РЕЗЮМЕТА НА НАУЧНИТЕ ТРУДОВЕ ИЗПОЛЗВАНИ ПРИ ПРИДОБИВАНЕ НА АКАДЕМИЧНАТА ДЛЪЖНОСТ „ПРОФЕСОР"

на доц. д-р *ГЕОРГИ НИКОЛАЕВ ЖЕЛЕВ,*

представен за участие в конкурс за академичната длъжност „Професор", обявен в Държавен вестник бр. 98 от 13.12.2019 г. от Института за космически изследвания и технологии - БАН в област на висше образование *4. Природни науки, математика и информатика,* професионално направление 4.4. Науки за Земята; научна специалност „Дистанционни изследвания на Земята и планетите" за нуждите на секция „Дистанционни изследвания и ГИС"

B4_1

Single- and Multi-Date Crop Identification Using PROBA-V 100 and 300 m S1 Products on Zlatia Test Site, Bulgaria

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Abstract: The monitoring of crops is of vital importance for food and environmental security in a global and European context. The main goal of this study was to assess the crop mapping performance provided by the 100 m spatial resolution of PROBA-V compared to coarser resolution data (e.g., PROBA-V at 300 m) for a 2250 km² test site in Bulgaria. The focus was on winter and summer crop mapping with three to five classes. For classification, single- and multi-date spectral data were used as well as NDVI time series. Our results demonstrate that crop identification using 100 m PROBA-V data performed significantly better in all experiments compared to the PROBA-V 300 m data. PROBA-V multispectral imagery, acquired in spring (March) was the most appropriate for winter crop identification, while satellite data acquired in summer (July) was superior for summer crop identification. The classification accuracy from PROBA-V 100 m compared to PROBA-V 300 m was improved by 5.8% to 14.8% depending on crop type. Stacked multi-date satellite images with three to four images gave overall classification accuracies of 74%–77% (PROBA-V 100 m data) and 66%–70% (PROBA-V 300 m data) with four

classes (wheat, rapeseed, maize, and sunflower). This demonstrates that three to four image acquisitions, well distributed over the growing season, capture most of the spectral and temporal variability in our test site. Regarding the PROBA-V NDVI time series, useful results were only obtained if crops were grouped into two broader crop type classes (summer and winter crops). Mapping accuracies decreased significantly when mapping more classes. Again, a positive impact of the increased spatial resolution was noted. Together, the findings demonstrate the positive effect of the 100 m resolution PROBA-V data compared to the 300 m for crop mapping. This has important implications for future data provision and strengthens the arguments for a second generation of this mission originally designed solely as a "gap-filler mission".

MAPPING OF FOREST COVER CHANGE BY POST-CLASSIFICATION COMPARISON AND MULTITEMPORAL CLASSIFICATION OF SPOT DATA – A BULGARIAN CASE STUDY

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Abstract

The paper presents the results of forest cover change mapping in two study areas in Bulgaria (in mountainous and plain-hilly terrain) for period of about 20 years. A comparison was made of two approaches for classification of multitemporal SPOT HRV/HRVIR data with 20 m spatial resolution. The first approach was the post-classification comparison, i.e. pixel-by-pixel comparison of forest/non-forest maps produced by separate classifications of the images from the two ends of the time period. The second approach was a direct multitemporal classification of an image stack comprised of the two-date image data. Following international guidance, instead of counting pixels in the map to obtain the area of forest loss and gain, the areas were estimated by applying an unbiased estimator to sample data collected by stratified random sampling. The map was used to stratify the study areas. Producer's, user's and overall accuracy were also estimated using the sample data. A comparison of accuracy and area estimates, and confidence intervals of estimates, showed that the map produced by direct multitemporal classification was more accurate. It yielded consistently higher class-specific accuracies than the map made by post-classification comparison. As expected, the accuracies of the change classes – forest disturbance and reforestation – were significantly lower than that of the stable classes regardless of the change detection approach. Finally, practical issues and guidelines for future forest change detection studies were discussed.

Comparison of Global and Continental Land Cover Products for Selected Study Areas in South Central and Eastern European Region

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Abstract: Land cover is one of the key terrestrial variables used for monitoring and as input for modelling in support of achieving the United Nations Strategical Development Goals. Global and Continental Land Cover Products (GCLCs) aim to provide the required harmonized information background across areas; thus, they are not being limited by national or other administrative nomenclature boundaries and their production approaches. Moreover, their increased spatial

resolution, and consequently their local relevance, is of high importance for users at a local scale. During the last decade, several GCLCs were developed, including the Global Historical Land-Cover Change Land-Use Conversions (GLC), the Globeland-30 (GLOB), Corine-2012 (CLC) and GMES/ Copernicus Initial Operation High Resolution Layers (GIOS). Accuracy assessment is of high importance for product credibility towards incorporation into decision chains and implementation procedures, especially at local scales. The present study builds on the collaboration of scientists participating in the Global Observations of Forest Cover—Global Observations of Land Cover Dynamics (GOFC-GOLD), South Central and Eastern European Regional Information Network (SCERIN). The main objective is to quantitatively evaluate the accuracy of commonly used GCLCs at selected representative study areas in the SCERIN geographic area, which is characterized by extreme diversity of landscapes and environmental conditions, heavily affected by anthropogenic impacts with similar major socio-economic drivers. The employed validation strategy for evaluating and comparing the different products is detailed, representative results for the selected areas from nine SCERIN countries are presented, the specific regional differences are identified and their underlying causes are discussed. In general, the four GCLCs products achieved relatively high overall accuracy rates: 74–98% for GLC (mean: 93.8%), 79–92% for GLOB (mean: 90.6%), 74–91% for CLC (mean: 89%) and 72–98% for GIOS (mean: 91.6%), for all selected areas. In most cases, the CLC product has the lower scores, while the GLC has the highest, closely followed by GIOS and GLOB. The study revealed overall high credibility and validity of the GCLCs products at local scale, a result, which shows expected benefit even for local/regional applications. Identified class dependent specificities in different landscape types can guide the local users for their reasonable usage in local studies. Valuable information is generated for advancing the goals of the international GOFC-GOLD program and aligns well with the agenda of the NASA Land-Cover/Land-Use Change Program to improve the quality and consistency of space-derived higher-level products.

Keywords: land cover; earth observation; validation; weighted accuracy; confidence levels; inter-comparison; SCERIN

Estimation of biophysical and biochemical variables of winter wheat through Sentinel-2 vegetation indices

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Abstract

Dimitrov, P., Kamenova, I., Roumenina, E., Filchev, L., Ilieva, I., Jelev, G., Gikov, A., Banov, M., Krasteva, V., Kolchakov, V., Kercheva, M., Dimitrov. E., & Miteva. N. (2019) Estimation of biophysical and biochemical variables of winter wheat through Sentinel-2 vegetation indices. *Bulgarian Journal of Agricultural Science*, 25(5), 819–832

Traditionally, the growth and physiological status of winter wheat (*Triticum æstivum* L.) is monitored in the field by measuring different biophysical and biochemical variables such as Above Ground Biomass (AGB), Nitrogen content (N), N uptake, Leaf Area Index (LAI), Fraction of vegetation Cover (fCover), Canopy Chlorophyll Content (CCC), and fraction of Absorbed Photosynthetically Active Radiation (fAPAR). The objective of this study was to investigate the possibility of estimating these crop variables through statistical regression modelling and spectral vegetation indices derived by the Sentinel-2 satellites. Field data were collected over two growing seasons, 2016/2017 and 2017/2018, in test fields around Knezha, northern Bulgaria. A combination of spectral data from Sentinel-2 images and field spectroscopy obtained through the first growing season was used for model calibration and cross-validation. The models were further validated with Sentinel-2 image data from the second growing season. The accuracy of the models varied widely across crop variables. According to the cross-validation, the relative RMSE was below 25% for fAPAR, fCover, and fresh AGB, with particularly good result for fAPAR (13%). For N content and dry AGB the error was between 25% and 30%. The accuracy was low for CCC, LAI, and N uptake (error between 30% and 43%). The models' performance was worse when they were applied to the data from the second growing season, resulting in relative RMSE which were 3-8% higher in the general case. The cross-validation results suggested that the variety-specific models are more accurate than the generally calibrated models for most crop variables. The accuracy obtained in this study for the prediction of fAPAR, fCover and AGBf through VIs is promising. Future studies and incorporation of new field data will be needed to better account for variety, season, and site variations in the modelled relationships and to improve their generalisation potential.

Keywords: biomass; canopy chlorophyll; leaf area; nitrogen content; satellite imagery

Sub-Pixel Crop Type Classification Using PROBA-V 100 m NDVI Time Series and Reference Data from Sentinel-2 Classifications

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Abstract: This paper presents the results of a sub-pixel classification of crop types in Bulgaria from PROBA-V 100 m normalized difference vegetation index (NDVI) time series. Two sub-pixel classification methods, artificial neural network (ANN) and support vector regression (SVR) were used where the output was a set of area fraction images (AFIs) at 100 m resolution with pixels containing estimated area fractions of each class. High-resolution maps of two test sites derived from Sentinel-2 classifications were used to obtain training data for the sub-pixel classifications. The estimated area fractions have a good correspondence with the true area fractions when aggregated to regions of 10×10 km^2, especially when the SVR method was used. For the five dominant classes in the test sites the R^2 obtained after the aggregation was 86% (winter cereals), 81% (sunflower), 92% (broad-leaved forest), 89% (maize), and 67% (grasslands) when the SVR method was used.

Applicability of parametric and nonparametric regression models for retrieval of crop canopy parameters for winter rapeseed and wheat crops using Sentinel-2 multispectral data

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ABSTRACT

Parametric and nonparametric regression methods have been proven to successfully retrieve crop canopy parameters. However, once those models are calibrated for certain crops or geographical place their applicability to other crops and places is still unclear and it is an important consideration in an operational context. The tested models are parametric with two or three bands Vegetation Indices and different fitting functions and nonparametric linear and non-linear kernel based. The studied crop canopy parameters are aboveground fresh and dry biomass, vegetation fraction, mean plant height and nitrogen concentration in biomass. For calibration of the models, in-situ data from winter rapeseed and wheat crops with bare soil pixel added and remote sensing data from Sentinel-2 is used. In this study two different scenarios are considered in order to determine the applicability of both types of models for rapeseed and wheat crop parameters retrieval: 1) When applying models to the crop and period they are calibrated for: only the models for wheat before and after winter period give very good results for all studies parameters. Gaussian Processes Regression and its Variational Heteroscedastic variant with dimensionality reduction are the best performing for most of the parameters' retrieval. Three bands Vegetation Index are the best parametric methods; 2) When applying the models to the crop and period they are not calibrated for: no model gives satisfactory results for any of the studied parameters.

CROP TYPE MAPPING USING MULTI-DATE IMAGERY FROM THE SENTINEL-2 SATELLITES

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Abstract

This paper presents the results of a crop type mapping exercise conducted in two study areas in Bulgaria and based on data from the Sentinel-2 (S2) satellites. A multi-date maximum likelihood classification approach was used in which nine spectral bands from three cloud-free images, well distributed across the growing season, were used. Validation was performed using field data collected as part of the study and data from the Integrated Administration and Control System (IACS) dataset. Depending on the validation dataset and the study area, an overall accuracy of 74–95% was achieved after the crop type maps were post-processed by mode filtering. Further increase in accuracy may be obtained if parcel boundaries, as defined in the IACS dataset, are used to aggregate the per-pixel classification to a parcel level.

Key words: remote sensing, Sentinel-2, satellite imagery, crop mapping, maximum likelihood classification

Qualitative Evaluation and Within-Field Mapping of Winter Wheat Crop Condition Using Multispectral Remote Sensing Data

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Abstract

This study presents a method for evaluation and mapping of winter wheat crop condition using a set of crop variables, e.g. leaf area index (LAI), fraction of absorbed photosynthetically active radiation (fAPAR), fraction of vegetation cover (fCover), fresh above ground biomass (AGBf), and Nitrogen uptake derived from multispectral imagery. First, the crop condition is assessed with respect to each variable using a qualitative, three-grade scale. In a second step, these individual assessments are combined to produce assessment map of the crop's general condition, discriminating between three possible conditions - Good, Fair, or Poor. The method was tested on winter wheat fields in Bulgaria in two agricultural years - 2016/2017 at phenological growth stage (FGS) Z31 to Z34 and 2017/2018 at FGS Z30. The results presented were based on Sentinel-2 satellite imagery (at 20 m spatial resolution) and imagery from Specialized Unmanned Aerial Vehicle (SUAV) senseFly eBee Ag, equipped with Parrot Sequoia camera (resampled to 10 m spatial resolution). The remotely sensed crop condition was validated against independent ground-based assessments in a number of elementary sampling units (ESUs). The proposed approach proved to be effective and the crop condition was accurately determined in 87% - 94% of the ESUs depending on the FGS/agricultural year and the imagery type. We observed only minor differences in the areas of the three crop conditions when mapped with Sentinel-2 and Parrot Sequoia data.

Keywords: winter wheat, crop condition, assessment map, Sentinel-2, Parrot Sequoia camera

Within-Field Mapping of Winter Wheat Biophysical Variables Using Multispectral Images from UAV

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Abstract

The paper presents the results from a study aiming to map the dynamic of biophysical variables of winter wheat crops in different phenological growth stages (PGSs) using multispectral camera data acquired by Unmanned Aerial Vehicle (UAV). The studied biophysical variables are Leaf Area Index (LAI), fraction of Absorbed Photosynthetically Active Radiation (fAPAR) and fraction of vegetation cover (fCover). During agricultural year 2016/2017, 4 field campaigns (FCs) were carried out in 6 farmer-managed fields sown with two winter wheat varieties. During the FCs, 8 UAV flight missions were accomplished. Linear and exponential regression models were designed and evaluated to derive predictive equations for the biophysical variables of the crops based on a set of vegetation indices (VIs). The best predictor for all biophysical variables was OSAVI (RMSE was 0.90 m2/ m2, 0.07 and 0.08 for LAI, fAPAR, and fCover respectively). The chosen models were used to compose maps of LAI, fAPAR, and fCover of the studied fields. The maps correspond well with the spatial distribution of the values of the respective biophysical variables measured during the respective field campaign.

Keywords: *Winter Wheat, LAI, fAPAR, fCover, UAV, Multispectral Camera*

LAND COVER AND LAND USE CHANGE IN KARST REGION DEVETASHKO PLATEAU

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Abstract

The data of Corine, land cover (CLC) are digital data about land cover which is distributed into 44 classes, whereas for the territory off Bulgaria, the classes are 36. The minimal mappable unit is 25 hectares (for 2D objects and 100 m for linear objects). Data sets for the years 1990, 2000, 2006, 2012, and 2018 are available, as well as for the changes which have occurred between each couple of years (1990-2000, 2000-2006, 2006-2012, and 2012-2018).

The great data sets provide to track over a nearly 30-year period of land cover changes in model karst regions which are strongly vulnerable to anthropogenic and natural influences.

This paper considers the changes in the land cover types on the Devetashko plateau – a typical karst plateau in North Bulgaria. Land cover and land use changes affect directly the processes of modern karst-genesis, the soil-vegetation cover, the quantity and quality of underground karst waters.

Keywords: *Land Cover, land use, Karst, karst geosystems, Devetashko plateau, Corine, land cover*

ABSTRACT

Of the PhD thesis:

STUDY OF THE VOLCANIC STRUCTURES IN THE AREA OF THE EASTERN RHODOPES THROUGH REMOTE SENSING AND GIS

Author: GEORGI JELEV

For awarding Doctor of Philosophy"PhD"

The scientific specialty 01.04.12 - "Remote Sensing of the Earth and the planets'

PhD thesis consists of 116 pages, including 34 figures, 20 tables, a bibliography of 151 titles, including 88 in Cyrillic and Latin 63. Additionally 4 fund materials are used and 22 websites.

It has the following structure:

Chapter I Introduction – 21 pages;

Chapter II Methodological basis of the study and structure of the GIS Database – 21 pages;

Chapter III Detection and analysis of rings and linear structures in the Eastern Rhodopes – 21 pages;

Chapter IV Determination of the geologic hazard degree in the study area – 20 pages,

Conclusion – 2 pages;

Contributions – 1 page;

Acknowledgements – 1 page;

Publications - 1 page;

Bibliography – 12 pages;

Abstract – 4 pages.

The object of this study is volcanic geomorphological structures, fault structures and ring domed structures in the Eastern Rhodopes.

The subject is the study of volcanic structures and the degree of geological hazard in the geomorphological (geological) area in the Eastern Rhodopes.

The main objective of this study is to assess the geological hazard and recognize ring structures and volcanogenic lineaments in the Eastern Rhodopes by remote sensing and ground-based methods in GIS environment.

The scientific tasks are:

1) Creation of GIS Database for the study of volcanogenic structures and lineaments and evaluation of geological hazard in the Eastern Rhodopes;

2) Identification and analysis of rings structures;

3) Identification and analysis of lineaments;

4) Elaboration of thematic layers for the study of geological hazard;

5) Analysis and evaluation of geological hazard using the Fuzzy Logic.

The study area (Eastern Rhodopes) is an interesting region from a geological, geomorphologic and aerospace point of view. The diverse terrain and geological history makes it an object for conductance of specialized regional geological, geomorphologic and others studies, as well as allows solving problems in the field of structural geology, geotectonics, geomorphology, geological risk, etc. The study area is one of the 7th aerospace test sites of the territory of Republic of Bulgaria, chosen in the early 70s for conductance of satellite and sub-satellite experiments under the "INTERCOSMOS" Programme.

Long-lasting research activities allow a lot of information to be collected in digital format, which can be integrated into a unified GIS database. This is a priority of the recent research due to the new formats and options for storage and processing of digital data, based on the successful implementation of the EU directive Infrastructure for Spatial Information in the European Community (INSPIRE).

In this work, a digital database of the study area is created in GIS environment (ArcGIS), which complies with the INSPIRE Directive. It is a dynamic and open GIS, which allow further updates. The collected and digitized archive and modern data and metadata for the study area was imported in it. The GIS database is supplemented with a large variety of new data, most of them free of charge or provided within the framework of various research projects. Data from external GIS databases, as well as from the established Scientific Information Complex (NIC) at the SRTI-BAS have been used.

The created GIS database of the study area consists of 20 raster layers, 18 vector layers, 3 datasets with satellite images, as well as field observation data and photographs. Sixteen

thematic maps and layers needed for determination of the degree of geologic hazard have been elaborated.

For the data processing and analysis, the remote sensing (heuristic, instrumental and complex) methods and tools of geographic information systems (3D analysis, spatial analysis, hydrological analysis, geostatistical analysis, histogram analysis, fuzzy logic), geologic (geological mapping and geomorphologic analysis) and statistical methods were used. The cartographic methods were applied for the visualization of the created thematic maps.

Based on the topographic and thematic maps, satellite images and digital terrain model (DEM), the ring and linear structures in the study area are hierarchically defined. They are determined by modern morphological view of the area and the inherited development through the late-Alpine stage (Paleogene and Neogene-Quaternary sub-stage). The observed and described ring structures coincide with the localities of various geophysical fields. It is easily distinguished the developed ring structures in the Rhodope metamorphic framework as a result of the block structure of the mountains, from those - in the Eastern Rhodopes depression, which are results of Paleogene volcanic activity and current erosion processes. A lineament analysis was performed and lineaments were effectively extracted in the study area using different filtering methods (Canny algorithm, directional filter, etc.), visual interpretation of satellite images, analysis of digital elevation model and data from thematic maps. The main reason for using several techniques is that a single method cannot detect all lineaments due to differences in the nature of the surface material in the region, such as changes in the vegetation density, topographic structure, lithological variations and etc. This is clearly distinguished from the rose-drawn diagrams of the distribution of lineaments and the maps of their density. A comparison of the distribution of lineaments and the river network shows that the extracted lineaments includes not only the elongated linear valleys but also a number of other linear structures - linear elongated ridges, faults and geological boundaries, linearity in phototone and structure of satellite images and many others.

The data for the study area are processed and 16 thematic layers are composed, which are used as input parameters in determining the geological hazard and as operators in the method of fuzzy logic. By applying this method, the various types of hazardous geologic processes and their combined influence and territorial combination are analyzed, as a main criterion for determining the areas with varying degrees of geologic hazards. Using the ArcGIS capabilities and functionalities, the fuzzy membership and expert

assessment for any of the factors influencing the geologic hazard degree in the study area were defined.

Using the Fuzzy Overlay tool and FuzzySum approach from the Spatial Analyst Tools in ArcGIS environment the individual layers are combined and as a result a map of the of geologic hazard degree were elaborated. Using the natural breaks classification method three degrees of geological hazard were defined: low (28% of the area), middle (48%) and high (24%). The landslides' boundaries, the rock cliffs, the areas with active water erosion and deeply carved river valleys, rock falls, linear and lateral erosion as well as tectonically active regions, etc. are well defined on the map as areas with high geologic hazard degree. The verification of the final results was made using data from literature, field observations and orthophoto map of Bulgaria with high spatial resolution from the external GIS database of the Ministry of Regional Development and Public Works.

The areas of potential geological hazards can be defined more detailed through applying additional data and information regarding geology and natural hazards processes, as well as using more precise fuzzy membership and expert assessments.

USING REMOTE DATA AND GIS IN RESEARCH OF MORPHOMETRIC CHARACTERISTICS OF THE COASTAL AREA IN BULGARIA

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Abstract

Remote methods provide information on both the natural objects on the earth's surface, water bodies, water-land boundaries, and relief and relief forms. Satellite images were used to determine the characteristics of the coastline and Black Sea area (about 50 km distance) of the Republic of Bulgaria. Its fractal dimension and curvature are determined. A number of thematic maps have been generated through the digital relief model to assist in the interpretation and geomorphologic characteristics of the study area. A database was created as part of the project MARINEGEOHAZARD – "Set-up and implementation of key core components of a regional early-warning system for marine geohazards of risk to the Romanian-Bulgarian Black Sea coastal area" from CBC Romania-Bulgaria Programme.

WATER SURFACE DYNAMIC'S OF THE STUDENA DAM, PERNIK USING SENTINEL 2A AND 2B SATELLITE DATA

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Abstract

This article presents the results of a study of the dynamics of the surface water area of the Studena dam using satellite images from Sentinel 2A and 2B. The period considered is from the beginning of 2019 to January 2020. The collected 35 cloud-free images from a total of 80 captured are organized in a spatial database in a GIS environment. A water index - MNDWI (Modified Normalized Difference Water) was used to determine the boundary of the water surface. The calculated areas for all images and their trends are analyzed by graph. For about seven months from the maximum annual area (0.91 km^2) in June, a rapid decrease of 0.10 km^2 per month is observed until the beginning of 2020, when the lowest value was measured - 0.23 km^2.

Keywords: *water surface, Studena dam, Sentinel-2a and 2b,*

Biometric State of Winter Wheat Agroecosystem Determined through Ground Based Measurements and Satellite Images with Different Resolution

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Abstract. The paper deals with the practical monitoring of fields and the ways of using the terrestrial and satellite data. Ground based data were used to validate the results obtained from the processing and interpretation of satellite images. They are collected within the bounds of conducted 2011 satellite experiments in the test area resident of Bulgaria as participant in the PROAGRO-BURO Project. During the experiments carried out, the obtained data were processed and analyzed in a GIS environment. We used additional information contained in the geo-database built on the project and related to the surveyed fields (soil and GPS data). To determine the phenological status of winter wheat crops, we used the data obtained by us through field observations and measurements and from the farmer-owner of the surveyed fields.

The timing of field measurements is determined according to the dates of recovery of vegetation of winter wheat in spring: tillering and stem elongation. They are predetermined by the WOFOST model calculation, using climatic values of meteorological elements for the 1971-2011 period. The normalized difference vegetation index (NDVI) is a potential indicator of the condition of winter wheat, which is informative to various degrees depending on the satellite source spatial resolution (SR), data on fields area of 1.5 km². NDVI values depend on the majority of biometric indices of winter wheat as: crop density, height of plants, fresh and dry biomasses, total area coverage, and soil moisture in the surface layer. The lowering of NDVI values during the active growing season is an indicator of the presence of stress (drought, hail, damage from pests and fires).

Key words: winter wheat agroecosystem, leaf area index (LAI), biomass, spatial resolution (SR), normalized difference vegetation index (NDVI).

INTRODUCTION

In the spring of 2013, the European Satellite Agency (ESA) launched **Proba-V** satellite, which goes to replace finishing its Spot – Vegetation mission. This satellite currently transmits to Earth daily spectral images of environmental objects such as agricultural crops, forests, watersheds and soils to determine their state. Testing and adjustment of the systems of **Proba-V** satellites in 2011 held a large-scale experiment in different parts of the world, part of which was studied in Bulgaria and Romania. The Project was entitled:

CROP TYPE MAPPING BY PROBA-V SATELLITE DATA WITH 100 M AND 300 M SPATIAL RESOLUTION AT ZLATIA TEST SITE, BULGARIA

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Keywords: Crop type mapping, Supervised classification, PROBA-V 100 m

Abstract: This paper presents some of the results obtained during a study carried out in 2014 in the framework of the "PROBA-V 100 m Exploration Exercise" initiative. The aim of the study was to assess the potential of PROBA-V satellite data with 100 m spatial resolution for crop type mapping. Distribution of four main crops was mapped over the territory of Zlatia test site in western Danube plain using multispectral images from 21 March and 8 July 2014. Using a maximum likelihood classifier, overall classification accuracy of 86% and 82% was achieved for the two dates. Classes to be distinguished in the 21 March image were wheat, rapeseed, and soil, while for the 8 July image maize, sunflower, and soil/stubble were sought. For comparison purposes, PROBA-V images with 300 m spatial resolution were also classified achieving accuracy of 80% and 70% for 21 March and 8 July respectively. The wheat and rapeseed areas estimated based on the classifications were compared with independent data for harvested areas from the Ministry of Agriculture and Food. Very good correspondence was observed between the two datasets for wheat, but the deviation for rapeseed was large.

BEST PRACTICES IN SATELLITE DATA APPLICATIONS FOR AGRICULTURE AND LANDSCAPE-ECOLOGICAL MONITORING IN BULGARIA

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Keywords: satellite data, agriculture, environmental monitoring

Abstract: The work is dedicated to some of the basic research in the application of aerospace data in agriculture and landscape-ecological monitoring on the territory of Bulgaria, carried out by members of the Section "Remote Sensing and GIS" at the Space Research and Technologies Institute - BAS.

RING STRUCTURES DETECTION IN SPACE (SATELLITE) IMAGES

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Keywords: ring structures, space (satellite) images

Abstract: In the present work, we applied a classification scheme for various types of ring structures recognizable space (satellite) images. Below are a few representative of each type to the classification, circular structures and their short descriptions.

CORRELATION ANALYSIS OF TIME SERIES NDVI DATA FOR CROP MAPPING

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Abstract: *NDVI time series analysis, using satellite imagery is an effective tool for crop mapping. It is based on the possibility to distinguish between crops using their phenological differences as represented in the annual NDVI profile. The aim of this paper is to test a supervised classification approach where the NDVI time series is compared, pixel wise, with a set of reference NDVI time series of the classes to be mapped. Each pixel is assigned to the most similar reference class. The measure of similarity is the coefficient of correlation. The method is applied to map six classes (wheat, rapeseed, maize, sunflower, tobacco and double crop) making use of 14 daily PROBA-V images collected between March and October 2014. The overall accuracy of the classification is 70.1%.*

WINTER WHEAT CROP STATE ASSESSMENT, BASED ON SATELLITE DATA FROM THE EXPERIMENT *SPOT-5 TAKE-5*, UNMANNED AIRIAL VEHICLE *SENSEFLY eBee AG* AND FIELD DATA IN *ZLATIA* TEST SITE, BULGARIA

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Abstract: *this article presents the first results from the agricultural application of satellite time series data from the SPOT5/HRG XS in Zlatia Test Site (ZTS), Bulgaria. Those time series were acquired within the SPOT 5 Take 5 experiment, which was carried out between April and September 2015 as an initiative of CNES and ESA. The main objective of the study is to perform spatial analysis and assessment of the winter wheat physiological state in three test fields using time series of satellite NDVI imagery from SPOT5/HRG XS (product level L2A). The crop state is assessed using a qualitative scale with three levels: poor, satisfying and good condition. This division was based on NDVI threshold values determined during this study using the method natural breaks classification. Assessment maps are prepared for three winter wheat phenological stages: stem elongation, milk development and dough development. Field experiment was carried out on 8 and 9 June 2015 to verify the maps. Image of the test fields was acquired using the specialized unmanned aerial system for mapping senseFly eBee Ag. In addition were performed phenological observations, biometrical measurements and plant samples were collected from nine sampling plots to assess the actual state of the crops. The NDVI values from both eBee Ag/S110NIR and from SPOT5/HRG2 XS pixels have been classified using natural breaks method in three NDVI ranges, corresponding to three classes of crop state (poor, satisfying and good). Those classes coincide entirely with the ground observations of the physiological crop state established during the field campaigns. The results from the study carried out in ZTS show that the high spatial and temporal resolution of the SPOT 5 Take 5 image dataset substantially increase the potential for monitoring of winter wheat and assessment of its state at local level.*

RADIOMETRIC CHARACTERIZATION OF IMAGING SPECTROMETERS

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Keywords: imaging spectrometers, radiometric characteristics, procedures for radiometric characterization

Abstract: In this work are described basic radiometric characteristics of imaging spectrometers defining radiometric accuracy of the instruments and are referred the methods for their determination. A part of the results obtained in the process of laboratory imaging spectrometers characterization are presented. The results are summarized in a proposed algorithm for radiometric characterization of imaging spectrometer devices.

Dimitar Dimitrov, Georgi Zhelev, Emil Botev

ANALYSIS OF THE DEFORMATION PROCESSES IN THE REGION OF THE MIROVO SALT DEPOSIT

(S u m m a r y)

After the analysis of the tectonic characterization of the region near city of Provadia and of the current instrumental seismicity are presented the results of the geodetic monitoring of the deformations in the region of the Mirovo salt deposit. The data analysis from the regional and detailed geodetic monitoring allows drawing a conclusion, that in the region of the exploitation of the salt deposit occur significant local deformations of the Earth's surface, as a result of many years intensive exploitation of the salt deposit. The deformation processes could not be related to movements on the main faults in the zone around city of Provadia, but could explain the concentration of the epicenters of different by force earthquakes in the region.

APPLICATION OF SPECIALIZED UNMANNED SYSTEMS SENSEFLY eBee AG FOR MAPPING AND EVALUATION OF MAIZE CROP STATE WITH DIFFERENT FERTILIZING RATE

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Key words: unmanned aerial vehicle, senseFly eBee Ag, agriculture, maize, mapping of crop state, NDVI

Abstract: This paper presents results from a field experiment carried out on July, 9th 2015 for mapping the state of maize cultivars Knezha-517 and Knezha-435 (FAO groups 500-599 and 400-499 respectively), grown at different fertilizing rates, using data from the specialized unmanned aerial vehicle (UAV) - senseFly eBee Ag. The generated map is based on NDVI image, acquired from the NIR/eBee Ag camera data, and depicts the differences in the state of maize crops grown on test plots with and without fertilizer. The state of the maize crop is characterized using a four-level scale – poor, satisfactory, good, and very good. Bare soil is mapped as separate class. In order to determine the actual state of the maize crops in situ measurements and observations were performed simultaneously with the aerial image acquisition on two of the test plots. The data from these measurements match the crop state determined by the NDVI threshold values of the four-level scale.
Based on these results a methodology for operational monitoring of maize crops state can be developed using the specialized UAV senseFly eBee Ag.

EMPIRICAL STUDY OF THE CORRELATION BETWEEN PHOTOSYNTHESIS AND VEGETATION INDICES IN SOYBEAN

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Key words: *photosynthesis; vegetation indices - REP, NDRE, PRI; soybean*

Abstract: *Photosynthesis is the most important process in plants, but its measurement by gas exchange method (most accurate for now) is time consuming and requires specialized equipment. Vegetation products derived from terrestrial, airborne or satellite data for reflective characteristics of plants are more often used in agricultural practices to assess plant status and take the appropriate cultivation action. The aim of this study is to access the correlations between photosynthesis measured by gas exchange method and the vegetation indices Red Edge Position (REP), Normalized Difference Red Edge Index (NDRE) and Photochemical Reflectance Index (PRI) by using pilot data for soybean. Diminished values of REP and NDRE that cannot be associated with decreases in photosynthesis were obtained from the pilot data, while the trend of the PRI reversely coincides with the daily course of photosynthesis. The correlation analysis between PRI and photosynthesis showed encouraging results, but also the need to improve the measurement protocol to offset the impact of soil's and other factors' reflective characteristics.*

A GEODYNAMIC MODEL OF QUATERNARY TECTONIC PROCESSES WITHIN THE SOFIA SEISMIC AND TECTONIC ZONE

Georgi Alexiev, Marinela Agalareva, Georgi Jelev

On the basis of a structural-geomorphological analysis of the deformation of the benchmark initial denudation surface area, the supporting foothill Gelasien and early Pleistocene inclined levels, the spectrum of river terraces, the changes in the thickness of Neogene and Quaternary lithologycally stratigraphic and lithologycally facial vertical sections and the stratification of ancient and young alluvial-diluvial-proluvial mantle trains, the network of contrasting tectonic deformations which underly the pattern of block-mosaic morphological structure of the central segment of the Sofia seismic-tectonic zone has been identified. In morphotectonic aspect, Sofia seismic and tectonic area is within the scope of the high west block foot of the Kraishte-Srednogorie morphotectonic zone. In the current plastic of the Earth crust, the foot is demonstrated as an integrated and deep, peneplanationed, oro-structural pedestal. In its morphotectonic style, a complex block-mosaic structure has been diagnosed, which is determined by the presence of several major submeridionally-oriented fault structures: Kolosh, Tran-Kosharevo, Pernik and Zadbalkan. These major fault structures outline the spatial parameters of a system of sub-parallelly alternating oro-structural chains with graben depressions and valleys between the mountains. The northern oro-structural frame of the seismic and tectonic zone is outlined by the massive segment of the West Balkanide horst-block morphostructure. The central place in the internal structure of the studied area is occupied by the linearly withdrawn from the southeast to the northwest Ruy-Plana swell-shaped horst-imaged ascent, with relatively stable mode of slow and moderate positive neo-tectonic deformations. The southern fence-frame of the central segment of the Sofia seismic and tectonic zone is formed by the asymmetric Verila, Kolosh and Zemenska Mountains' oro-structural morpho block. In the spaces between the central swell-shaped ascent and the southern and northern fence-frame of the studied area are - unilaterally

imposed - the Radomir and Sofia graben valleys. The main geotectonic process, which determines the general regularities in the spatial location of the earthquakes, is the dominant regional subductional extensional and transforming mode after Early Paleogene stage of the development of the research area. In this background, within the frames of the researched area, the basic seismogenerating morphostructures appear to be the unilaterally set and asymmetric graben morphostructures: the ones of Radomir, Sofia and Pernik. The basic energy of the impulse tectonic processes is generated by the appearance of tensions of extension and active subequatorial and sub-parallel abruptions, and as a result of it - a mechanism of step-like differentiation of their hollow foundations occur most often. Quaternary geodynamic localities fixed by contrast listric fault deformations are formed. A map of the spatial values of Quaternary tectonic processes and linear abruptions along the Early Quaternary and especially Holocene listric faults – the ones of Kalishte, Kolosh, Izvor, Chervena Mogila, Radomir, North Vitosha, Iskar, Bezden-Gorna Malina and Rudartsi-Divotino fault-flexure zone, etc. has been drawn up. The values of deformations along those faults range between 40 and 100-120 m. The highest values of deformations are found along the length of the fault planes of Kolosh, Izvor, Kalishte, Bezden-Gorna Malina, North Lozen and North Vitosha, as well as the Iskar submeridional fault. On the basis of the morphotectonic model, a direct spatial and dynamic relation between the seismic potential on one hand, and the Quaternary extensional mechanism of formation of the block-mosaic structure in the central segment of the Sofia seismic zone on the other, has been found.

Keywords: morphotectonics, geomorphology, neotectonics, geodynamics, listric faults

TYPES OF DRONES

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Keywords: *Drones, Multirotor, Classification*

Abstract: *An attempt is made for systematization and classification of the most common types of drones. The presented classification takes into account the physical parameters of the drones and their area of application. More emphasis is given to the civil drones while these within the military domain are only mentioned. Discussed are the areas of application as a function of the size and the flight distance.*

DIFFERENT TYPES CAMERAS FOR DRONES

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Keywords: *Drones, Cameras, Classification*

Abstract: *An attempt has been made to systematize and classify the variety of professional cameras used for drone shooting. The classification made is based on the technical characteristics and areas of application of the cameras.*

Complex Assessment of Winter Wheat Growing Conditions in Northwestern Bulgaria

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Abstract

The objective of the study is to make a complex assessment of the winter wheat (*Triticum aestivum* L.) statusin case of two commonly used varieties in Bulgaria - ,,Annapurna" and ,,Enola", grown on Chernozems inNorthwestern Bulgaria. Thirty elementary sampling units (ESUs) have been located on the field units' territory for performing the observations on phenological stages, presence of weeds, crop disease and pests and for collecting of soil and plant samples for laboratory analyzes. The following indicators were used to evaluate the growing conditions of the crop during the phenophases: sum of precipitation; land evaluation; soil nutrient supply; soil moisture supply; number of emerged plants per area; height of plants; weight of the aboveground dry biomass; number of stems per area; number of productive tillers per area; Nitrogen uptake by plants; presence of weeds;crop damage caused by diseases and pests.A three-stage ranking of the crop conditions was defined: 3 - high, 2 - average and 1 - low. The complex evaluation of the development of the crop throughout the growing season is presented as an arithmetic mean of the indicators estimates for each phenological phase. The complex assessment for the studied field Units ranges from average to high according to the conditions and the state of the crop during the whole growing season.

Keywords: winter wheat, growing conditions, ranking, Chernozems

Using UAV Spectral Vegetation Indices for Estimation and Mapping of Biophysical Variables in Winter Wheat

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Keywords: Unmanned aerial vehicle, Red-edge band, Regression models

Abstract

In the recent years, data obtained by Unmanned Aerial Vehicles (UAV) are intensively tested for operational applications in agriculture. Advantages of UAV, such as flexibility of image acquisition and high spatial resolution, are particularly important in precision agriculture where timely, within-field crop characterisation is desired. In particular, the on-demand very high resolution (VHR) data from satellite sensors may not suits the farmer needs in terms of exact time of acquisition because the needs of many users must be balanced during the acquisition plan preparation. Moreover, few VHR satellite sensors with red edge band are available (e.g. WorldView-2 and -3). UAV may be easily customised by mounting a camera with the needed spectral bands. As with the other types of remote sensing images, however, an information extraction strategy is needed to derive quantitative parameters of the imaged crop.

In this study a *senseFly eBee Ag* drone with multispectral camera *Sequoia* was tested for estimation and mapping of dry Above Ground Biomass (AGBd), fresh Above Ground Biomass (AGBf), Nitrogen content (N), Nitrogen uptake (Nup), Canopy Chlorophyll Content (CCC), Leaf Area Index (LAI), fraction of Absorbed Photosynthetically Active Radiation (fAPAR), and fraction of vegetation Cover (fCover). The *Sequoia* multispectral camera acquire images in four spectral bands: green (550 nm), red (660 nm), red edge (735 nm), and NIR (790 nm).

A simple information extraction strategy was adopted based on spectral Vegetation Indices (VIs) and regression analysis. The ground data used for regression models calibration and validation were collected from winter wheat fields (*Annapurna* variety) located near the town of *Knezha*, north-western Bulgaria. Four field campaigns were carried out during the 2016/2017 growing season: November 2016, March 2017, April 2017, and May 2017. The 2016/2017 data (n=48) were used for model calibration and for leave-one-out cross-validation. In addition, data from April 2018 (n=15) were available for independent validation. Simultaneous with the ground measurement aerial images were acquired by the SUAV. The prediction capability of each VI was assessed based on the Root Mean Square Error (RMSE). Based on simple linear regression and the lowest cross-validation RMSE, the best VI was selected for each biophysical variable. For AGBf, N uptake, LAI, fAPAR and fCover the best performing index was reNDVI (red-edge Normalised Difference Vegetation Index = (NIR-red edge)/(NIR+red edge)). For AGBd and CCC the best index was Clre (Chlorophyll Index red edge = (NIR/red edge)-1). Both, reNDVI and Clre use the red edge band in their formulae. The nitrogen content was most strongly correlated with DVI (Difference Vegetation Index = NIR-red). The corresponding models had the following relative RMSEs (the RMSEs from the independent validation are shown in parentheses): AGBf: 21% (20%); AGBd: 21% (42%); N: 32% (40%); N uptake: 49% (37%); CCC: 30% (33%); LAI: 29% (29%); fAPAR: 13% (23%); and fCover: 16% (28%). The best performing regression models (RMSE ≤ 21%) are those for AGBf, AGBd, fAPAR, and fCover. Exponential regression models were also examined but, in general, they did not improve the estimation accuracy.

Note that when some of the models are applied to the independent dataset from April 2018 the errors are higher than those obtained by the cross-validation procedure. This emphasises the fact that multi-year datasets with higher number of observations are highly desirable and would permit better model calibration by accounting for between-season variability. At the other hand, even with the small dataset used in this study it was possible to develop quite stable models for AGBf and LAI. Figure 1 shows an example of high resolution (~30 cm) AGBf map derived by the empirical equation. It illustrates that Test Unit 1 is characterised with higher AGBf values. The same situation was observed in the field. The difference is due to the fact that the crop in Test Unit 1 has higher density and height and is more homogeneous. It also is characterised with more intensive tillering and more advanced development phase compared with the other two Test Units.

In conclusion, the regression method seems promising for deriving biophysical variables of winter wheat from UAV multispectral images, in particular, when data in the red edge band is available. This potential should be further evaluated with the ultimate goal of providing operational methods for quantitative crop characterisation by UAV data in precision agriculture.

GIS research project on karst in Bulgaria

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Abstract

This paper is focusing on the development of geographic information system (GIS) which aim is to facilitate the study of anthropogenic influence on karst systems in Bulgaria by analyzing characteristic model areas. Five model areas are selected representing different types of karst systems in the context of the political, socio-economic, and global changes. This study is part of the project „Current impacts of global changes on evolution of karst (based on the integrated monitoring of model karst geosystems in Bulgaria)", Science Research Fund

Key words: GIS, karst systems, land cover, remote sensing

Color models are used for the visual interpretation of satellite data

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ABSTRACT

This study presents the possibilities for using different color models for visual interpretation of satellite imagery. Using the RGB model to visualize different spectral bands as a false color composite image make it possible for different types of objects and features on the Earth surface to be highlighted and easily discerned based on their specific color. Examples are shown based on satellite imagery from several free sources, e.g. the USGS's Earth Explorer, the ESA's Copernicus Open Access Hub, etc.

Key words: remote sensing, RGB color model, false colors, satellite images

с модул за предварителна обработка на многоканалните изображения (3); модулът за предварителна обработка на многоканалните изображения (3) е свързан с модула за вегетационни индексни изображения (4); модулът за вегетационни индексни изображения (4) е свързан с модул гео-база данни (6); модул за регресионни модели (5) е свързан с модул вегетационни индексни изображения (4) и с модул гео-база данни (6). Системата за генериране на картографски продукти (200) включва модул за гео-база данни (6), свързан двупосочно с модул за генериране на растерни слоеве на параметри на посева (7) и е свързан двупосочно и с модул статистически анализ (12); модул за генериране на растерни слоеве на параметри на посева (7) е свързан с модул за генериране на оценъчни растерни слоеве на параметри на посева (8) и е свързан двупосочно с модул за гео-база данни (6); модулът за генериране на оценъчни растерни слоеве на параметри на посева (8) е свързан с модул за гео-база данни (6), с модула за генериране на оценъчни карти на параметри на посева (9) и модула за генериране на оценъчен растерен слой на общото състояние на посева (10); модулът за генериране на оценъчен растерен слой на общото състояние на посева (10) е свързан с модула за генериране на оценъчна карта на общото състояние на посева (11) и с модул за гео-база данни (6). Съгласно полезния модел интегрираната система за дистанционно определяне на състоянието на посеви от земеделски култури включва и сървър (300), който е свързан двупосочно със система (100) и система (200).

1 претенция, 11 фигури

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