Comparative Analysis of Land-Use/Land-Cover 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 the SPOT VEGETATION, MODIS, and NOAA AVHRR, makes real-time and near-real time earth observation (EO) data indispensable for monitoring of world vegetation resources. The data continuity of SPOT VEGETATION mission is to be ensured by PROBA-V ("V" standing for "Vegetation"). The present study aims to reveal the potentialities of PROBA-V mission and its comparative advantages to SPOT VEGETATION mission based on comparison of accuracy assessments of land-use/land-cover maps. The scope of the study is achieved by using unsupervised ISODATA and supervised maximum likelihood classification (MLC) algorithms on a single-date PROBA-V simulated data and SPOT VEGETATION images, and comparison of classification accuracies. The results show that single-date PROBA-V simulated images provide better land-use/land-cover classifications compared to SPOT VEGETATION with 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 using land-use/land-cover maps with its high User's and Producer's accuracy.

1. Introduction

The environmental changes caused by the interactions of natural and anthropogenic factors results in diverse land-use/land-cover (LU/LC) pattern across the globe. With the increasing anthropogenic pressure over the natural landscapes there is a need of contemporary LU/LC data at various spatial scales. The accuracy and timely availability of such data is of crucial importance for its usefulness, either as an aid for policymakers, or as a basis for climate change, ecosystem/landscape or land-use modelling. At present, there are numerous examples of using low resolution satellite data for LU/LC 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 mid 2012 by Belgium [1]. This instrument has four spectral bands identical to these 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 to compare LU/LC classification results from SPOT VEGETATION and PROBA-V based on accuracy assessment. The subject of study is arable lands on the territory of Zhiten test area (Bulgaria) and Fundulea test area (Romania). The study objective is to implement a referent LU/LC classification scheme for the comparative analysis of the accuracy assessment of supervised LU/LC classifications of PROBA-V simulated data (SD) and SPOT VEGETATION images on both test areas.

1.1. 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).

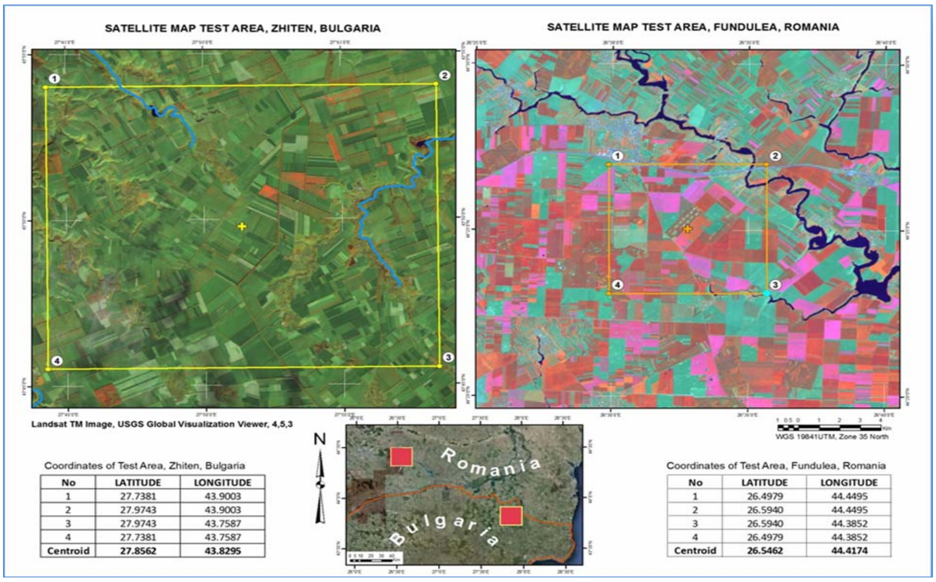

Figure 1: Overview map of the Zhiten test area (Bulgaria) and Fundulea test area (Romania).

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 next year. The summer crops are sown in April and harvested in August. Some small crofts, which are sized below the spatial resolution of PROBA-V and SPOT VEGETATION, are occupied by orchards, vineyards and other agricultural crops.

2. Methods

In the present study two single-date PROBA-V L2A simulated products derived from high Spatial Resolution (SR) satellite images (Table 1) and two single-date SPOT VEGETATION S1 products from the same dates were used. At that time, winter crops are in the *Maturity 100%* phenological stage, while spring crops are in the *Flowering* (sunflower) and *Leaf formation* (maize) phenological stages. Simulation of PROBA-V data was carried out by VITO-BE (Flemish Institute for Technological Research - Belgium) 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 high SR images used for the simulation of the corresponding PROBA-V bands are presented on Table 1.

Table 1. The corresponding bands of the high SR images used for PROBA-V simulation.

Proba-V bands (μm)	Corresponding ALI bands (μm)	Corresponding Landsat 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)

Output data from the simulation in the form of Top Of the Atmosphere (TOA) reflectance and cell size of approximately 150 × 150 m for VNIR bands and 300 × 300 m for SWIR band was used. These images were georeferenced and resampled to the planned PROBA-V spatial resolution, i.e. 300 m for VNIR and 600 m for SWIR band, using the nearest neighbour method. After that, the individual bands were stacked into one file with cell size of 300 m. As a result, it became possible to use the SWIR band in LU/LC classifications jointly with the other bands.

SPOT VEGETATION S1 images were received from VITO-BE upon submission of a project proposal for data. The 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 projection UTM, Zone 35N, datum WGS84. The image's bands were also converted from Digital Numbers (DN) to radiances by applying equation 1, [5]:

$$Radiances=0.004.DN-0.1 \quad (1)$$

The study methodology used in present work is presented on Figure 1.

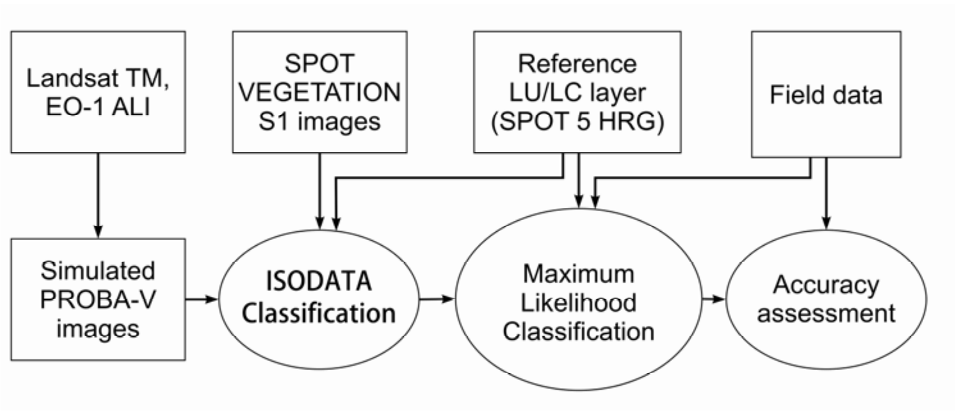

Figure 2: Flowchart of the study methodology.

In order to assess the spectral domain of both radiometers and to provide the reference layer for the test sites, LU/LC maps based on unsupervised Iterative Self-Organizing Data Analysis Technique Algorithm (ISODATA) clustering were prepared. The ISODATA clustering method uses spectral distance to classify iteratively the pixels, redefines 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. After the unsupervised classification, an assignment of LU/LC class names to each class was made.

The Supervised classification using 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 allow the formation of 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. Reference LU/LC layer derived from SPOT 5 HRG image from 21.04.2011 have served as reference information in the accuracy assessment. Stratified random sample of 250 points was used for accuracy assessment of each classification output from MLC. The percent of overall accuracy, producers, and users' accuracy and the Kappa statistic, for each class were assessed.

The LU/LC classification scheme used is based on GLC2000 [10], [11]. The GLC2000 legend was used to assign names to the classified images and was modified with an additional classification scheme level representing the type of the crops – "cultivated and managed areas" class that shall be present in the images. Two LU/LC classes within the "cultivated and managed areas" class were recognised depending on the date of the images acquisition: 1) winter crops (winter wheat and rapeseed) and 2) spring crops (sunflower and maize).

3. Results

A series of unsupervised classifications with 5 classes at 95% Confidence Intervals (CI) have been prepared. They have been used for finding spectrally homogeneous Area Of Interest (AOI) for subsequent supervised LU/LC classification. ISODATA classes have not been mapped accurately to the LU/LC classes from GLC2000 due to mixing up the 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 discriminate spectrally up to 2 classes in the arable lands of the test sites.

The classification outputs of PROBA-V SD and SPOT VEGETATION LU/LC 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 on Figure 2. The results from 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 stage next to each date of image acquisition is after [12].

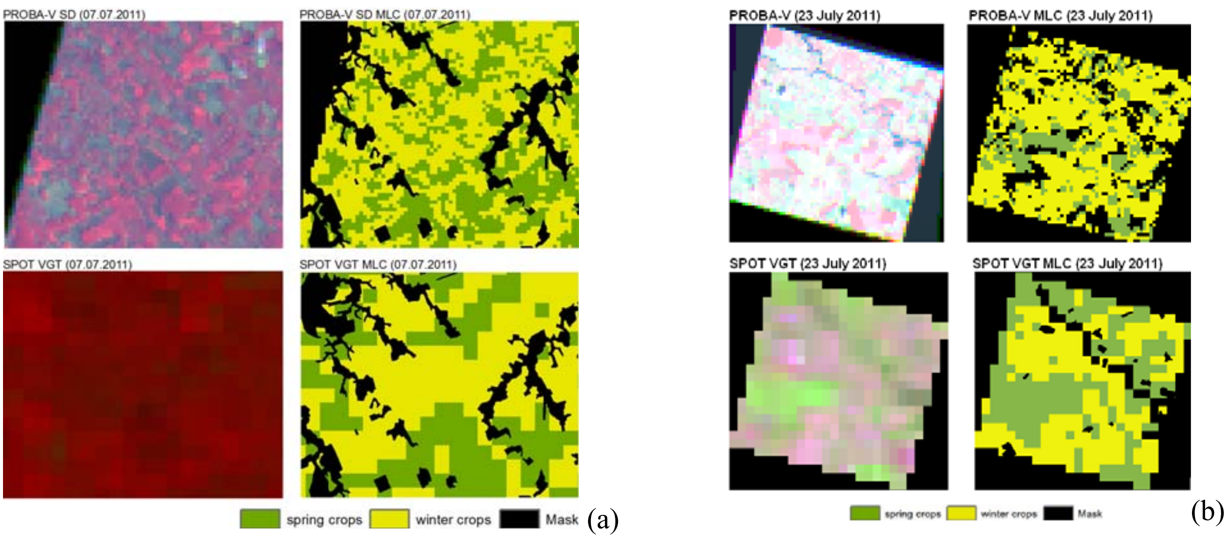

Figure 3: Supervised MLC of LU/LC on PROBA-V SD and SPOT VEGETATION images for Zhiten test area (Bulgaria) (a) and Fundulea test area (Romania) (b) (Maturity 100%).

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		

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 in July 2011 is also confirmed from the classifications on the *Fundulea* test area (Romania). The results showed that single-date PROBA-V simulated images provide for better land-use/land-cover classifications than those from SPOT VEGETATION with 15 to 22 % higher overall accuracy, and Kappa statistics of 0.31 to 0.33 higher for *Zhiten* test area (Bulgaria) and *Fundulea* test area (Romania) respectively.

4. Conclusions

The supervised LU/LC MLC of PROBA-V SD on both test areas have 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 holds for the MLC of LU/LC on 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%).

In conclusion, PROBA-V performs comparatively better than SPOT VEGETATION in LU/LC supervised classifications of winter and spring crops.

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