

HYPERSPETRAL EVALUATION OF THE PEAR TREES ON THE BASIS OF THE GENETIC COLLECTION OF THE DIFFERENT SPECIES

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ABSTRACT:

The principle task of the sustainable development is the preservation of the genetic variety, which is similar challenge in the horticulture regarding the sublimation of fruit species. The breeders of the traditional fruit strains give stock to the sustenance diversity of the agri-environment on the species and landscape level. In 2009, hyperspectral images have been taken by AISA Dual sensors from the pear gene pool in Újfehértó, Hungary. The hyperspectral data cube (in the wavelength range of 400-2500 nm, with 1.5 m ground resolution) ensured possibility to make the spectral library of pear species. In the course of the simultaneously field work the spatial position and individual extent of all pear trees was defined to set up a detailed GIS data base. The water stress sensitivity of single species and the descriptive spectral curves were determined with common evaluation of the spectral and spatial data. Based on the unique methodology processing and the hyperspectral data base suitable strains can be chosen for agri-environment and let take adaptive stocks regarding climate change into the genetic grafting work. Furthermore we could determine and map the sparsely species in the region with the help of the hyperspectral data.

1. INTRODUCTION

On the basis of the United Nations Earth Summit in Rio de Janeiro in 1992 the biodiversity conversation is the important task for every country. Even so numerous species is disappearing off the earth decreasing Earth's biodiversity. Plant and animal species collected by human genetic breeding works and selected over more hundred years are less emphasized contrary to wild species.

Our experimental respects the pear species (*Pyrus communis* L.). The pear is the second more important fruit in temperate zone following apple worldwide. It produces 4-4.5 million tonnes per year in Europe especially in Italy, France and Spain, while the pear is the fourth important fruit in Hungary with the amount of 40000-80000 tonnes.

There are numerous species of these, which can only be found in a certain landscape. These species mean irreparable genetic sources same as wild and rare species. There are innumerable genetically encoded qualities – eg. resistivity against the diseases and frost, drought tolerance, unique colour and taste, and storage tolerance, which lack partly or in gross from the commercial species. Because of the continually changing consumer demand, and environmental and landscape aspect the preservation of every pear species having special or useful quality is necessary.

The countries maintain this particular genetic property in the special plantations – gene pool. In Hungary these examination plantation can be found in 4 different production site - Cegléd, Érd, Fertőd, Újfehértó, where 7833 trees are cultivated with professional technology and high cost. The items of the genetic collections are fully documented and the data are registered by international norm. The recorded data ensure the identification, central registration, suitable access to provide using for the national or international researchers, breeders and teachers.

The greater part of data was in analogous form and the smaller part of it was in digital form until 2008. The most important cause of the establishment of the geoinformatical system was the dismembered database and the difficult management or actualizing.

The aim was to create a new GIS – Remote Sensing data system, which can be the basis of the later agri-ecological decision support system.

2. MATERIAL AND METHODS

The Fruit growing Research and Consultant non-profit company created the genetic collection of pomum fruits (apple, pear, quince, naseberry) at Újfehértó (47° 49' 30" N; 21° 40' 27" E) in 1980, which recorded 1876 trees in 2009. The area of the research company is situated in north direction from the town of Újfehértó, in Nyírség landscape NE Hungary. It consists of fixed sand dunes accordingly the relief is heterogeneous. The total cultivated area (fruit plantations and arable land) of the research company is approximately 3 km².

In the 5 ha plantation of genetic collection it can be found 673 apple, 480 pear, 57 quince and 28 naseberry species, variety and hybrid at present. The pear plantation is situated in the east part of the gene pool covered by 28000 m², where the planting started in 1982. According to the traditional cultivation methods the row pace is 8 m and the space between the trees is 2 m.

In course of the establishment of the GIS logical model we determined the types of the accessible data and the forms of utilization in the geoinformatics system. The fruit tree was the smallest unique entity, which has individually pollable attributes (name of species, planting date, height, condition etc.) It was also important to ensure the uploading of the phenological data such us blossoming, ripening time, and

yields. To grant the agricultural subsidy it had to record the cultivation data of the area too. On the basis of field works new digital soil and nutrient supply maps were created to evaluate agri-ecological environment. Digital elevation model with 1 m vertical and 0.2 m horizontal RMS was produced.

In the course of the field works every stock place in the pear genetic collection were measured by DGPS methods, where the survey accuracy was $RMS < 0.2$ m after the TRIMBLE PATHFINDER compensating calculation in Geostation environment. The height and width of trees were defined with the help of Leica Distro 8 laser distance meter. To prepare the hyperspectral flight we used a digital orthophoto, which was taken in 2007 with a ground resolution of 0.5×0.5 m.

The spatial data were completed by airborne hyperspectral data, which in general makes possible to perform botanical and special soil investigations (Nagy et al, 2006).

Since the applied joint camera is less known in Europe and it can also be reached as an investigation delivery, the details of the measurement are described below.

In 2007, the first high-tech AISA DUAL airborne hyperspectral image spectroscopy system (AIS) was installed and operated in cooperation the University of Debrecen, AMTC, Department of Water and Environmental Management with the Hungarian Institute of Agricultural Engineering in Gödöllő-Hungary funded by NKTH. The most important parts of the hyperspectral sensors are the spectrograph, which dissolve the electric waves arrived through the optical rift with the help of prisms and optical screen. The two hyperspectral sensors are mounted and synchronized in a common house; therefore it is known ASIA DUAL system (Milics et al. 2010).

The two cams can perceive in the visible wavelength, near infrared range and short wave infrared range. Technical information of applied ASIA DUAL hyperspectral system as follows: Push-broom hyperspectral imagery sensor with the fibre optic radiation meters (FODIS); Miniature integrated GPS/INS sensor, which serves the position, height and momentary situation (pitch, roll, yaw) of plane, Compact PC-based data collector and mobile receiver unit; CaliGeo software runs as a separate software package under the ITT ENVI software package to do the spectral and geometrical corrections. The parameters of the hyperspectral image: Wavelength: 400-2450 nm (EAGLE: 400-970 nm and HAWK: 970-2450 nm); Spectral sample taking: 1,2-10 nm; Ground resolution: 0,4-3 m (with plane flight altitude), The photogrammetric and spectral accuracies were evaluated by different GPS/Inertia systems in different flight conditions in Europe (Germany, Finland, Switzerland and Hungary) in 2008-2009.

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 800-1000 m and the average speed was 200-250 km/h, with minimum swath width of 500m. Studying the navigation data it can be determinable that the angle deflection of the flight remains within 10 degree in case of taking image in general climatic conditions (Table 1.). However in special meteorological condition we also measured larger deflections rates, which was rarely exceeded 15 %.

Angle deflecti on	Roll		Pitch		Yaw	
	(%)	sum (%)	(%)	sum (%)	(%)	sum (%)

0-2	31.2	31.2	31.5	31.5	35.8	35.8
2-4	39.6	70.8	54.0	85.6	18.6	54.4
4-6	17.1	87.9	9.3	94.9	28.3	82.7
6-8	8.1	96.0	1.9	96.8	15.6	98.4
8-10	3.9	100	3.18	100	1.58	100

Table 1. Flight parameters

The hyperspectral DUAL sensor is fixed without gyrostabilizer in the airplane, so the deflection originating from the motion of the airplane is corrected by CALIGEO program with the navigation data of GPS/INS system in the course of the geometric correction. Before the flight boresight type calibration was carried out (Holzwarth et al., 2005).

The images of the flight campaign using in this paper were taken in the early afternoon in cloudless condition in June 2009, where the mean angle deflection was lower than 4%.

Before mosaicing of the images parametrical correction and radiometrical normalization between the bands were applied (Burai and Tamás, 2004) (Figure 1.).

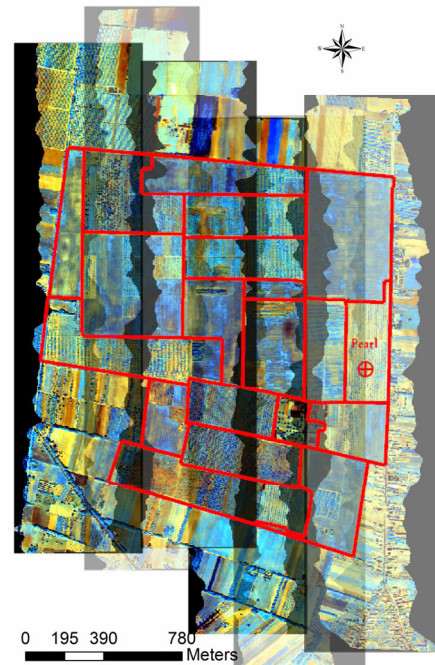


Figure 1. Georectified flight strips of the hyperspectral images and the Újfehértó Research Station (red border lines)

The accurate geometrical correction of the hyperspectral image taken by AISA DUAL push-broom sensor with high spatial resolution (< 1.5 m) could be achieved by OxTS RT 3003 positioning system working with two antenna. The atmospherical correction was done on the basis of the direct radiation measured by FODIS sensor detecting the changing of the radiation above the sensor. We modified the effects from the movements of the airplane with the navigation values, which is necessary to define the FODIS ratio. The high angle deflection values were separated from the FODIS data, which was replaced by data generated linear interpolation.

3. RESULTS

In our investigations, the airborne imaging system was used in fruit researches to develop a new GIS based recording system of

fruit plantations and study the relationships between remotely-sensed indices and ground control measures of fruit trees. Based on field work unique data of all pear trees, registered in the genetic collection, were collected to one ESRI ARCGIS data base. Height measurements and digital photos of the trees were also carried out during the survey. Digital photos were taken of the fruits as well, although earlier taken photos of genetically typical, ripe fruits were set to the database. The pictures were geotagged to air photo based on coordinates.

The n-dimensional hyperspectral image contained 359 channels. The bad bands, having bad signal/noise rate were excluded from further assessments (Tamás et. al 2005).

The characteristics of the reflectance curves of each pear tree species result from the large amount of absorption of chlorophyll 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 (Tamás, 2010). 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 phenological phase (Burai et al. 2009). The leaf samples taken with R-Row/T-Tree positions in the study area were collected and analyzed on the basis of the field measured spectral curves (Table 2).

Pearl Species	R/T	NDVI	SRI	REP	chlorophyll µg/g
Napoca	19/ 103	0.62	4.96	718.4	883.52
Márianosztrai	19/ 113	0.41	4.95	720.7	509.12
Republica	19/ 83	0.58	3.39	712.1	982.72
Ananász (Ananas)	19/ 79	0.69	5.26	710.9	4522.88
Nyári esperes (summer dean)	19/ 70	0.67	4.84	712.9	3960
Kiev	19/ 109	0.489	2.79	721.7	407.36

Table 2. Example for chlorophyll content and spectral indices

The Pearson correlation between chlorophyll and Normalized Vegetation Index (NDVI) was 0.8, between chlorophyll and Simple Ratio Index (SRI) was 0.54, between chlorophyll and Red Edge Position (REP) was -0.76.

During the survey NDVI index was calculated from the hyperspectral image. The segmentation of the NDVI image was based on the GIS database of field measurements. After vectorising the obtained segments, those pear species having different biomass weight were selected. Pixels covered by canopies of these trees, could be spectrally clear and unmixed. Although the results show, that real endmember pixels can only be found at trees having several canopy level and at least 1 m canopy diameter. Because of the replacement of necrotized trees the spectral properties of grass zone between rows can provide spectrally mixed values (as a 2nd type errors of commission) due to the possible underdevelopment of trees. On the other hand, the spectral properties of neighboring trees can be mixed due to the overdeveloped tree canopy having more than 4 m diameter, which larger than the spacing in the row. Generally these errors of omission (1st type) had minor role. The resulted, classified spectral data could be applied as a spectral library, which are

suitable for the detailed examination of plant physiology and spectral data. The optimal climatic conditions for pear are generally cooler and humid, with at least 65% of relative air humidity. There is a lack of these conditions in Újfehértó at the 30-40% in a year. At the examined site, pear species with large biomass concerned as those species which had major tolerance against drier and unfavourable environmental conditions. These genetic properties could be very important in the frame of the potential climate change. Stress, caused by the relative water lack, evolves in a short term physiological process. The first symptoms of water stress are often not visually observed, although those have negative effect on the yield quantity and quality. The conventional invasive measurements can hardly be reproduced, because of the sampling (cut) of the vegetation tissue (i.g. leaf, shoot) or only few cm² of leaf area is measured, which limits the representative sampling. The airborne hyperspectral remote sensing data eliminate these disadvantages, since it can provide detailed spectral data from the whole canopy.

In Figure 2 the continuum removed spectra of Bajai, KörteB/3, Szentendrei császár, Vérteskozmai pear species are shown descending order of biomass. Continuum Removal is to normalize reflectance spectra to compare individual absorption features from a common baseline. The continuum is a convex hull fit over the top of a spectrum using straight-line segments that connect local spectra maxima. The first and last spectral data values are on the hull; therefore, the first and last bands in the output continuum-removed data file are equal to 1.0. The resulting image spectra are equal to 1.0 where the continuum and the spectra match, and less than 1.0 where absorption features occur.

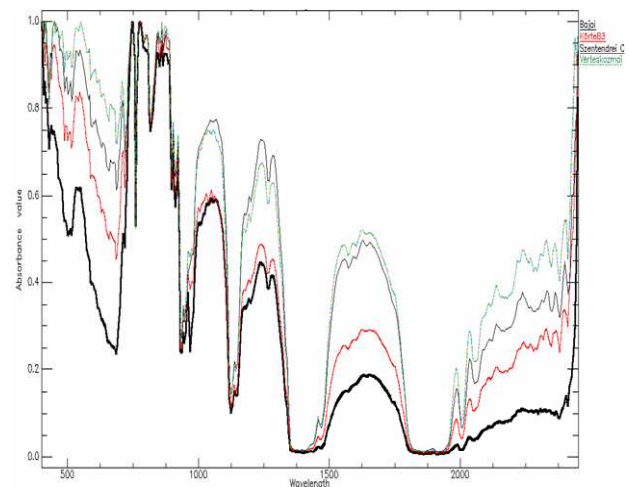


Figure 2. The pear species have species specific spectral properties

Based on the horticultural data, the four biomass segments showed strong correlation with the water stress tolerance. The pear tree species were grafted to the same wild pear rootstock, thus there were no differences in the water consumption root zone. In accordance with the spectral data, the “Bajai” species produced large canopy with 5.7 m height and large yield quantity (Figure 3).



Figure 3. The water stress tolerable „Bajai” species

The “Szentendrei császár” species grown on the same soil type, just some meters away from the presented “Bajai”, has just 2m height canopy and its yield is the one quarter of the “Bajai” one (Figure 4).



Figure 4. The water stress sensitive “Szentendrei Császár” species

The Water Band Index (WBI) is a reflectance measurement that is sensitive to changes in canopy water status. As the water content of vegetation canopies increase, the strength of the absorption around 970 nm increases relative to that of 900 nm. WBI is defined by the following: $WBI = \delta_{900} / \delta_{970}$ (Champagne et al. 2001). According to our examinations as well, channel with 900nm is found to be a sensitive water stress indicator, although the minimum value of the first derivative of the reflectance curve was at 930-940 nm wavelength interval. The 970 nm channel provided less usable values as a denominator for WBI (Figure 5).

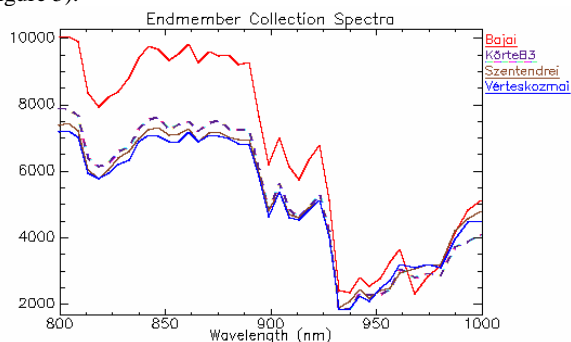


Figure 5. Spectral interval regarding water stress in the case of 4 pear species.

Based on the abovementioned results, the reflectances of 886 and 937 nm can result more accurate WBI ($WBI = \delta_{886} / \delta_{937}$) in the case of pear trees. The spectral data also confirmed that the “Bajai” pear species can tolerate more the dry conditions of Újfehértó than the “Szentendrei császár” or the “Vértesszomszmai” pear species.

4. CONCLUSIONS

Based on the results, the airborne hyperspectral remote sensing is a very effective method for surveying the vegetation. The environmental a climatic stress has an effect on vegetation, as well as other living creature. Species, grown in the concerned landscape had enhanced tolerance for harmful effects and water stress, thus it is especially important to prevent these genetic properties for further generations. The spectral library of the pear genetic collection in Újfehértó and the integrated GIS research database provide new opportunity to researchers and breeders in vegetation analysis. Due to this complex database and spectral library the effectiveness of understanding spectral anomalies and changing detection can be significantly increased.

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