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CROP INVESTIGATION USING HIGH-RESOLUTION WORLDVIEW-1 AND QUICKBIRD-2 SATELLITE IMAGES ON A TEST SITE IN BULGARIA

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Abstract

The paper aims to investigate the capabilities of using high-resolution satellite images: panchromatic WorldView-1 satellite image acquired on 30/11/2011 and multispectral QuickBird-2 satellite image acquired on 31/05/2009 for crop analysis, which includes crop identification, crop condition assessment and crop area estimates applications in Bulgaria using the power and flexibility of ERDAS IMAGINE tools. The crop identification was accomplished using unsupervised and supervised classification processing techniques using as reference ground data. After the supervised classification, fuzzy convolution filter was applied to reduce the mixed pixels using ERDAS Imagine software. Accuracy totals, error matrix and kappa statistics were calculated using accuracy assessment tool in ERDAS Imagine to assess the quality of the classification process. Crop condition assessment was accomplished using the derived Normalized Difference Vegetation Index (NDVI) image from the QuickBird-2 image, which was reclassified and was given meaningful estimations on the crop condition. Crop area was estimated using pixel counting approach. Pixel counting methods are known for introducing bias to the crop area estimates but using the high Overall Accuracy of 90.86% and overall Kappa Statistics of 0.8538 for the classified QuickBird-2 image and Overall Accuracy of 86.71% and overall Kappa Statistics of 0.7721% for the classified WorldView-1 allows that option to be utilized according to (Gallego, 2004). As a conclusion it can be stated that using the benefits that high-resolution satellite images gives in combination with the power and flexibility of ERDAS Imagine tools, crop identification can be achieved more accurately by increasing the identification accuracy and also by having the necessary ground information for selecting appropriate training samples. Crop identification by applying an arable mask is better practice, because it is reducing the mixed pixels problem i.e. also known as "salt and pepper effect" (common for coarse and low resolution satellite images), As a result it is making the map products much more useful thus making more accurate crop area estimates when pixel counting methods are used.

1. Introduction

Accurately identifying crops using information derived from earth observation can contribute to improved use of resources and aids agricultural planning. On the other hand, using high- resolution satellite images is useful for delineation of crop fields and accurate crop area estimates. In the past, remote sensing has been shown to be valuable tool in separate applications in agriculture. Remote sensing techniques have been successfully applied in classifications of arable crops and in quantification of vegetation characteristics at different spatial and temporal scales. The crop discrimination and mapping using space data is carried out either by visual or digital interpretation techniques. Visual techniques generally are based on standard FCC (False Color Composite) generated using green, red and near-IR bands assigned blue, green and red colors. The digital techniques are applied to each pixel and use full dynamic range of observations and are preferred for crop discrimination. The field size was shown to have a strong effect on classification accuracy with small fields tending to have lower accuracies even when the effect of mixed pixels was eliminated (Batista et al. 1985; Buechel et al. 1989). Medhavy et al. (1993) showed that when supervised classification is adopted, use of training strategy based on selection of isolated pixels has higher classification accuracy than selecting blocks of pixels as training set.

- Scope of the research

The agricultural land in Bulgaria in its majority is represented by small in size fields with mixed crops, which makes the crop identification process rather difficult by applying coarse and low resolution satellite images, caused by the mixed pixel occurrence. The current paper will apply high-resolution satellite images for investigation of crops. Utilizing the capabilities of high-resolution imagery will give opportunity to investigate the possibilities of crop identification, crop condition assessment and crop area estimates on a test site in Bulgaria. The QuickBird-2 satellite image gives a substantial opportunity of identifying crops and crop condition analysis with its spectral and spatial resolution and the WorldView-1 image for crop area estimates using its spatial resolution. Using high-resolution satellite images aids precision agriculture applications as well, which will be attempted in this paper. The RED and NIR bands have traditionally great application in crop conditions assessment by deriving Normalized

Difference Vegetation Index (NDVI) images (Rouse, 1973). The objectives of the present paper are highlighted below:

- Identifying appropriate sample fields and training samples for different crops like: winter wheat, winter rapeseed, grain maize and sunflower using collected ground truth data.
- Using one panchromatic WorldView-1 and one multispectral QuickBird-2 satellite images for crop identification and crop area estimation applications on a test site in Bulgaria.
- To classify the test site using unsupervised classifiers (ISODATA algorithm) and supervised (Maximum Likelihood classifier).
- Calculate the accuracy assessment of the classified images using accuracy assessment tool and evaluate the crop classes classified.
- Deriving conclusions for crop condition assessment and precision agriculture using multispectral QuickBird-2 satellite image and reclassified NDVI image.
- Assessing crop area estimates using the classified images by applying pixel counting methods.

- Study Area

The test area of Zhiten is one of the Bulgarian Aero-Space Test Sites (BASTS) and is associated with investigating agricultural applications using satellite images with different spatial, spectral and temporal resolution on the territory of Bulgaria (Figure 1.). The test site is located in Dobrich Region, North-East Bulgaria, and represents intensively cultivated area sowed mostly with cereals and sunflower. This territory is one of the main agricultural regions of the country. The geology is presented mainly by Miocene limestone, clay and marl covered subsequently by loess. The region is about 200 m a.s.l. Its relief is characterized by wide, flat ridges and steep-sided dry valleys. The area is part of the European-continental climatic province of the temperate climatic belt. Climate is moderately warm with no distinctive dry season. Mean annual air temperature is 10.2°C. Precipitation maximum is in June and minimum – in February. Overall annual precipitation is 540 mm. Due to the carbonate bedrock, i.e limestone, marl, the hydrographic network is represented by intermittent streams. The main soil types are chernozems from zonal ones and fluvisols from azonal ones.

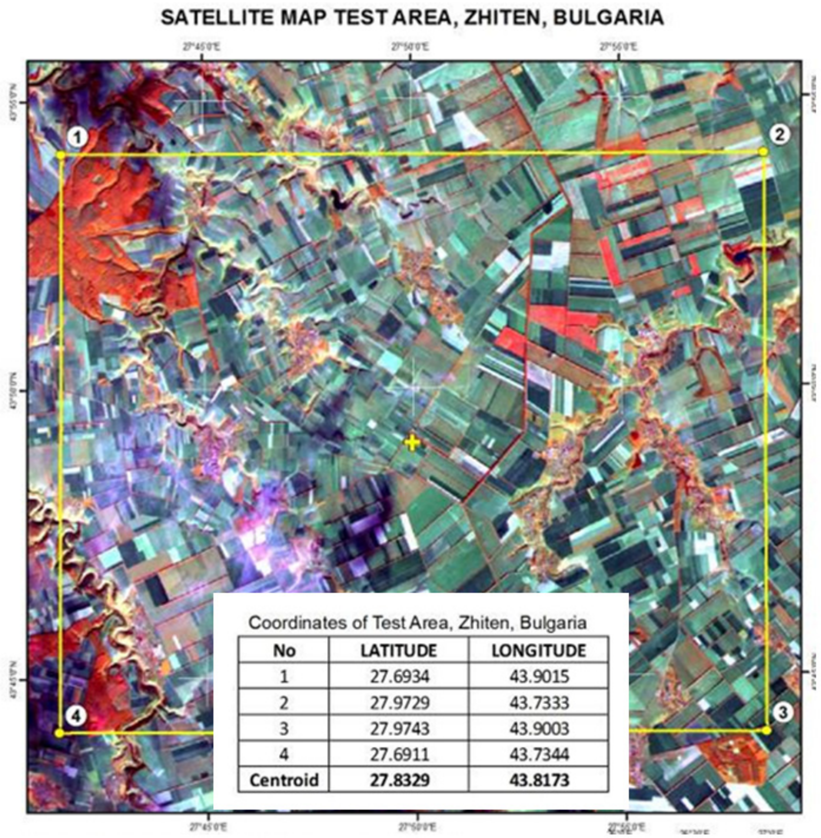

Fig. 1. Zhiten test site, Bulgaria

- **Collection of field data and used satellite images**

During the 2010-2011 agricultural season and in particular in the period between March–July 2011 four exhaustive field surveys were carried out and ground data was collected and organized in a geodatabase. Field data was collected in the framework of a project financed by the Belgian Federal Science Policy Office (BELSPO) under the PROBA-V Preparatory Programme, contract Ref. No CB/XX/16, with acronym – PROAGROBURO (http://proagroburo.meteoromania.ro/). The ground-truth data consists of descriptions of the LU/LC types, phenological stages and total projective cover (TPC) of crops, GPS measurements, and photos. The collected ground data will contribute of selecting appropriate training samples for the supervised classification on the chosen satellite images. Two satellite images were used in this study: a WorldView-1 panchromatic satellite image with 0.50m spatial resolution, acquired on 30/11/2011 and QuickBird-2 multispectral (2.4m spatial resolution) and panchromatic image (with 0.60m spatial resolution), acquired on 31/05/2009 (Figure 2).

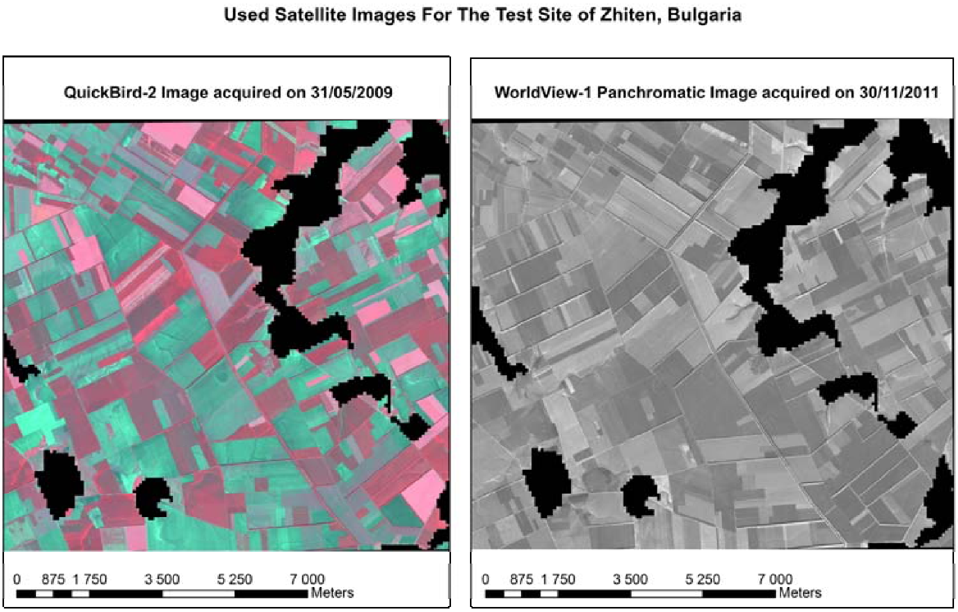

Fig. 2. Used satellite images

2. Methodology

An arable land mask using CORINE data was applied on the images used for the research in order to work only with the arable land. For the process of crop identification and crop area estimates, unsupervised and supervised classifications were used which is common method for mapping crops, utilizing also the ground information collected. Fuzzy convolution filter option was used to reduce the mixed pixel problem using ERDAS Imagine software. After applying the image classifications, accuracy assessment tool was used and the accuracy totals, error matrix and kappa statistics was calculated and the high overall accuracy assessment of the satellite images was used for crop area estimation applying pixel counting methods. Crop condition assessment was accomplished using the supervised classification and also by composing an NDVI image from the QuickBird-2 image and reclassifying the image to differentiate between crops in good or bad vegetation status on the test site. All the benefits that these high-resolution satellite images give makes it possible to conduct rather quick and interesting research which provides without a doubt intriguing results concerning crop identification, crop condition assessment and crop area estimated using ERDAS Imagine software (Figure 3).

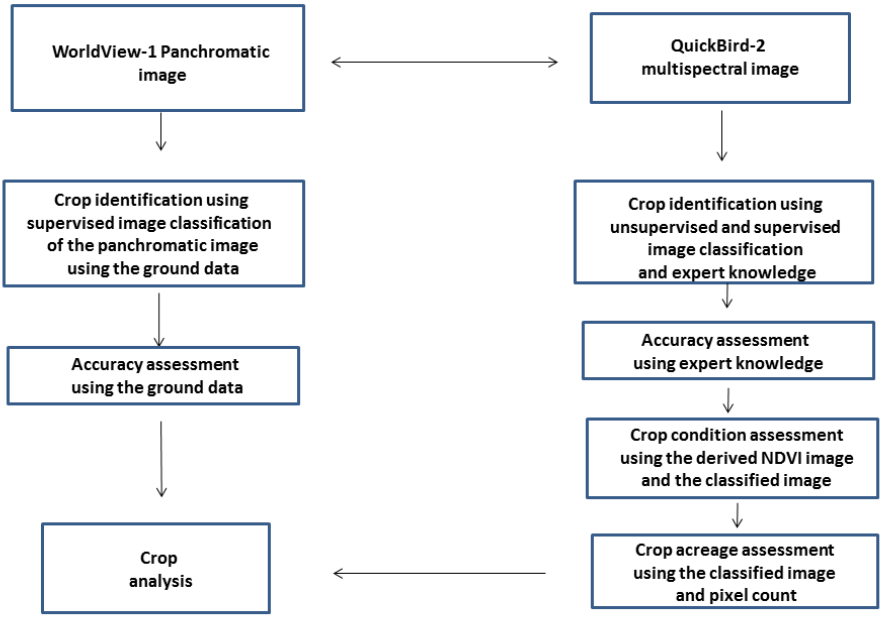

Fig. 3. Methodology of the research

3. Results and discussions

3.1. Crop identification by applying unsupervised and supervised classifications

An arable land mask using CORINE data was applied on the WorldView-1 and the QuickBird-2 images in order to classify only the arable land and reduce the occurrence of mixed pixels. The WorldView-1 image is acquired on 30/11/2011 and was used for delineation of crop fields using its spatial resolution and the fact that it is acquired in the year of the field data collection surveys. The QuickBird-2 image is acquired on 31/05/2009 and although it does not coincide with the ground surveys of the territory of research that were undergone was used for crop analysis of the territory of research. The reason behind that decision was that the rate of land cover change in the test site is not great and the use of image from previous year can be used without introducing severe bias in the analysis. The crop identification process was accomplished firstly by conducting unsupervised classification (using ISODATA algorithm) with 4-5 classes for both the QuickBird-2 and WorldView-1 image and for the derived NDVI image from the QuickBird-2 satellite image. The purpose of that step is to use that spectral information derived as an indicator on which fields to use as training samples for the supervised classification in combination with the ground data. The unsupervised classification is traditionally the first step and is accommodating the interpreter to understand the image. Supervised classification using the Maximum Likelihood Classification (MLC) algorithm was applied to the arable land images (Figure 4 and 5). In the MLC procedure, a key concern is to collect a training set comprising of at least 10–30 independent training cases per class per discriminatory variable (e.g. band) to allow the formation of a representative description of the class, so that its mean and variance can be reasonably estimated (Piper, 1992; Mather, 2004). For example, the spectral response of an agricultural crop class in an image might vary as a function of variables, such as: the crops growth stage, topographic position, density of cover, health, impact of management activities, substrate conditions and instrument view angle (Foody, 2002). The gathered training set from the field data was good enough to make representative training samples for the arable land classes. The unsupervised classification in combination with the ground information and the derived NDVI image helped to choose and delineate appropriate training samples for the supervised classification of the QuickBird-2 image. The classes chosen for the QuickBird-2 image are: Stubble fields/bare soil, Spring Crops – Sunflower and Maize, Bad Status – Winter Wheat/Winter Rapeseed, Average Status – Winter Wheat/Winter Rapeseed and Good Status – Winter Wheat/ Rapeseed. From (Figure. 4) it can be seen that some fields are in bad vegetative status, this can be due to late planting or utilizing different types of winter crops seeds, which can result in late developing stage of winter wheat/rapeseed crops. Average status of winter wheat/rapeseed class can be explained with delayed cropping procedures, which outcomes in experiencing low vigor status. While the good status –

Winter wheat/rapeseed class is in the best vigor status for the period of acquisition of the satellite image – 31/05.2009. This is also proved by the NDVI image derived (Figure 8).

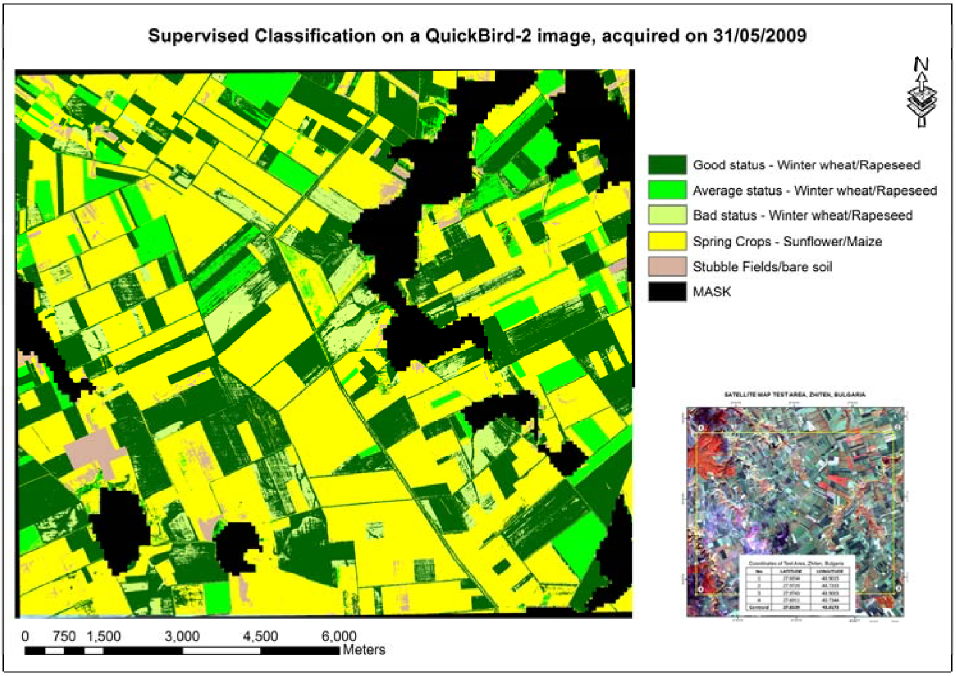

Fig. 4. Supervised classification on a QuickBird-2 image, acquired on 31/05/2009

Supervised classification was conducted on the panchromatic WorldView-1 image, acquired on 30/11/2011 as well (Figure 5). The classes that are classified are: Stubble fields, spring crops represented by sunflower and maize and the class winter crops, represented by winter wheat and winter rapeseed. For the panchromatic image classification the actual choice of training samples was marginally more difficult. For assessing the training samples a big effect played the ground data which helped point out appropriate training samples, although the ground surveys took place couple of months earlier. A rather important part of the study is that after the supervised classification a fuzzy convolution filter followed which was applied to the final resulted supervised classifications by using ERDAS Imagine software. The purpose was to smooth and try to reduce the mixed pixel effect on the classified images. As a result better cartographic product was possible to be visualized and supports more accurate crop area estimates.

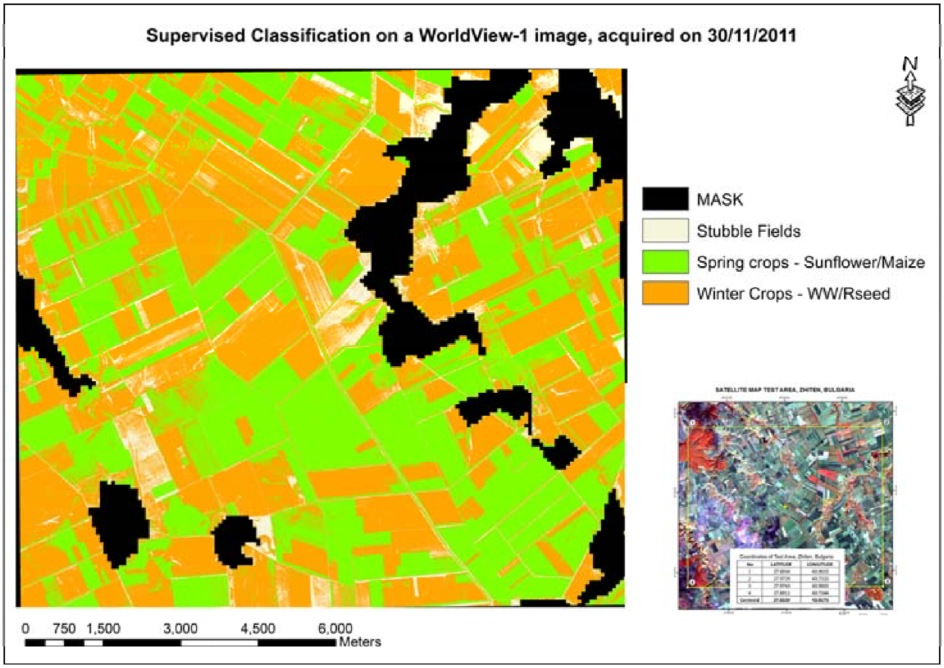

Fig. 5. Supervised classification on a WorldView-1 image, acquired on 30/11/2011

3.2. Accuracy Assessment

The accuracy assessment was accomplished using the fuzzy convolution classified images and the accuracy assessment tool in ERDAS Imagine software. Around 160-170 randomly distributed points were assessed for both classified images. Accuracy assessment was applied on the WorldView-1 classified image for crop identification using its high spatial resolution by applying visual interpretation on the panchromatic and both on the unsupervised and supervised classifications in combination with the ground data (Figure 6.). The accuracy totals show overall classification accuracy of 86.71% and overall kappa statistics of 0.7721 (Table 1.). The class stubble fields show high accuracy. This is due to the fact that the class is easily identified both on the unsupervised classification and on the panchromatic image. The choice of good and representative training sample was achieved by using visual interpretation techniques utilizing the high spatial resolution. The actual strong point of this supervised classification on this panchromatic WorldView-1 satellite image is the other two classes – winter crops and spring crops.

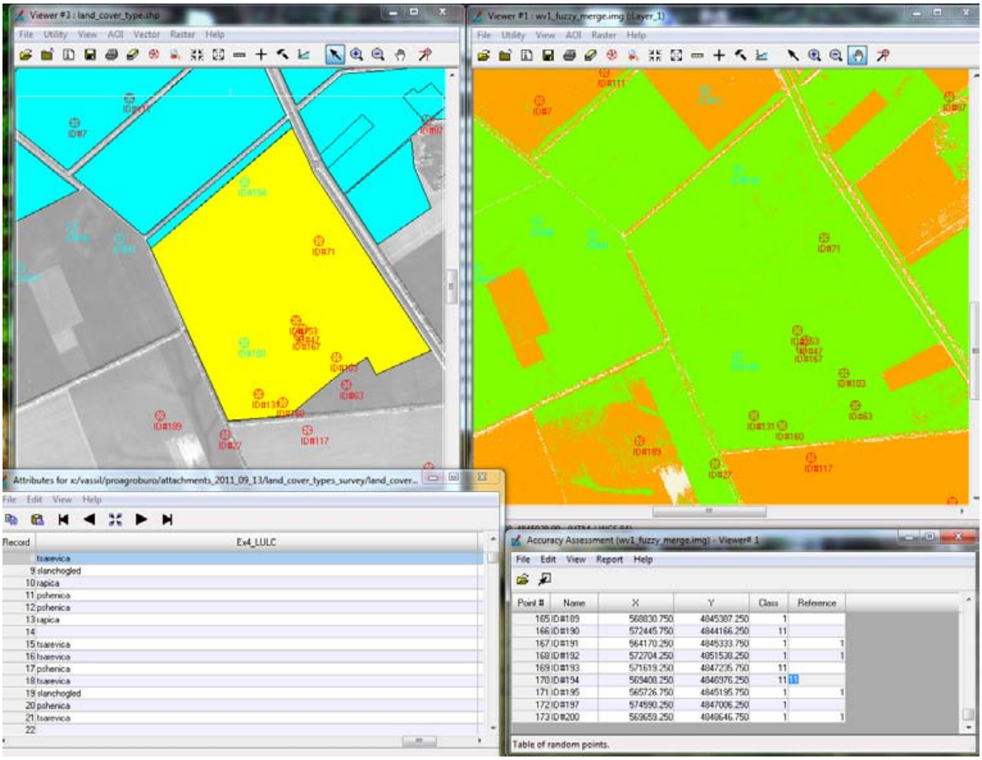

Fig. 6. Accuracy assessment on a WorldView-1 image

For both classes the producer and users accuracy is above 83%, which is quite a reasonable accuracy. For both classes the reference totals are more than 70 points, which makes the accuracy assessment process reliable. The high accuracy assessment is most likely due to the reference data used (unsupervised and supervised classification also with the ground data used) and the good choice of training samples, which is the most important thing for the classification process. It is not common practice to classify panchromatic images but nevertheless the high overall accuracy shows encouraging results.

Table 1. Accuracy totals for WorldView-1 image

Class name	Reference Totals	Classified Totals	Number Correct	Producer Accuracy	Users Accuracy
MASK	0	0	0	-	-
Stubble Fields	19	15	14	73.68%	93.33%
Winter Crops – winter wheat/Winter Rapeseed	73	77	64	87.67%	83.12%
Spring Crops – Sunflower/Maize	81	81	72	88.89%	88.89%
Totals	173	173	150	-	-

The accuracy assessment of the QuickBird-2 satellite image was accomplished using the fuzzy supervised classification and the accuracy assessment tool in ERDAS Imagine software (Figure 7). Randomly distributed 175 points were used (Table 2). The overall classification accuracy is 90.86% and overall kappa statistics is 0.8538. The class stubble field is with high accuracy, the reason is that the class is easily identified using the multispectral QuickBird-2 image. In this case the precise delineation of the training sample in ERDAS Imagine is the key for achieving high accuracy. The class spring crops, represented by sunflower and maize are with extremely high accuracy (Table 2.), with 90 reference points used for assessment of that class, which suggest that the accuracy assessment is reliable.

Considering the acquisition date of the QuickBird-2 image – 31/05/2009 the identification of spring crops is accomplished using the unsupervised classification in combination with the derived NDVI image. All this information accompanied with the ground surveys, although done 2 years later help the analyst. Thus some rotations of the crops is undergone this will inevitably help in assessing the accuracy of the supervised classification better. The class good status – winter wheat and winter rapeseed is with relatively high accuracy, with both the producer and users accuracy are above 85%. The high accuracy is due to the good information that was extracted from the derived NDVI image. The NDVI image was used to establish and to select good training samples for the supervised classification. A big advantage was also using the unsupervised classification, which in many cases gives the right set of mind in order to appoint appropriate training samples.

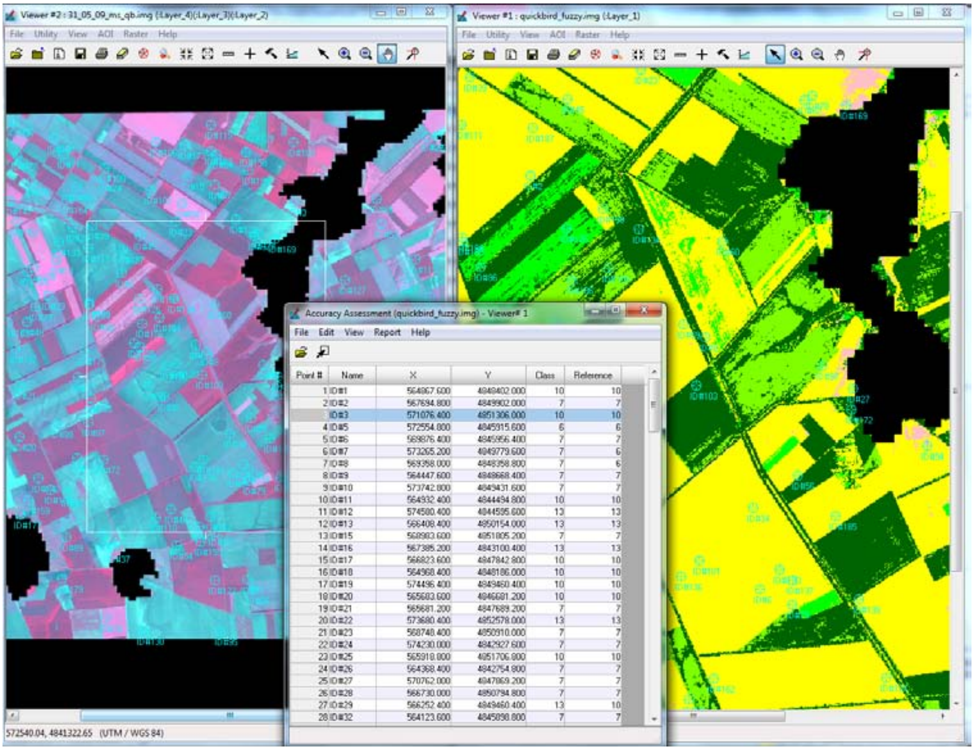

Fig. 7. Accuracy assessment on a QuickBird-2 image

Looking at the accuracy totals, the classes that are experiencing lower accuracies are the average status class and bad status class of winter wheat and winter rapeseed, with both of them having producers accuracy around 60%, although the users accuracy for both classes is above 90% (Table 2). The lower producers accuracy is probably due to the fact that these classes are representing different status of winter crops, which is always difficult to apply. The idea behind these two classes is indeed to try to identify different status of the winter wheat and winter rapeseed. The two classes are actually attempt to apply precision agriculture on the test site fields and identify where the winter crops are experiencing growth problems. This is very useful information if it can be delivered in real time or almost real time, so precision agriculture practices can be applied on specific places on the fields. For the time being this application is difficult to be put in practice considering the problems of high-resolution data acquisitions. But in the future this could be feasible.

Table 2. Accuracy totals for QuickBird-2 image

Class name	Reference Totals	Classified Totals	Number Correct	Producer Accuracy	Users Accuracy
MASK	0	0	0	-	-
Stubble Fields	6	5	5	83.33%	100.00%
Bad Status – winter crops	14	8	8	57.14%	100.00%
Average Status – winter crops	21	15	14	66.67%	93.33%
Good Status – winter crops	44	48	42	95.45%	87.50%
Spring Crops – Sunflower/ Maize	90	99	90	100.00%	90.91%
Totals	175	175	159	-	-

3.3. Crop condition assessment

The crop condition assessment was applied using the NDVI image derived from bands 3 and 4 of the QuickBird-2 image, representing RED and NIR spectral bands respectively. The Normalized Difference Vegetation Index (NDVI) is calculated as follows:

$$NDVI = \frac{(NIR - VIS)}{(NIR + VIS)},$$

where VIS and NIR stand for the spectral reflectance measurements acquired in the visible (RED) and near-infrared regions (NIR), respectively (Rouse, 1973).

The NDVI image was used to identify the main groups of crops based on the presence of vigor of green vegetation within the fields. Precision agriculture analysis is attempted using the high spatial resolution NDVI image. Considering the time of acquisition of the QuickBird-2 satellite image, a reclassification of the derived NDVI image was undergone in order to give reasonable meaning of the NDVI index and to try to establish differences between crops with good condition and these experiencing late development or bad vigor status and map that crop condition for each crop field (Figure 8).

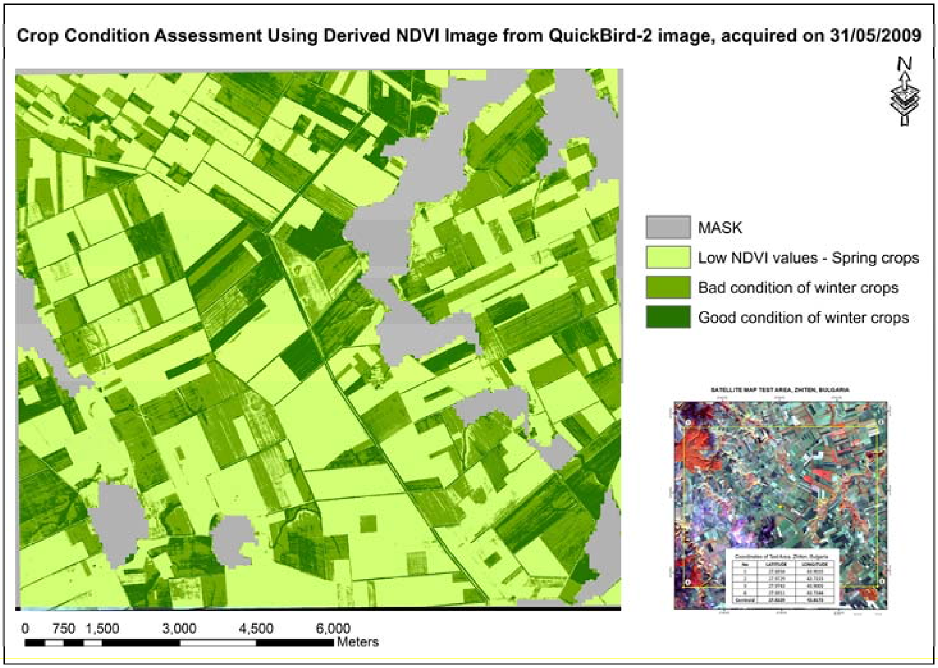

Fig. 8. Crop condition assessment using derived NDVI image from QuickBird-2 image

The NDVI image was reclassified using as reference the unsupervised and supervised classification and the histogram of the QuickBird-2 image. It was quite a challenge to establish reasonable thresholds for that matter. It was decided to divide the NDVI image in three classes – low NDVI, which in that acquisition date (31/05/2009) will represent the spring crops. The other two classes will be separated depending on their condition, which will be defined by either bad or good conditions. From the map it is quite easy to understand that the class spring crops is homogenous, which is due to the development stage of these crops and the NDVI doesn't separate them at the current stage. The conclusions that you can draw from that map can give some clear idea where the agronomical procedures were appropriate and as a result the crop status is good and where the agricultural practices were not so suitable, either not applied on appropriate date or using inappropriate products for plant protection. Having that information in short time frame will really make a difference in all stages of crop development, where each agronomical practice should be carefully planned and accurately and precisely executed by the farmers.

3.4. Crop area estimation

The crop area estimates were calculated for both classified images WorldView-1 and QuickBird-2 using the fuzzy supervised classifications. The crop area estimates are calculated using the followed formula: number of pixels for each class of the classified image multiplied by the area represented by each pixel (Gallego, 2004). This method was selected because the overall classification accuracy was high enough to apply that method and in the same time not introducing bid bias. The crop area estimated for the WorldView-1 image show (Figure 9.) the following distribution: 36% class spring crops, 45% class winter crops and 6% of class Stubble fields. The mask class is 13% from the scene used.

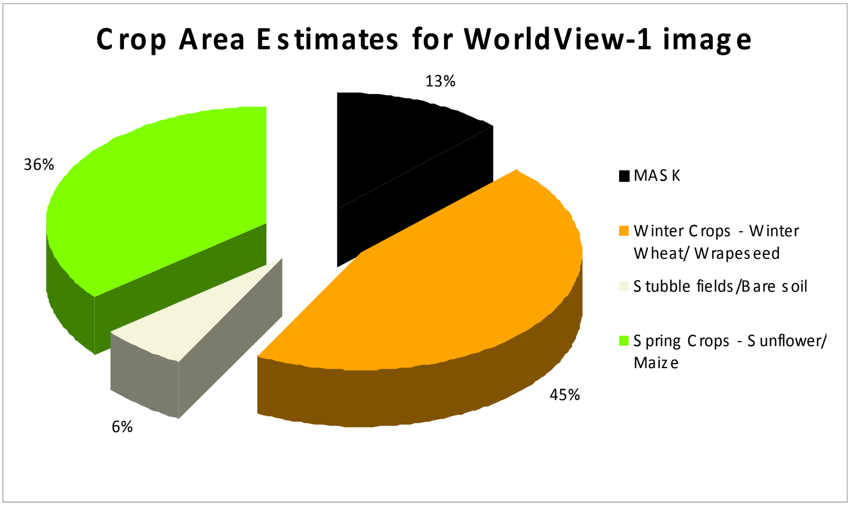

Fig. 9. Crop area estimates for WorldView-1 image

The crop area estimates for the QuickBird-2 classified image show the following figures (Figure 10): The class spring crops represents 43% of the studied territory. The sum of 42% is represented by winter crops, divided by status: 28% - good status, 8% - average status and 6% - bad status. Only 2%

represent stubble field class, which is reasonable having in mind the acquisition date of the satellite image – 31/05/2009. The stubble fields are the territories left for fallow lands for that agricultural year.

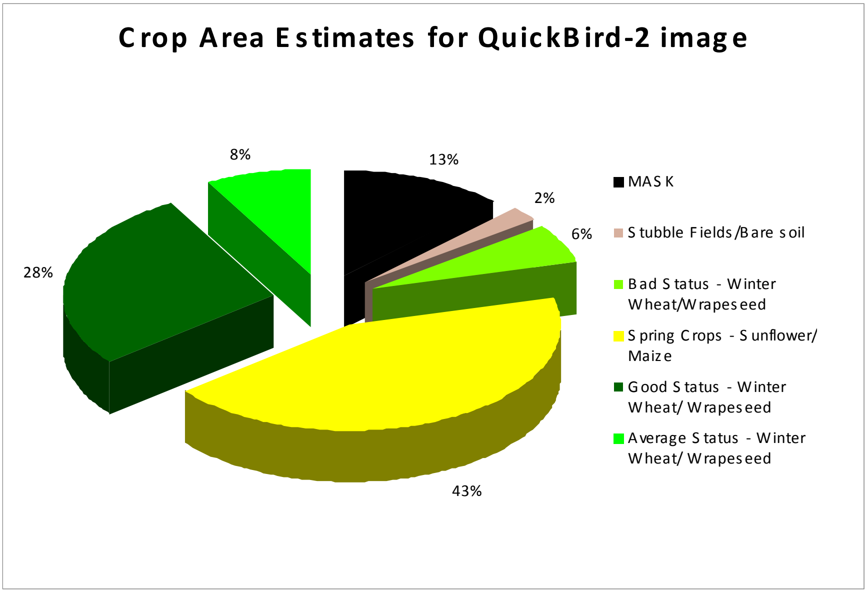

Fig. 10. Crop area estimates for QuickBird-2 image

4. Conclusions and future work

Using high-resolution satellite images in combination with ground data can be a strong combination for making crop analysis. High-resolution satellite images make it possible to accomplish accurate and precise crop identification on arable land. Thus, assessing crop condition and making some conclusions on crop status. Using NDVI as an indicator of crop condition is commonly used practice and is giving reliable results. The high accuracy assessment of both WorldView-1 and QuickBird-2 satellite images makes the crop area estimates as much as accurate as possible using the pixel counting approach. As a conclusion from the crop area estimated it can be highlighted that although the supervised classifications were applied on one panchromatic and one multispectral image, in different agricultural years, the results are almost identical (Figure 9 and 10). This can only be explained with the high accuracy of the research conducted and that the spatial distribution of winter crops and spring crops is well regulated on the test site. Having good and reliable ground data has proven to be of great use together with expert knowledge from the analyst. This research is one of the first applying high-resolution satellite images on that test site. The encouraging results will be used for future work related with attempts of getting even more accurate estimates and applying coarse and low resolution satellite images on the same test site and using the achieved result from this research for validation of low-resolution vegetation products.

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АНАЛИЗ НА ЗЕМЕДЕЛСКИТЕ КУЛТУРИ ПО СПЪТНИКОВИ ИЗОБРАЖЕНИЯ СЪС СВРЪХ-ВИСОКА ПРОСТРАНСТВЕНА РАЗДЕЛИТЕЛНА СПОСОБНОСТ ОТ WORLDVIEW-1 И QUICKBIRD-2 ЗА ТЕСТОВИ УЧАСТЪК НА ТЕРИТОРИЯТА НА БЪЛГАРИЯ

В. Василев

Резюме

Целта на настоящият доклад е да се изследват възможностите при спътникови изображения със свръх-висока пространствена разделителна способност от панхроматично изображение на WorldView-1 и многоканално изображение на QuickBird-2, заснети на 30.11.2011г. и 31.05.2009г. съответно за земеделски приложения, включващи разпознаване на земеделски посеви, оценка състоянието и оценка на площите. Разпознаването на земеделските посеви е извършено, чрез прилагане на неконтролирана и контролирана класификация. След контролираната класификация, фъзи филтър е приложен за да се ограничи проблема със смесените пиксели, използвайки програмния продукт ERDAS Imagine. Обща точност, матрица на грешките и капа статистика са изчислени при оцеката на точността, с цел проверка на резултата от класификациите. Оценка състоянието на земеделските култури е извършена на базата на изчисление на Нормираният Разликов Вегетационен Индекс (NDVI) за изображението на QuickBird-2, което бе рекласифицирано на основата на хистограмата си. Оценка на площите е изчислена по принципа на (Gallego, 2004), където се преброяват класифицираните пиксели. Този подход не дава най-надеждни резултати, но при обща точност за изображението на QuickBird-2 от 90.86% и 86.71% за изображението на WorldView-1 дава възможност да се приложи. Прилагането на маска на обработваемите земи с цел разпознаване на земеделските култури е по-добрия подход, защото ограничава проблема със смесения пиксел.