MAPPING AQUATIC VEGETATION OF THE RAKAMAZ-TISZANAGYFALUI NAGY-MOROTVA USING HYPERSPECTRAL IMAGERY

PÉTER BURAI[1] – GABRIELLA ZSUZSANNA LÖVEI[2] – CSABA LÉNÁRT[3] – ILDIKÓ NAGY[4] – PÉTER ENYEDI[5]

[1]Károly Róbert Collage, Faculty of Natural Resources Management and Rural Development, Institute of Agroinformatics and Rural Development, H-3500 Gyöngyös Mátrai út 36., Hungary, E-mail: pburai@karolyrobert.hu; [2]University of Debrecen, Department of Hydrobiology, H-4032 Debrecen, Egyetem tér 1., Hungary, E-mail: loveigabby@gmail.com; [3]Károly Róbert Collage, Faculty of Natural Resources Management and Rural Development, Institute of Agroinformatics and Rural Development, HU-3500 Gyöngyös Mátrai út 36., Hungary, E-mail: lenart@karolyrobert.hu; [4]University of Debrecen, Faculty of Agricultural and Food Sciences, and Environmental Management, Department of Water and Environmental Management, H-4032 Debrecen, Böszörményi út 138., Hungary, E-mail: inagy@gisserver1.date.hu; [5]Envirosense Hungary Ltd, H-4028 Debrecen, Kassai út 129., Hungary, E-mail: enyedi@envirosense.hu

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Abstract
Rapid development in remote sensing technologies provides more and more reliable methods for environmental assessment. For most wetlands, it is difficult to walk-in without disturbing the endangered species living there; therefore, application of opportunities provided by remote sensing has a great importance in population-mapping. One effective tool of vegetation pattern estimation is hyperspectral remote sensing, which can be used for association and species level mapping as well, due to high ground resolution. The Rakamaz-Tiszanagyfalui Nagy-morotva is an oxbow lake, located in the north-eastern part of Hungary. For this study, a wetland area of 1.17 km^2 containing the original water bad and shoreline was selected. For the image analysis, images taken by an AISA DUAL system hyperspectral sensor were used. At the same time, 7 main vegetation classes were separated, which are typical for the sample plot designated on the test site. Classification was performed by the master areas signed by the most common associations of the Rakamaz-Tiszanagyfalui Nagy-morotva with determined spectrums. During the image analysis, SAM classification method was used, where radian values were optimized by the results of classification performed at the control area.

Keywords: remote sensing, hyperspectral, image classification, ecology, wetland, oxbow lake

1. Introduction

Hungary, thanks to its geographical position, has unique facilities in Europe in respect to wetlands. Despite the river control, there are number of different oxbow lakes in the Great Plains, which more or less preserved their natural wildlife and landscape image. For the majority of wetlands, it is difficult to walk-in without disturbing the endangered species found there, and make an accurate vegetation estimation with ground based tools. However, rapid development of remote sensing technologies provides more reliable methods for environmental assessment. Nowadays, for vegetation mapping and plant covering mapping of the domestic flood plain, data of satellite images are applied primarily. For the assay of the surface cover, and determination of the different ecological morphological types, Landsat satellite images were used e.g. by Szabó et al. (2004), in case of Bodrogköz. However, in order to create species-level maps, images with larger spatial and spectral resolution are needed (Rosso et al., 2005). During testing, Tamás et al. (2006) established the spatial spread of weed associations on a sample plot on the Great Plain, and concluded that weed mapping by time series LANDSAT satellite images has low reliability, because of the low geometric resolution of the images and high spatial heterogeneity of the plants. Today's satellites may not have sufficient resolution, either spatially or spectrally to monitor wetland. An effective tool of the exact vegetation estimation can be hyperspectral remote sensing, which may be used for the association and species level mapping as well by high terrain resolution (Hamada et al., 2007; Hirano et al., 2003; Underwood et al, 2003; Underwood, 2006). Underwood et al. (2007) mapping of invasive plants had shown that the higher spectral and spatial resolution significantly improves the reliability of classification, to the point, while the spatial diversity of the examined characteristic is not higher than geometric resolution of the image. Analysis of these large data sets required developing specialized methods. Roberts et al. (1998) argued the need for regionally specific spectral libraries for semi arid ecosystems, and Hirano et al. (2003), Schmid et al. (2004), Zomer et al. (2009) for wetlands. Hyperspectral data requires improved methodologies and tools that facilitate analyses and mapping which can be specifically applied to wetlands requirements.

2. Materials and methods

The Rakamaz-Tiszanagyfalui Nagy-morotva is an oxbow lake located in the north-eastern part of Hungary. A wetland area of 1.17 km^2 containing the original water bad and shoreline was selected (Fig. 1).

The major part of the study area is covered by aquatic vegetation and this plant mass cause huge organic matter load reproduced yearly, thereby timely accelerating sedimentation. On major part of the oxbow lake, significant macro-vegetation can be found with notable aquatic plants. For the selection of training sites used for image classification, representative vegetation types were appointed by GPS on terrain visit.

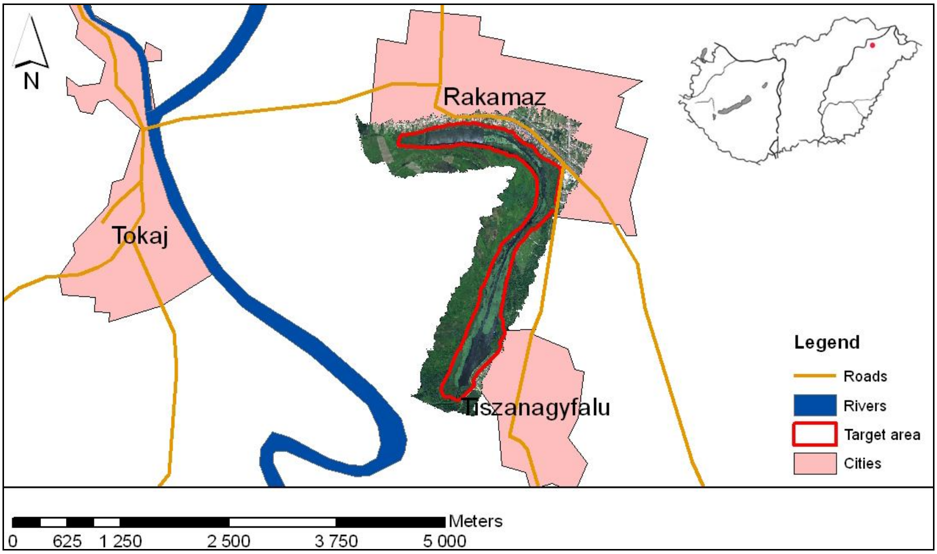

Fig. 1. Rakamaz-Tiszanagyfalui Nagy-morotva on the hyperspectral mosaic

Major vegetation types and their dominant and subdominant species were identified. By training sites, classes that should be given for the classification algorithm as input parameters had to be defined. In field, 7 main dominant species were separated, which are typical for the sample plot designated on the oxbow lake (Table 1). Separation of the classes was carried out based on the dominant species. Training areas covering the searched dominant species in more than 75%, for the sample were assigned. As training area classes and species that create association were designated.

Table 1. Dominant and subdominant species of Rakamaz-Tiszanagyfalui Nagy-morotva

Abbreviation	***Dominant species***	***Subdominant species***
SALIX	*Salix sp.*	*Phragmites australis, Typha angustifolia*
TYPHA	*Typha angustifolia*	*Phragmites australis, Lemna sp.*
STRATIOTES	*Stratiotes aloides*	*Trapa natans, Lemna sp.*
PHRAGMITES	*Phragmites australis*	*Typha angustifolia*
TRAPA	*Trapa natans*	*Ceratophyllum sp., Lemna sp.*
CERATOPHYLLUM	*Ceratophyllum sp.*	*Stratiotes aloides, Lemna sp., Trapa natans*
NYMPHAEA	*Nymphaea alba*	*Trapa natans, Lemna sp.*

Hyperspectral imaginary was performed by AISA DUAL system hyperspectral sensor, which was put in operation in 2006, in cooperation of University of Debrecen Centre of Agricultural and Technological Sciences, Department of Water- and Environmental Management with FVM MGI Institute of Gödöllő. The sensor is able to collect data in the 400-2450 nm wavelengths range, by 1.25-10 nm bandwidth, and 0.5-3 m terrain resolution (Deákvári et al., 2008). First domestic use of the images taken by this sensor was in 2006, till then, they were mainly used in precision agricultural and environmental protection researches (Milics et al, 2008). DUAL sensor was used for the whole sample area in VNIR range (400-1000 nm), 5nm (12 bit), while in SWIR range (1000-2450 nm) with 6nm (14 bit) spectral resolution, with 1.5m ground resolution, from 1128 m flight altitude, with 444 m bandwidth and 30% overlapping. Towards the precise geometry, a high-precision OxTS 3003 type GPS/INS system was used for the collection of navigation data. Flight time of the sample area was on 19th June, 2009, in 9:30-12:30 period (GMT), and 4 images were taken at the sample area.

The first step of data processing was performed with the application of Caligeo 4.9.7 version program developed by Specim, in which the primary radiometric and geometric corrections were calculated. During the radiometric correction, data of the raw images (DN) were accounted to physical radiometric value (16 bit) by the program (radiance). Calculation of direct georeference was performed also in Caligeo program with the navigation data from GPS/INS system, digital terrain model (SRTM) and other external parameters (boresight values, external DGPS data). Boresight calibration was used for calculation of the angle deviation between GPS/INS system and the axis of the sensors, which was determined by CaliGeo processing software in first step, then by progressive iteration calculated for terrain DGPS points. With the refined boresight values, geometric accuracy calculated at the control points was RMSE = 1.06. Process of the pre-processing mechanism is represented in Fig. 2.

ENVI 4.4 (Environment for Visualization of Images ENVI; ITT Visual Solutions) program was used for image processing, post processing and raster-vector conversion. Other vector operations were carried out in ArcGIS 9.2 environment.

3. Results

As a first step of image analysis, band selection was applied; when 259 channels were selected form the 359 channels of the original image. Ranges, having high absorption due to the atmospheric absorbents, or scattering were excluded from the further study. Further classification algorithms were not taken into account during the application, designated range used for the atmospheric correction and "noisy" channels that can be seen visually. More noise, or dimension reduction was not used in the image. Using SAM classification with Minimal Noise Fraction transformation on AISA images has no more accurate result, than calculations with the original images (Mucsi et al., 2008).

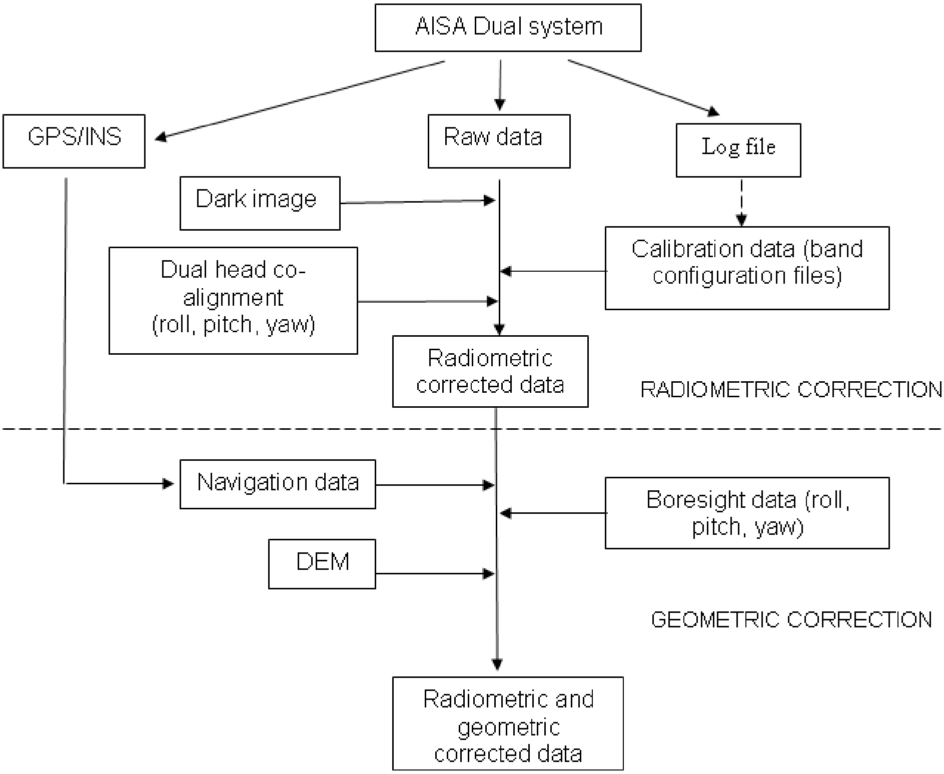

Fig. 2. Workflow of radiometric and geometric correction

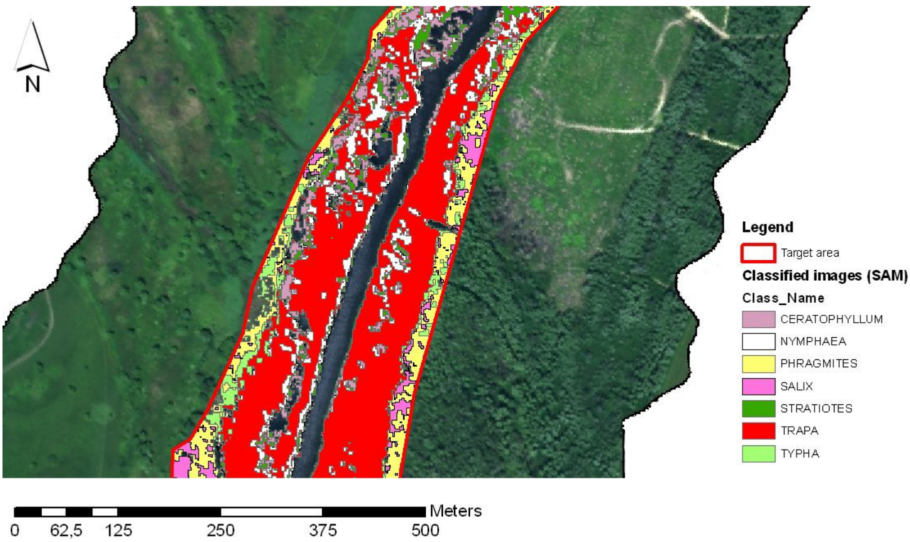

Fig. 3. Subset of the classified image (SAM)

Conventional classification methods, such as the Gaussian Maximum Likelihood algorithm cannot be applied to hyperspectral images due to the high dimensionality of the data and the relatively small number of available training samples (Chi et al., 2008). For teaching area classification, „Spectral Angle Mapper" – SAM method was applied. This method regards spectrums to n-dimensional vectors - where n is the number of spectral channels - and calculates the angle between them. The method is less sensitive to deviations due to intensity difference caused by the different lighting conditions of the pixel-points of the images. Smaller angles represent closer matches to the reference spectrum. From the traning area, spectrum belonging to the requested property was determined, thus a spectral database was created (*endmember collection*). Mean reflectance spectra were calculated from the selected training areas (Fig. 4).

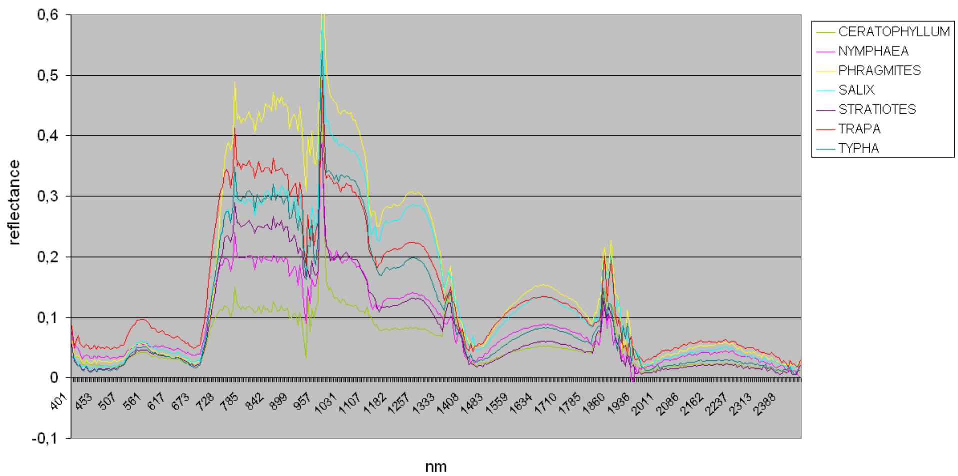

Fig. 4. Mean reflectance spectra of different classes

After band selection and masking of the sample area, image analysis algorithm was run per track. First 0.1 radian value was proposed by the basic settings of the software during the analysis, than by reclassification of the control area, radian value, which gives the most reliable classification result, was determined with 0.01 radian increments. For validate the accuracy of the classification, error matrix was applied (Table 2).

Table 2. Error matrix (%) of SAM classification method (Rows are came from classified images)

CLASS	***SALIX***	***TYPHA***	***STRATI-OTES***	***PHRAG-MITES***	***TRAPA***	***CERATO-PHYLLUM***	***NYMPHAEA***
SALIX	**91.41**	0.00	2.06	4.08	0.00	0.00	0.00
TYPHA	0.00	**92.50**	30.29	8.16	0.00	0.00	0.37
STRATIOTES	0.00	1.25	**30.88**	0.00	1.24	23.93	6.96
PHRAGMITES	8.59	5.00	0.00	**87.76**	0.00	0.00	0.00
TRAPA	0.00	1.25	34.41	0.00	**91.91**	0.31	30.40
CERATOPHYLLUM	0.00	0.00	0.00	0.00	0.13	**73.01**	0.73
NYMPHAEA	0.00	0.00	2.35	0.00	6.72	2.76	**61.54**
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00

The accuracy of classification can be seen in the major diagonal of the error matrix (*production accuracy*). Non-classified areas were not taken into account in the error matrix. By the results of the classification, it can be stated that reliable results were achieved in the classification in case of the woody willow (*Salix sp.),* the broad-leaved reed mace (*Typha angustifolia*), reed (*Phragmites australis*), and water chestnut (*Trapa natans*), however, the applied method was less accurate in case of the hornworts (*Ceratophyllum sp.*) and white lily (*Nymphaea alba*) association. In case of water soldier (*Stratiotes aloides*), number of misclassified pixels was higher in the control area, than correctly classified ones. Increase in the value of SAM radian did not improve significantly the accuracy of classification in this case, however, it increased the incorrectly classified areas of other classes (Table 3).

Table 3. Accuracy of classification (SAM)

Class	***Commission (%)***	***Omission (%)***	***Production Accuracy (%)***	***User Accuracy (%)***
SALIX	3.04	8.59	91.41	97.21
TYPHA	60.01	7.50	92.50	39.78
STRATIOTES	54.74	69.11	30.88	45.26
PHRAGMITES	31.74	12.24	87.76	68.25
TRAPA	8.60	8.09	91.91	91.40
CERATOPHYLLUM	2.01	26.99	73.01	97.94
NYMPHAEA	50.88	38.46	61.54	49.12

The overall performance of classification was correct with overall accuracy of 78%, and kappa coefficient of 0.63. Each area of classes was calculated based on the classified images (Table 4).

Table 4. Estimated areas of classes, based on the results of classification

Class	***Area (m^2)***	***Area (%)***
SALIX	151133	19.86
TYPHA	60822	7.99
STRATIOTES	38360	5.04
PHRAGMITES	188345	24.75
TRAPA	199690	26.24
CERATOPHYLLUM	58522	7.69
NYMPHAEA	64145	8.43
SUM	760017	100

From the target area, 0.76 km^2 (65.1%) was classified, while the residual area contains particularly open water surface and mixed pixels. According to the vegetation map, water chestnut (*Trapa natans*) makes contiguous floating vegetation particularly in swallow water body. White lily (*Nymphaea alba)* and water soldier (*Stratoides aloides)* make small isolated or mixed spotted associations. Woody willow (*Salix sp.) and* reed (*Phragmites australis*) are dominant in the shore area.

4. Discussion

This study illustrates the potential for wetland assessment using advanced aerial hyperspectral imagers, and applications for vegetation community monitoring. Classification, applied for the sample area represents 82.7% accuracy by the data of the control areas, which can be considered good in the case of a mixed compound aquatic ecosystem. The accuracy of the classification was better than 90% in 3 categories, lower accuracy was received in case of 3 categories (87.7%, 73.0%, and 61.5%). Differences mainly arose from the structure of the vegetation, since the water chestnut (*Trapa natans)* association composed almost homogeneous and closed association in most cases, while the white lily (*Nymphaea alba)* and hornworts (*Ceratophyllum sp.)* composed stain form and mixed association with other species. However, in case of water soldier (*Stratoides aloides)* association, classified image was equaled to control area in 30.88%. If the average size of the stain size is considered, the classification accuracy of associations with smaller stain size is lower than associations that have larger connected stains. For the extension of classification to other areas, development of spectral library evolved specially for wetlands would be required, which justify further development of the terrain spectrophotometry measurements and atmospheric correction, particularly by the reason of the reduction of atmospheric effects. The ability to monitor vegetation at higher spatial and spectral information allows changes in vegetation composition to be accurately mapped using advanced geospatial methods. Future efforts will focus on to develop a spectral library for wetland vegetation.

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