COMPARATIVE ANALYSIS OF CROP MAPS FOR CHOSEN TEST AREAS ON THE TERRITORY OF BULGARIA AND ROMANIA USING SIMULATED PROBA-V AND SPOT VEGETATION DATA

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ABSTRACT

The operational capabilities of low-resolution satellite instruments, such as SPOT VEGETATION, MODIS, and NOAA AVHRR, make real-time and near-real time Earth Observation (EO) data indispensable for monitoring world vegetation resources. The data continuity of the SPOT VEGETATION mission is to be ensured by PROBA-V ("V" standing for "Vegetation"). The present study aims to reveal the potentialities of the PROBA-V mission and its advantages as compared to SPOT VEGETATION based on a comparison of accuracy assessments of crop identification maps. The scope of the study is achieved by using unsupervised ISODATA and supervised Maximum Likelihood Classification (MLC) algorithms on single-date PROBA-V simulated data and SPOT VEGETATION images, and a comparison of classification accuracies. The results show that single-date PROBA-V simulated images provide better crop map classifications than SPOT VEGETATION images with a 15 to 22% higher overall accuracy, and Kappa statistics of 0.31 to 0.33 higher for the *Zhiten* test area (Bulgaria) and the *Fundulea* test area (Romania), respectively. It was also established that single-date PROBA-V simulated data can serve as a basis for reliable crop identification of winter crops with high users and producers accuracy.

INTRODUCTION

The agricultural environments are formed by the interactions of natural and anthropogenic factors resulting in a diverse crop pattern across the globe. With the increasing anthropogenic pressure on environment there is a need of contemporary agricultural crop data at various spatial scales. The accuracy and timely availability of such data is of crucial importance to its usefulness, either as an aid for policy makers or as a basis for modelling climate change, ecosystem/landscape or land use. At present, there are numerous examples of using low-resolution satellite data for crop mapping at different spatial scales. A new low-resolution satellite mission called PROBA-V (Project for On-Board Autonomy "V" standing for "Vegetation") is scheduled for launch in the middle of 2012 by Belgium (1). This instrument has four spectral bands identical with those of SPOT VEGETATION. The increase of spatial resolution (SR) of this instrument is supposed to improve the quality of the VEGETATION-like products provided by PROBA-V (2). The present work aims at comparing the accuracy assessment of supervised classification results from SPOT VEGETATION and PROBA-V. The subject of study is arable lands on the territory of *Zhiten* test area (Bulgaria) and *Fundulea* test area (Romania). The objective of the study is to implement a referential crop classification scheme for a comparative analysis of the accuracy assessment of supervised classifications of PROBA-V Simulated Data (SD) and SPOT VEGETATION images on both test areas.

Study area

This study was conducted on the territory of the *Zhiten* test area (North-East Bulgaria) and *Fundulea* test area (South-East Romania) (Figure 1).
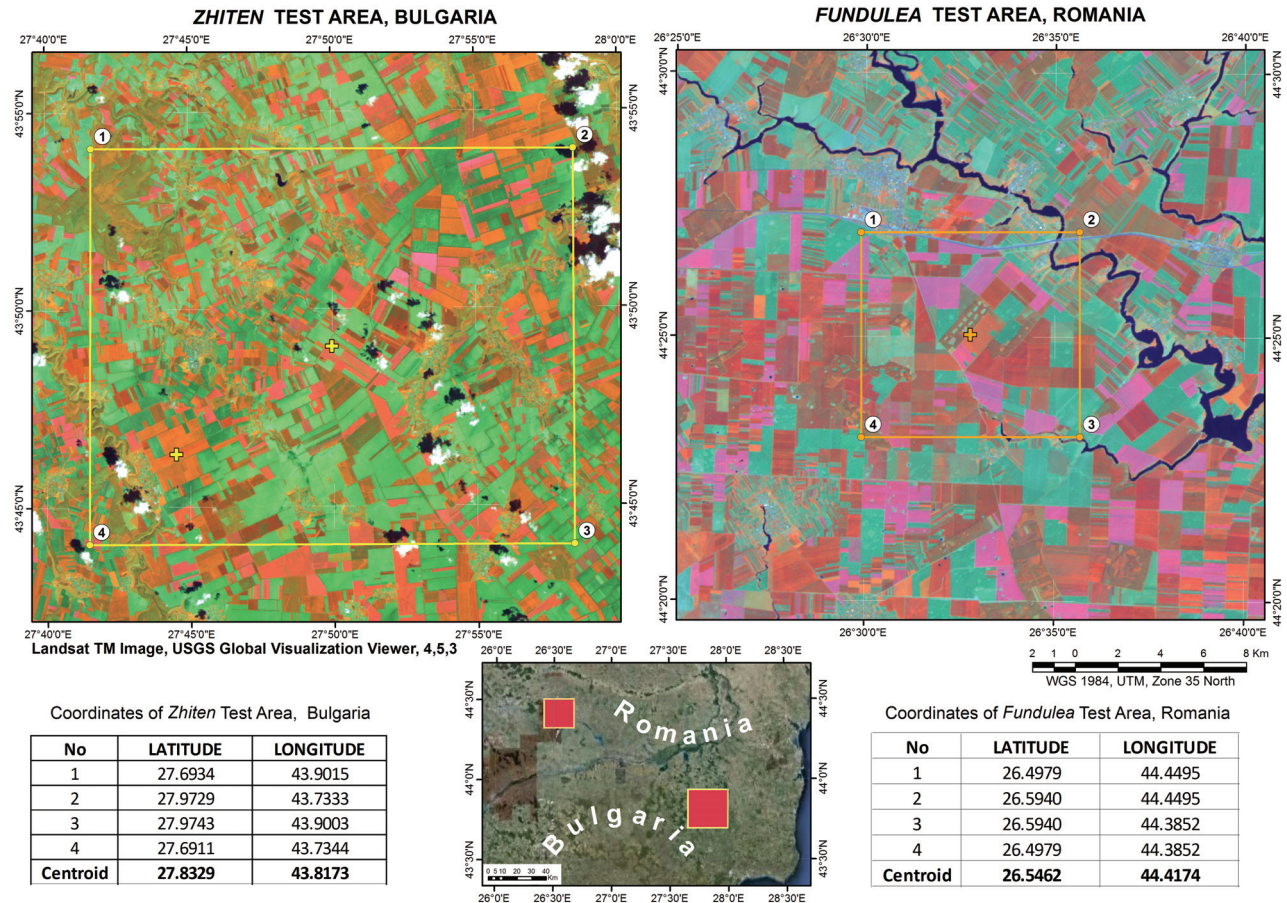

Figure 1: Overview map of the Zhiten test area (Bulgaria) and Fundulea test area (Romania).

The test areas are located in the major agricultural regions of Bulgaria and Romania. The territories are about 200 m a.s.l. They are located in the European continental climatic province of the temperate climatic belt. Climate is moderately warm with no distinctive dry season (3). The territory is sown mainly with winter crops (winter wheat and rapeseed) and summer crops (sunflower and maize). The winter crops are sown in October-November and are harvested at the end of July of the following year. The summer crops are sown in April and harvested in August. Some small crofts, which are sized below the spatial resolutions of PROBA-V and SPOT VEGETATION, are occupied by orchards, vineyards, and other agricultural crops.

METHODS

In the present study, two single-date PROBA-V L2A simulated products derived from medium (4 - 30 m) Spatial Resolution (SR) satellite images (Table 1) and two single-date SPOT VEGETATION S1 products dated 07.07.2011 and 23.07.2011 were used. At that time, winter crops were in the phenological stage of Maturity 100%, while spring crops were in the phenological stages of Flowering (sunflower) and Leaf formation (maize). Simulation of PROBA-V data was carried out by the Flemish Institute for Technological Research - Belgium (VITO-BE) using System Performance Simulator (SPS) developed by the SPS team at VITO-BE. The SPS software expects input scene values to be stored in radiances (W m^{-2} sr^{-1} μm^{-1}). The bands of the medium SR images used for the simulation of the corresponding PROBA-V bands are presented in Table 1.

Output data from the simulation in the form of Top Of the Atmosphere (TOA) reflectance and cell size of approximately 150 × 150 m^2 for Visible and Near Infrared (VNIR) bands and 300 × 300 m^2 for ShortWave InfraRed (SWIR) band was used. These images were georeferenced in UTM, Zone 35N, datum WGS84 and resampled to the planned PROBA-V SR, i.e. 300 m for VNIR and 600 m for SWIR band, using the Nearest Neighbour (NN) method. Subsequently, the individual bands were stacked into one file with a cell size of 300 m. As a result, it became possible to use the SWIR band in crop classifications with the other bands.

Table 1: The corresponding bands of the medium SR images used for PROBA-V simulation

PROBA-V bands (μm)	Corresponding EO-1/ALI bands (μm)	Corresponding Landsat 5 TM bands (μm)
Blue (0.45-0.49)	Band 03: Blue (0.45-0.515)	Band 1: Blue (0.45 -0.52)
Red (0.61-0.69)	Band 05: Red (0.63-0.69)	Band 3: Red (0.63 -0.69)
NIR (0.78-0.89)	Band 06: NIR (0.775-0.805) Band 07: NIR (0.845-0.89)	Band 4: NIR (0.76 -0.90)
SWIR (1.57-1.65)	Band 09: SWIR (1.55-1.75)	Band 5: SWIR (1.55 -1.75)

The S1 products from SPOT VEGETATION were received from VITO-BE upon submission of a project proposal. The SPOT VEGETATION S1 products are daily Maximum Value Composites (MVC) derived from the P products, which are the strips acquired by the SPOT VEGETATION instrument (4). By using PROBA-V Simulation Processing Tools, developed under the PROAGROBURO Project, the image series from SPOT VEGETATION were transformed from plate caree geographic projection to UTM projection, Zone 35N, datum WGS84. The image bands were also converted from Digital Numbers (DN) to radiances by applying Eq. (1) according to (5):

$$\text{Radiances} = 0.004 \cdot DN - 0.1 \tag{1}$$

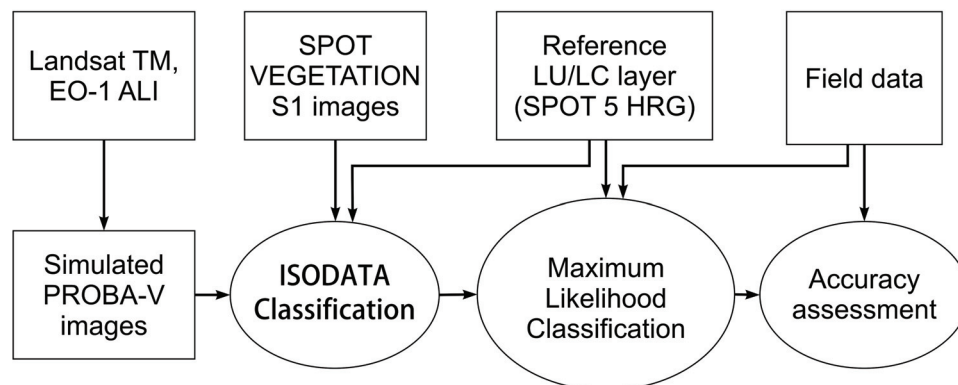The study methodology used in the present work is presented in Figure 2.

Figure 2: Flowchart of the study methodology.

In order to assess the spectral domain of both radiometers and to provide the reference layer for the test sites, crop maps were prepared based on unsupervised Iterative Self-Organizing Data Analysis Technique Algorithm (ISODATA) clustering. The ISODATA clustering method uses spectral distance to iteratively classify the pixels, redefining the criteria for each class, so that the spectral distance patterns in the data gradually emerge (6). The unsupervised image classification was organized in 3-5 LU/LC classes with α=0.05. Following the unsupervised classification, an assignment of crop names to each class was done.

The supervised classification using the Maximum Likelihood Classification (MLC) algorithm was applied to the images from both sensors and for both test areas. With the MLC, a key concern is to form a training set comprising of 10–30 independent training cases per class per discriminatory variable (e.g. waveband) to enable a representative description of the class, so that its mean and variance can be reasonably estimated (7,8). For example, the spectral response of an agricultural crop class in an image might vary as a function of variables, such as the crop's growth stage,

topographic position, density of cover, crop health, impact of management activities, substrate conditions and sensor view angle (9). An arable land mask was used to exclude forest, water, and settlements from the images. A reference LU/LC layer derived from SPOT 5 HRG images dated 21.04.2011 served as reference information in the accuracy assessment. The reference layer from SPOT 5 HRG was prepared by visual computer-aided image interpretation. A stratified random sample of 250 points was used for accuracy assessment of each classification output from MLC. The percentages of overall accuracy, producers and users accuracy, and the Kappa statistics for each class were assessed.

The crop classification scheme used is based on GLC2000 (10,11). The GLC2000 legend was modified with an additional level to the classification scheme representing the type of crops, i.e., a "cultivated and managed areas" class that is to be included in the images. Two crop classes within the "cultivated and managed areas" class were recognized depending on the date of image acquisition:

1) winter crops (winter wheat and rapeseed) and
2) spring crops (sunflower and maize).

RESULTS

A series of unsupervised classifications with five classes at 95% Confidence Intervals (CI) were prepared. They were used for finding spectrally homogeneous Areas Of Interest (AOI) for subsequent supervised crop classification. Initially, the ISODATA classes were not mapped accurately to the LU/LC classes from GLC2000 due to mixed up LU/LC classes, such as winter and spring crops. Then the number of classes, discernible by the ISODATA, was reduced to two. The result was compared with the reference LU/LC layer derived from SPOT 5 HRG, and proved the hypothesis that PROBA-V SD and SPOT VEGETATION data can spectrally discriminate up to two classes in the arable lands of the test sites.

The classification outputs of PROBA-V SD and SPOT VEGETATION Supervised MLC with two classes, i.e. spring and winter crops, for the July 2011 sub-satellite experiment for *Zhiten* test area (Bulgaria) and *Fundulea* test area (Romania) are shown in Figure 3. The results of the accuracy assessment of the supervised classifications of PROBA-V SD and SPOT VEGETATION for *Zhiten* test area (Bulgaria) and *Fundulea* test area (Romania) are presented in Table 2. The phenological stages next to each date of image acquisition are defined after Meier (12).
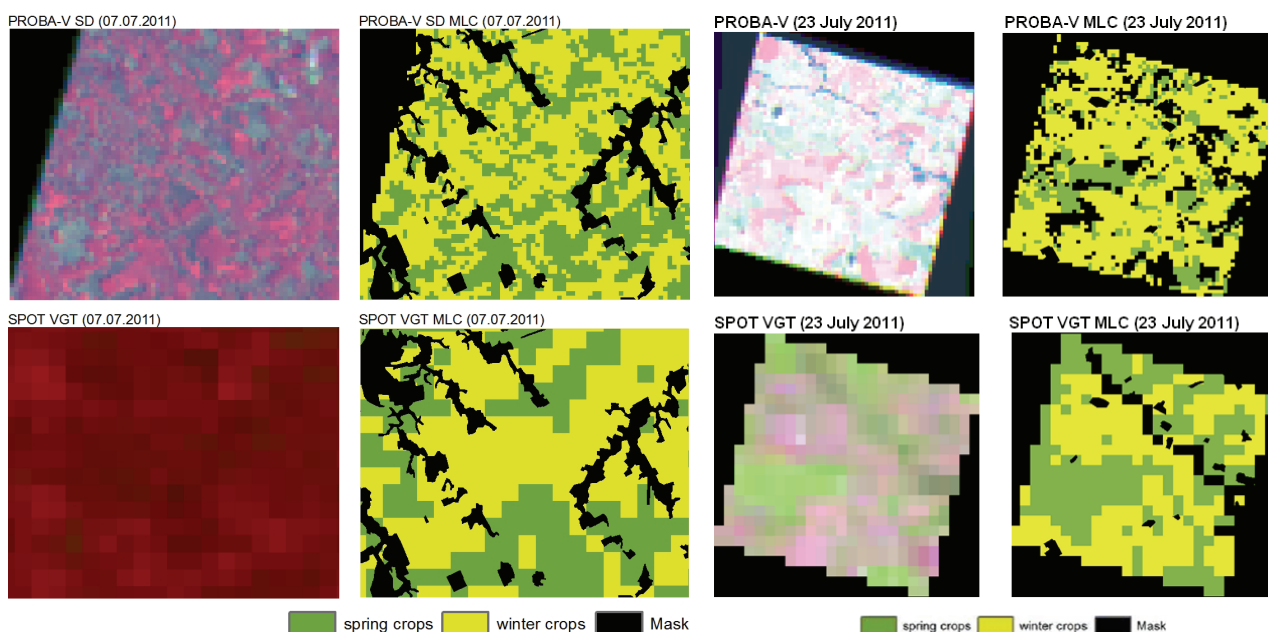

Figure 3: Supervised MLC on PROBA-V SD and SPOT VEGETATION images for Zhiten test area (Bulgaria) (left) and Fundulea test area (Romania) (right) (Maturity 100%).

The overall accuracy of the classifications of PROBA-V SD over *Zhiten* test area (Bulgaria) ranges between 57% and 72%. Good separation between winter and spring crops classes in July 2011 is confirmed also from the accuracy assessment on the *Fundulea* test area (Romania). The results showed that single-date PROBA-V SD provides better crop classifications than SPOT VEGETATION with 15 to 22 % higher overall accuracy, and Kappa statistics being 0.31 to 0.33 higher for *Zhiten* test area (Bulgaria) and *Fundulea* test area (Romania), respectively.

Table 2: Classification accuracies for the PROBA-V SD and SPOT VEGETATION classified images.

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy (%)	User Accuracy (%)
PROBA-V SD 7 July 2011 (Maturity 100%) *Zhiten* test area					
Winter crops	122	150	102	83.61	68.00
Spring crops	128	100	80	62.50	80.00
Totals	250	250	182		
Overall Classification Accuracy = 72.80%			Overall Kappa Statistics = 0.4586		
SPOT VGT 7 July 2011 (Maturity 100%) *Zhiten* test area					
Winter crops	121	150	82	67.77	54.67
Spring crops	129	100	61	47.29	61.00
Totals	250	250	143		
Overall Classification Accuracy = 57.20%			Overall Kappa Statistics = 0.1494		
PROBA-V SD 23 July 2011 (Maturity 100%) *Fundulea* test area					
Winter crops	171	211	168	98.25	79.62
Spring crops	87	55	50	57.47	90.91
Totals	267	267	219		
Overall Classification Accuracy = 82.02%			Overall Kappa Statistics = 0.5787		
SPOT VGT 23 July 2011 (Maturity 100%) *Fundulea* test area					
Winter crops	19	23	12	63.16	52.17
Spring crops	28	23	17	60.71	73.91
Totals	48	48	29		
Overall Classification Accuracy = 60.42 %			Overall Kappa Statistics = 0.2531		

CONCLUSIONS

The supervised MLC of PROBA-V SD on both test areas show a higher overall accuracy (72÷82%) compared to SPOT VEGETATION classifications (57÷60%). This can be attributed to the higher spatial resolution of PROBA-V SD considering the size of the fields in the test area. Winter crops were better separated (producers accuracy 83.61%; users accuracy 68.00%) from spring crops (producers accuracy 62.50%; users accuracy 80.00%) on the PROBA-V SD image (7 July 2011) on *Zhiten* test area (Bulgaria). The same conclusion holds good for the MLC of PROBA-V SD (23 July 2011) for *Fundulea* test area, where the winter crops (producers accuracy 98.25%; users accuracy 79.62%) are better discriminated from spring crops (producers accuracy 57.47%; users accuracy 90.91%).

Altogether, PROBA-V SD performs better than SPOT VEGETATION in supervised classifications of winter and spring crops.

ACKNOWLEDGEMENTS

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