or the rate of carbon dioxide uptake by foliage per unit energy absorbed. As such, it is used in studies of vegetation productivity and stress. Applications include vegetation health in forests, and agricultural crops prior to senescence. The value of this index ranges from -1 to 1. The common range for green vegetation is -0.2 to 0.2. Stress-related pigments include carotenoids and anthocyanins, which are present in higher concentrations in weakened vegetation. Carotenoids function in light absorption processes in plants, as well as in protecting plants from the harmful effects of high light conditions. The Carotenoid Reflectance Index 1-2 (CRI1-2) is a reflectance measurement that is sensitive to carotenoid pigments in plant foliage. Higher CRI1 values mean greater carotenoid concentration relative to chlorophyll A (Gitelson et al., 2002). The value of this index ranges from 0 to more than 15. The common range for green vegetation is 1 to 11. CR2 provides better results in areas of high carotenoid concentration.

Anthocyanins are water-soluble pigments abundant in newly forming leaves and leaves undergoing senescence. The Anthocyanin Reflectance Index 1 (ARI1) is a reflectance measurement that is sensitive to anthocyanins in plant foliage. Increases in ARI1 indicate canopy changes in foliage via new growth or death (Gitelson et al., 2001). The ARI2 is a modification of the ARI1 which detects higher concentrations of anthocyanins in vegetation. Water content is an important quantity of vegetation because higher water content indicates healthier vegetation that is likely to grow faster The value of these indexes ranges from 0 to more than 0.2. The common range for green vegetation is 0.001 to 0.1. The values of the indexes obtained by examination are lower than appeared in the literature, at the same time the indexes vary proportionally with regard to the state of health of the vegetation. But this varying ratio can differ by index calculation methods. It can be a possible explanation that the radiance conditions in the nature

differ from examined in the laboratory. Since this divergence is systematic, it influences all pixels equally, so the relative examination is ignored.
According to the investigation, the NDVI, SR, ARVI, NDVI705, VOG1 indexes responded to the values of chlorophyll absorption of vegetation and reflectance, so the calculated Pearson correlation was 0.47-0.72 corresponding to other studies (Blackburn, 2002; Herold et al., 2005; Dunkel, 1997). The lower values were given by broadband indexes. Further indexes were responsive to other effects of pigment absorption, thus the ratio of it played an important role over the absolute value. The best results can be obtained if the effects of the indexes from first sensitive chlorophyll class and the second lower sensitive class are examined together. In the case of the peach trees, mSR and ARI2 examination can be suggested. Naturally, the spectral definition of the airborne camera is very important, namely the values of band width (2-10nm). An alternative explanation could be that the biophysically effective reflectance bands measured in artificial circumstances and the on-field reflectance conditions are different. The method presented above uses a determined geometry of the spectral area of the on-field reflectance conditions for selecting and classifying the clean endmember pixels. According to the experiences, the errors given by the different light are much lower than they were in the case of classifying with the data of external spectral libraries. The disadvantage of the examined method is that more detailed on-field experiments are required. But during the planning procedure of precision agriculture, the implementation of more input information to the GIS clears the costs shortly with the optimization of the place and time of action.

4. SUMMARY

To be able to grow stone fruit species, the peach varieties, yield stability is very relevant. However, the climate is suitable in Hungary for growing stone fruits, thus damage should be calculated. Significant water stress and spring frost damage occur in every second –third year on the Great Plain. To reveal the frost tolerance of cultivars and to clarify the differences among growing areas is the most important point of peach production. In order to achieve this goal, the main objectives of collecting and processing airborne hyperspectral data cube were evaluated. Specification of data collection was also interpreted based on photogrammetric processes. The MNF and PPI processes were feasible methods for compressing the information of the n-dimensional spectral space in order to make it possible to select no spectral-autocorrelated endmembers, and then SAM classification. Based on the selected spectral classes, 14 vegetation indices were calculated. Before and parallel to the flight campaign, intensive soil and vegetation sampling were carried out, supported by GPS. Based on the findings, VIs can be an effective tool for vegetation analysis with calibration to the actual vegetation and utilization of several indices. The results can be applied for precision agriculture works in orchards for years, thus it is recommended to apply this kind of spatial decision supporting system with special regard to the management of large orchards.

5. ACKNOWLEDGEMENTS

These research works were funded by OM-00270/2008 NKTH gyüm2008 and OM-0042/2008 JEDLIK biodeb07 projects.

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