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CROP MONITORING USING SPOT-VGT NDVIs S10 TIME-SERIES PRODUCT FOR THE ARABLE LAND OF BULGARIA

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Abstract
The objects of investigation are the major crops in Bulgaria (winter wheat, winter barley, sunflower and maize). The purpose of this paper is to 1) identify major crops using satellite data with low spatial resolution of 1000 m using agro-phenological information; 2) monitoring based on NDVI time-series values for the years 2007, 2008 and 2010, where anomaly events occur based on the information in the National Institute of Meteorology and Hydrology at the Bulgarian Academy of Sciences (NIMH-BAS) agrometeorological monthly bulletins. The current paper shows the massive potential of using low spatial resolution satellite data in identfying crops and monitoring the development anomalies on crops. This research will contribute in applying and elaborating JRC MARS methodology in Bulgaria by using low resolution SPOT-VGT NDVIs S10 satellite product.

Introduction

Satellite remote sensing (RS) provides synoptic, objective and homogeneous data, which can be geographically and temporally registered, and therefore, could be an efficient tool for providing standard, high quality information on agriculture, evenly over the whole of Europe. The Monitoring Agriculture with Remote Sensing (MARS) project of the European Union was established in order to define and demonstrate how RS could be used operationally to supplement, interpret, and standartize agricultural statistical data provided by conventional techniques (Meyer-Roux and Vossen, 1994; de Winne, 2004). Satellite remote sensing techniques have proven to be effective and useful in broad-scale agricultural surveys such as: large area crop inventory experiment (LACIE) in the USA and monitoring agriculture with remote sensing (MARS) in Europe (Cohen and Shoshany, 2002). Experiments such as Crop Identification Technology Assessment for Remote Sensing (CITARS) and Large Area Crop Inventory Experiment (LACIE) were conducted to demonstrate the capabilities of RS for crop inventory and forecasting (MacDonald, 1984; Blaes, 2005). Crop identification during the growing season is currently a major challenge for forecasting crop production as well as for controlling area-based subsidies (Blaes, 2005).

Materials and Methods

The whole arable territory of the Republic of Bulgaria was used for applying the proposed methology. The most commonly used vegetation index for agricultural applications using RS data is the Normalized Difference Vegetation Index (NDVI), expressed with the following formula:

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

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

Time-series of SPOT-VEGETATION NDVIs S10 smoothed actual product with spatial resolution of 1000 m. for three year (2007, 2008 and 2010), where anomaly events were observed, based on the information from the monthly bulletins from NIMH-BAS. Overall the used low-resolution satellite images for the study were 108.

The two major tasks are the following:

1) Identification of crops in the arable territory of Bulgaria, for the years 2007, 2008 and 2010, using the cluster analysis method upon a 10-day SPOT-VGT NDVIs S10 product by extracting agro-phenological information from the NIMH-BAS monthly bulletins;
2) Monitoring the NDVI time-series values for the years 2007, 2008 and 2010, where anomaly events occur based on the information of the NIMH-BAS monthly bulletins.

A complex approach has been undertaken in order to achieve the purpose of the study. The methodological scheme includes the sequence of the following working tasks Figure 1:

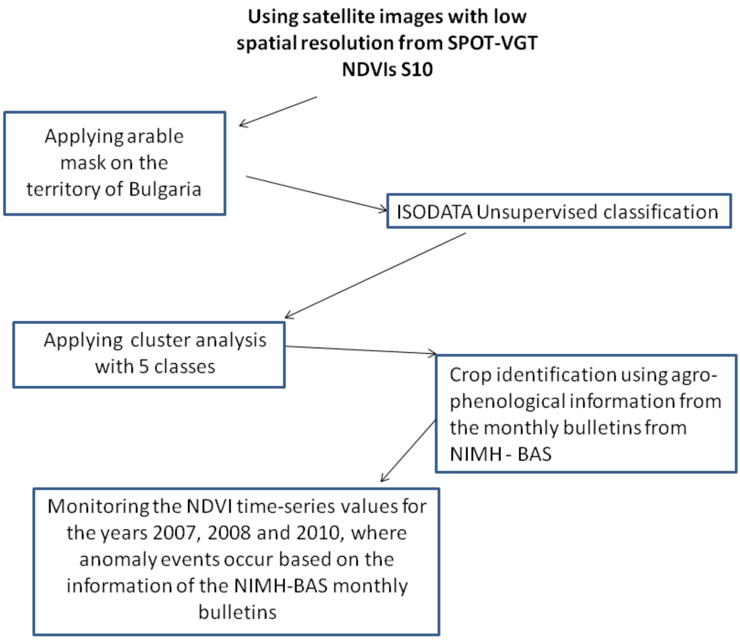


Fig. 1. Workflow of the study

Short desription of the methodology

An arable mask was applied in order to extract only the arable land using information from CORINE 2000 database and then aggregated to the spatial resolution of the used SPOT-VGT NDVIs S10 product – 1000 m. The images were stacked on yearly basis (one file with 36 bands, repsesenting the 36 decads of the year) in order to work with more concise data. Unsupervised ISODATA classification with five classes was used on the individual yearly stacked images in ERDAS Imagine software (Groom et al., 1996; Garcia-Consuerga and Cisneros, 1999; Yang et al., 1999). Using this method the arable territory of Bulgaria was devided into five clusters based on the differences of their spectral reflections. Following the classification, a cluster analysis was conducted, which extracts the mean NDVI values for each 10-day for every cluster separately. Using that information NDVI time-series profiles of the five clusters were created for the period January 01 – December 31, for each year (2007, 2008 and 2010). The crop identification process was accomplished using a summary table derived from the agro-phenological montly bulletins of National Institute of Meteorology and Hydrology at Bulgarian Academy of Sciences (NIMH-BAS) at the following web site - http://www.meteo.bg/, where information for the specific growth stages (phenophase), agro-technical theatments throughtout the growing season and some experienced anomaly events for each 10-day is given. Monitoring of these three years for every 10-day period was initiated using SPOT-VGT NDVIs S10 product in order to investigate its capabilities to detect anomaly events. The data absolutely corresponds to the temporal resolution of the satellite data that was used. The time-series profiles were interpreted and the major crops were identified using the ground data summarized in the table for each 10-day period The table includes the phonological stage and stage of deleopment for every 10-day periods of the year, information on the agronomical practices that are applied on the crops and if any anomaly events have accured during this period (Table 1). There is an example of crop growth stages for cereals: sowing, seedling growth, tillering, stem elongation, flowering, grain-filling periods (milk and dough development), ripening and harvest.

Table 1. NIMH-BAS agro-phenology summary table with an interpretation key

Месец / Година	Януари	Февруари	Март	Април	Май	Юни	Юли	Август	Септ.	Октомври	-	-
2012	През периодите: 6-8.I и 25-27.I се запази положителна, тенденцията на есенно-зимното влагонатрупване. Обилни валежи, вследствие на наднормените топлинни условия през през първото десетдневие на месеца - стопяване на снежната покривка в равнините -	Интензивните валежи в края на януари и през първите две седмици на февруари - съществено увеличение на запасите от влага в почвата (ППВ). През периода 1- 5-8.II, на много места паднаха обилни валежи, надхвърлили в Северна и Южна България месечните норми (над 79-142 l/m2 (Хасково 142 l/m2, Кърджали 79 l/m2, Пловдив 47 l/m2, Благоевград 46 l/m2, Пазарджик 43 l/m2, Сливен 40 l/m2, Видин	Падналите валежи бяха под нормата. През 1- валежи и интензивното снеготопене ограничаваха възможностите за нормално провеждане на сезонните полски работи. 2- преваляванния от дъжд. Това възпрепятства навременното азотно подхранване на есенниците и провеждането на механизирани почвообработки. На 17.03. почвените влагозапаси в страната са над 85-90% от ППВ. В началото на пролетния вегетационен период запасите от продуктивна влага в	Валежите в част от Северна, Централна и Източна България количеството надхвърлили нормите за месеца, докато в Южна България и Подбалканските полета сумата на априлските валежи бе едва 13-18 l/m2, което е под 50% от месечната норма. 1- ниски нива на ППВ. 2- валежи повишиха стойностите на 80-85 % от ППВ. 3- малкото валежи доведоха до рязко снижаване на продуктивната влага (Дунавска равнина и Южните	1- Задълбочаващо засушаване в (североизточни и южни райони 2- наднормените валежи (с количества над 120-150 l/m2) и градушките, ветрове - щети на част от земеделските култури. 1- високите темп. - рязко намаление на влагата в 20 и 50-сантиметровите почвени слоеве. Критично ниски (от 43 до 58% от ППВ), при зимни посевите встъпили във фаза изкласяване. 2- валежите отново бяха обилни и повсеместни. 2- рязко повишение на ППВ в почвата. 3-	Липса на валежи - през климатично най-дъждовния месец от годината, дефицитът на запасите от влага в почвата - Източна и Южна България. В края на месеца продуктивната влага в отделни части на Южна България (Кюстендил, Хасково, Кърджали) бе почти изчерпана. Провеждането на земеделските мероприятия бе силно затруднено. Понижението на водните запаси в края	Сухо време през юли задълбочи още повече сушата. Постепенно изчерпване на продуктивната влага както от горните, така и от по-дълбоките почвени хоризонти. Оцеляване само чрез напояване. Почти унищожен и пролетни култури на места при неполиване. Наднормени температури – скъсяване на	Горещо и сухо време. 1- валежи в Западна Б-я, подобриха съществено почвеното влагосъдържание. Културите зависими от напояване (зеленчуци и овошки). 2-3- дефицит на почвена влага. Критично състояние на пролетни култури без напояване. 1- скъсяване на	Топло за сезона време в повечето полски райони. Затрудняване на сезонните мероприятия. Ускорено развитие на късните земеделски култури. ППВ е оскъдна. 1- ускори последните етапи на развитие на земеделските култури. Царевица – средноранни – восъчна зрелост, а късните – млечна зрелост. Узряване	1- Драстично намаление и пълно изчерпване на запасите от влага в горните и по-дълбоки почвени слоеве. Изключения се наблюдаваха единствено в районите на Разград, Хасково и Чирпан. 2- Продуктивна влага около и под критичните граници. 1-3 Провеждането на есенната сеитбена кампания и механизир		

Results and discussions

Cluster analisys

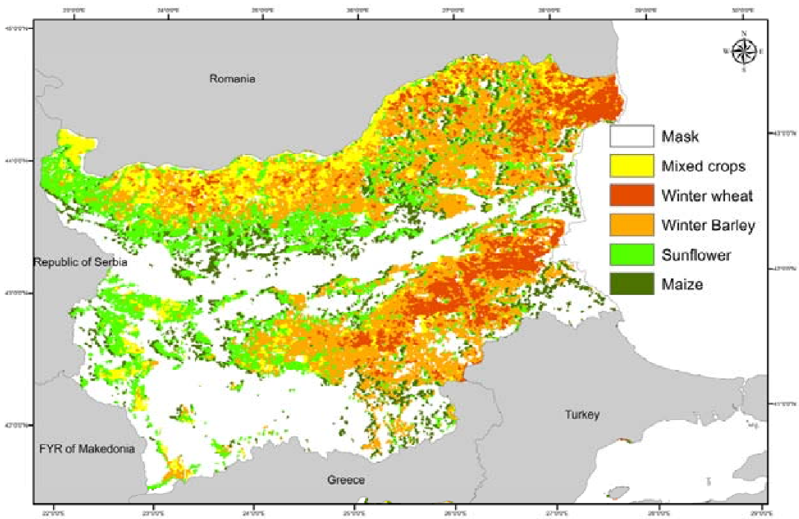
The following crops were identified for each cluster from (1-5) using as reference the summarized agro-phenological information and the cluster analysis: 1) mixed crops 2) winter wheat 3) winter barley 4) sunflower, and 5) maize.

Figures representing the spatial distribution of the cluster classes together with time-series profiles for the anomaly years (2007, 2008 and 2010) were prepared.

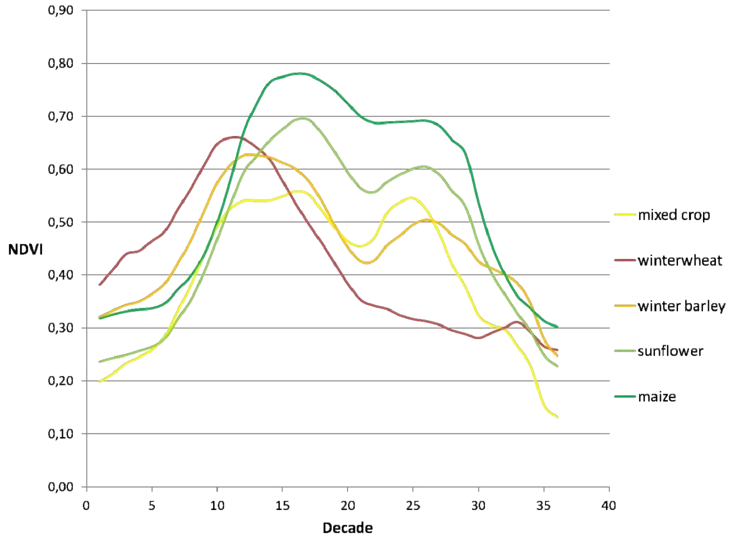
Analysis of 2007

The year 2007 was characterized as anomalous as the winter crops at the beginning of the year were ahead of their development by 45 days. In March they were already in heading phenophase. In May caused by bad agrometeorological conditions shortening of the phenophase periods were observed and as a result the collected yield from both winter crops and spring crops were small. The harvest of the late cultivars of maize was delayed due to intensive fainfall in the beginning of September.

The cluster map of actual NDVI values shows the spatial distribution of the identified crops. The classes' winter wheat and winter barley are distributed in the most common for them areas: Dobrudja plain and Upper-Tracian valley. The classes' sunflower and maize are distributed in the west part of the Danube plain (Figure 2a). Classes that were identified as winter wheat and winter barley were clearly separated, because since the first decade the NDVI values were above 0.38, which was a clear indication for winter crops (Figure2b). The cultivars of winter wheat and winter barley reach their mean maximum NDVI values (0.67 and 0.63 respectively) at the end of April and at the middle of May when flowering and grain filling phenophases occur, and this corresponds to the information summarized from NIMH-BAS monthly bulletins. Winter wheat and winter barley are harvested during the first decade of June, and this can be observed in the time-series profiles where the NDVI values decreese to 0.35. Sunflower and maize cultivars reach their peak of NDVI values in June (0.69 and 0.78, respectively) when they are at flowering phenophase (Figure 2b).



a)



b)

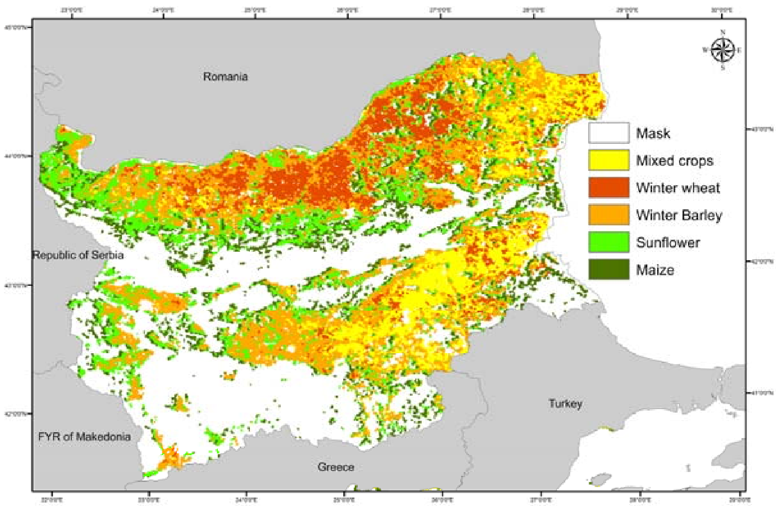
Fig. 2. a) Cluster map of actual NDVI values for 2007 b) NDVI cluster time-series profiles for 2007

Analysis of 2008

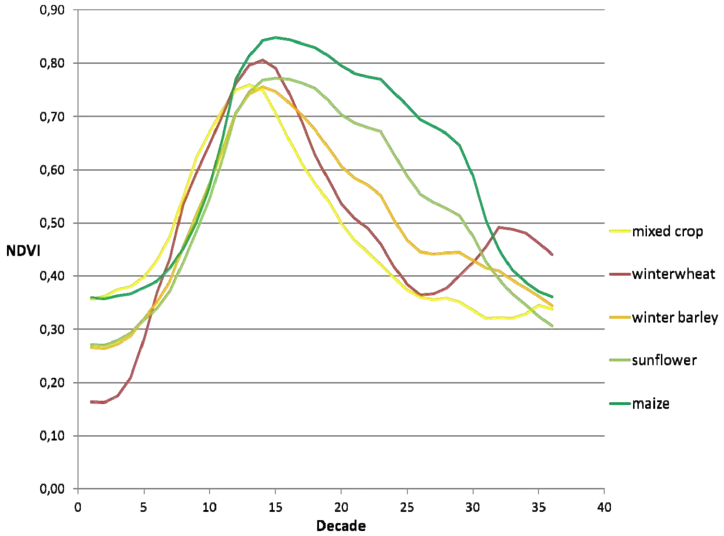
The year 2008 was characterized as anomalous year in terms of favourable agrometeorological conditions and in-time conducted agrotechnical procedures, which is having great impact on the achieved yield values.

The cluster map (Figure 3a) shows that the class mixed crops was situated in the northeast part of the country, whereas the cultivars of winter crops (winter wheat and winter barley) were located in the central north parts of Bulgaria.

The time-series profiles of the winter crops reflects very precisely the late onset of the tillering and heading phenophases, at the beginning of March due to the late snow melt reported in the NIMH-BAS monthly bulletins. The cultivars of winter wheat and winter barley reach their mean maximum NDVI figures at the end of May with very high values (0.81 and 0.76, respectively). Meanwhile, classes' sunflower and maize reach their peak of NDVI in June with exceptionally high values (0.77 and 0.85, respectively). This high NDVI values for the year 2008 corresponds to the official statistics where highest yields have been reached for the last 20 years (Figure 3b).



a)



b)

Fig. 3. a) Cluster map of actual NDVI values for 2008; b) NDVI cluster time-series profiles for 2008

Analysis of 2010

The agrometeorological conditions in 2010 regarding the crop condition can be summarized as unfavourable, which causes delay of the harvest and has negative impact on the achieved crop quality and yield figures.

The cluster map (Figure 4a) shows that classes' winter wheat and winter barley are located in Dobrudja plain and the Danube valley, as well as in the South-East part of Bulgaria (upper-Tracian plain), while sunflower and maize cultivars are distributed in western part of Danube plain. The NDVI values for every class in the beginning of the year experience a slight increase than usuall due to the favourable conditions – high temperatures for January, which keeps the vegetative state of the winter crops. In the middle of the month the temperatures decreese rapidly, which returns the crops to dormancy. Nevertheless, this anomalies were clearly identified using the NDVI time-series profiles. It is recognizable from the time-series profiles that winter crops renew their vegetative stage with NDVI values between 0.35-0.43. They reach their mean maximum NDVI values in May and at the begining of June when they are in grain filling and ripening phenophases, while at the beginning of June winter barley is at maturity stage with NDVI values 0.69. In the end of June and July the spring crops (sunflower and maize) reach their mean maximum NDVI values accumulating to 0.75 and 0.74, respectively (Figure 4b).

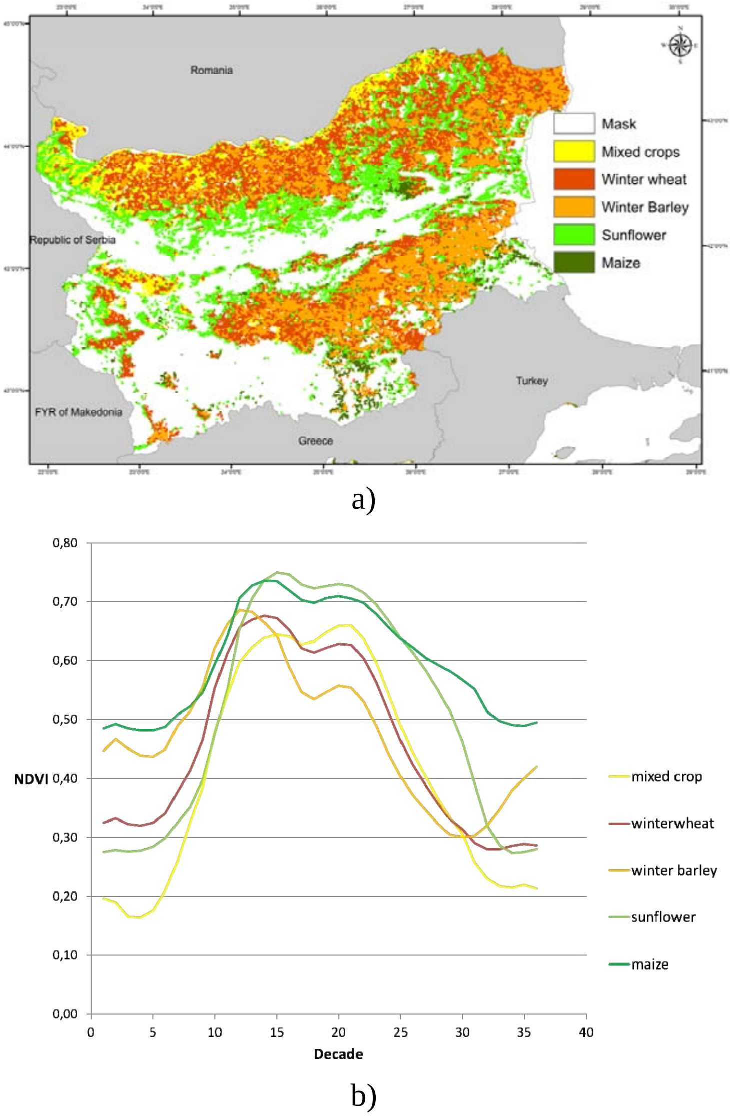


Fig. 4. a) Cluster map of actual NDVI values for 2010; b) NDVI cluster time-series profiles for 2010

Conclusions

The possiblity of identifying and monitoring the development of the major cultivated crops on the arable territory of Bulgaria using data from low spatial resolution satellite images from SPOT-Vegetation NDVIs S10 product combined with well organized ground data from NIMH-BAS was investigated in this paper. The applied methodology proves that the low resolution satellite images are an ideal solution for crop identification and monitoring on large arable territories; however they must always be supported by and used in combination with agro-phenological ground data. The monitoring analysis using cluster maps and time-series data from SPOT-VGT NDVIs S10 product shows great potential to follow the development of crop cultivars throught out the year. Using the agro-phenological monthly bulletins from NIMH-BAS together with the low resolution satellite images can be used operationally for detecting anomaly events as well as monitoring crop condition and development.

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МОНИТОРИНГ НА ЗЕМЕДЕЛСКИТЕ КУЛТУРИ ПО ВРЕМЕВИ СЕРИИ ОТ ВЕГЕТАЦИОНЕН ПРОДУКТ SPOT-VGT NDVIs S10 ВЪРХУ ОБРАБОТВАЕМАТА ТЕРИТОРИЯ НА Р. БЪЛГАРИЯ

В. Василев

Резюме

Обектът на изследване в настоящата статия са основните за България земеделски култури (зимна пшеница, зимен ечемик, слънчоглед и царевица), а целта е да се извършат следните задачи: 1) идентифициране на основните за България земеделски култури чрез прилагането на спътников продукт с ниска пространствена разделителна способност от 1000 м. от SPOT-Vegetation NDVIs S10 с помощта на информация от месечните агрометеорологични бюлетини на Националния Институт по Метеорология и Хидрология към Българската Академия на Науките (НИМХ-БАН); 2) провеждане на мониторинг по NDVI времеви серии от данни от продукт SPOT-Vegetation NDVIs S10 за календарните 2007, 2008, 2010 години, които се считат за аномални по своите агрометеорологични условия, съдейки по месечните бюлетини на НИМХ-БАН. Настоящата статия показва огромния потенциал при използването на спътникови продукти с ниска пространствена разделителна способност при идентифицирането и мониторинг развитието на земеделските култури върху обработваемата територия на България. Това изследване ще допринесе с прилагането на JRC MARS методологията за мониторинг на земеделските култури в България.