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DROUGHT MONITORING USING REMOTE SENSING DATA

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Abstract

The paper deals with the application of the remote sensing for drought monitoring. A way of their application in practice are shown through example for monitoring of drought that is done for three different area in Bulgaria with different pattern, for the same time (July) and for eleven randomly selected years from 1994 to 2009. For the purpose, NDVI, LAI and FPAR vegetation indexes are used. According to Intergovernmental Panel on Climate Change (IPCC) drought and floods are the most severity events threatening the country, so attention is paid on drought monitoring.

Introduction
Theoretical Description of Vegetation Indices

The theoretical basis for ‘empirical-based’ vegetation indices is derived from examination of typical spectral reflectance signatures of leaves. The reflected energy in the visible is very low because of high absorption by photosynthetically active pigments with maximum sensitivity in the blue (470 nm) and red (670 nm) wavelengths. Nearly all the near-infrared radiation is scattered (reflected and transmitted) with very little absorption, in a manner dependent upon the structural properties of a canopy (LAI, leaf angle distribution, leaf morphology). As a result, the contrast between red and near-infrared responses is a sensitive measure of vegetation amount, with maximum red-NIR differences occurring over a full canopy and minimal contrast over targets with little or no vegetation. For low and medium amounts of vegetation, the contrast is a result of both red and NIR changes, while at higher amounts of vegetation, only the NIR contributes to increasing contrasts as the red band becomes saturated due to chlorophyll absorption.

The spectral reflectance of vegetation is detectable in three major Electromagnetic spectrum regions [1, 2]:

1. Visible region (400–700 nm) – Low reflectance, high absorption, and minimum transmittance. The fundamental control of energy-matter interactions with vegetation in this part of the spectrum is plant pigmentation.

2. NIR (700–1350 nm) – High reflectance and transmittance, very low absorption. The physical control is internal leaf structures.

3. MIR (1350–2500 nm) – As wavelength increases, both reflectance and transmittance generally decrease from medium to low, while absorption increases from low to high.

Method

Drought monitoring using NDVI NOAA AVHRR data

NOAA AVHRR and MODIS (Terra/Aqua satellites) data are used for drought monitoring. They can be summarized in: MOD13 A1 (250 m 16 days NDVI, 250 m 16 days EVI); MOD13 A2 (1 km 16 days NDVI, 1 km 16 days EVI) MOD15A1 (Fpar 1 km, Lai 1 km); MOD17 (Npp 1km); MOD44A (Land Cover Change Metrics Past 3 Months)

Land cover monitoring using NOAA NDVI is done by calculations of NDVI for three different regions with various land patterns for following years: 1994, 1997, 2000, 2002, 2005, 2007, 2009, 2010 2005, 2007 and 2009: region 1 – Central North Bulgaria (Fig. 5); region 2 – Central Bulgaria, around Chirpan city (Fig. 6); and region 3 – part of Rhodope mountain, Eastern Rhodope (Fig. 2). Selected regions are shown on the image below.

Normalized Difference Vegetation Index (NDVI) provides information of vegetation health and a means of monitoring changes in vegetation over time. NDVI is calculated from the visible and near-infrared light reflected by vegetation. Healthy vegetation absorbs most of the visible light that hits it and reflects a large portion of the near-infrared light. Unhealthy or sparse vegetation reflects more visible light and less near-infrared light. Calculations of NDVI for a given pixel always result in a number that ranges from minus one (–1) to plus one (+1); however, no green leaves give a value close to zero. A zero means no vegetation and close to +1 (0.8–0.9) indicates the highest possible density of green leaves.

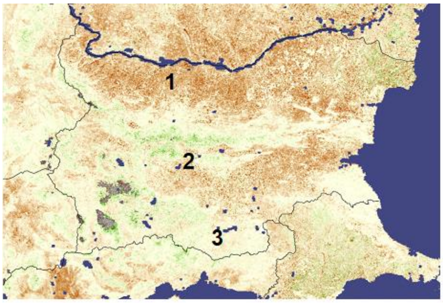

Fig. 1. Vegetation anomaly in 2007(earthobservatory.nasa.gov) and selected areas

NOAA AVHRR NDVI database used for land cover monitoring contains monthly and weekly reference images for the period from April to October (weekly image is composed by 21 images – 3 images per one day). Database is made with the data published in DLR EOWEB and the data received in former Space Monitoring Center at the Ministry of Interior (Bulgaria). Because of the large volume of data for the selected regions, in the report are presented only the result for Rhodope mountain region (Region 3). The pixel values are presented in DN from 0 to 255. Each DN value corresponds to NDVI value. Calculations of NOAA NDVI for a given pixel always result in a number that ranges from minus one to 0,7.

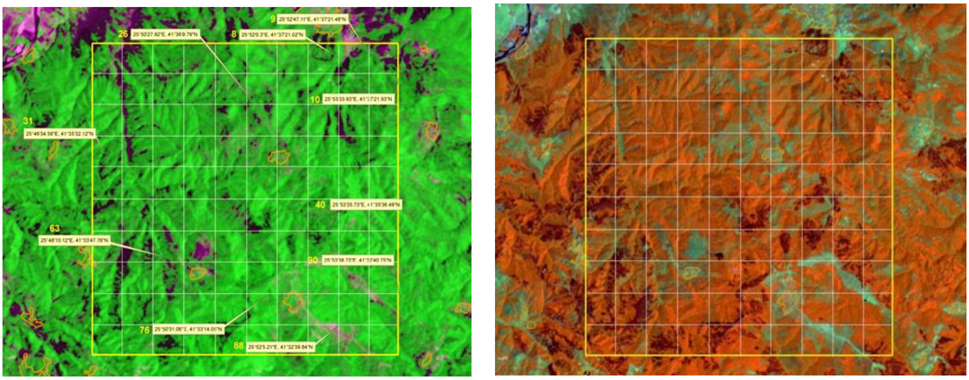

Fig. 2. DMC satellite images. Region 3, July 2008 and 2011. Each selected area is divided on the grid with dimension of 10x10 km.; each one pixel has resolution of 1000 m.
41°37'26.28", 25°46'13.81"; 41°37'30.57", 25°53'14.81"
41°32'10.23", 25°46'19.80"; 41°32'14.50", 25°53'20.23"

Table 1. DN and NDVI value

NDVI	0–255	NDVI	0–255	NDVI	0–255
0.1 – 0.2	94	0.3 – 0.4	127 – 158	0.5 – 0.6	191 - 218
0.2 – 0.3	95 – 126	0.4 – 0.5	159 – 190	0.6 – 0.7	219 – 254

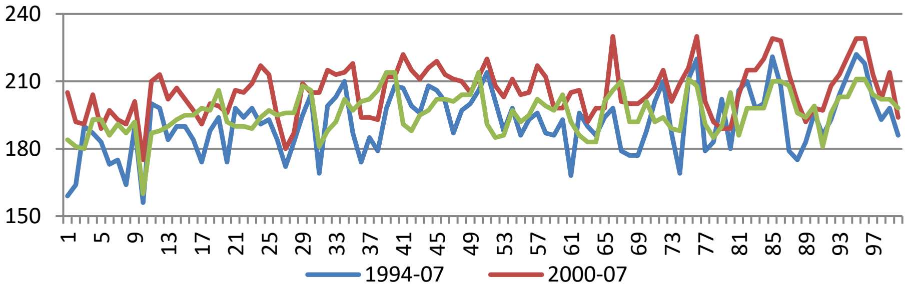

Fig. 3. Years with minimal values of NOAA NDVI

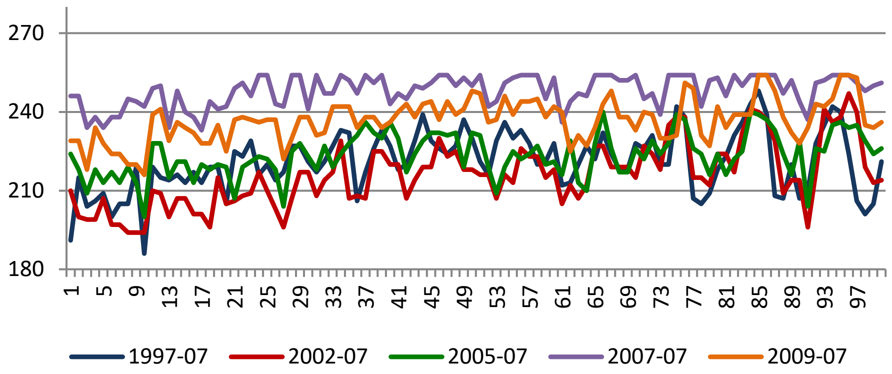

Fig. 4. Years with maximal values of NOAA NDVI

The average annual temperatures are progressively increased in the recent decades. They are highest in 1994, by 1–2 °C higher than average. The maximum temperature in July 2000 was a record - 40–45 ° C, with 2–4 ° C above the climatic norms. Minimum temperatures are consistently abnormal, with excesses to 22 °C. 2002 remains the third warmest year in recent years, following by 2000.

According to the results, we can conclude that the data from 1994, 2000 and 2007 can be used as lower threshold for monitoring and risk assessment of drought. For the Eastern Rhodope (Region 3) years with minimal values for July are 1994, 2000, 2002 and 2010 (Fig. 3), and the years for maximal values are 1997, 2002, 2005, 2007 and 2009 (Fig. 4).

Table 2. Amounts of rainfall for summertime from 2000 to 2010 (http://eea.government.bg)

	Precipitation-mm	Precipitation-mm	Precipitation-mm	Precipitation-mm	Precipitation-mm
Month/Year	**2000**	**2001**	**2002**	**2003**	**2004**
June	**82.35**	93.2	98.6	118	204
July	**11.82**	118.41	348	78	106
August	8.47	58.712	129	66	128
September	35.07	46.887	165	73	72

	Precipi-tation	Precipi-tation	Precipi-tation	Precipi-tation	Precipi-tation	Precipi-tation
Month/Year	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
June	56	219	15	154	**85**	**210**
July	178	86	2.8	12.6	**55.0**	**117**
August	1	9	96.1	19.5	18.5	7
September	39	57	125.3	29.4	119.6	54

MODIS NDVI, LAI and FPAR comparative analysis and correlation

The aim of the study is to show the relationship between vegetation indices derived from satellite data, and the way in which they are change for different types of surfaces. There is a strong relationship between NDVI-LAI, FPAR-NDVI and LAI-FPAR as is shown on the figures below.

The MOD 15 Leaf Area Index (LAI) and Fraction of Photosynthetically Active Radiation absorbed by vegetation (FPAR) are 1 km at-launch products provided on a daily and 8-day basis. LAI defines an important structural property of a plant canopy, namely the one-sided leaf area per unit ground area. FPAR measures the proportion of available radiation in the photosynthetically active wavelengths (400 to 700 nm) that a canopy absorbs. The LAI product will be a LAI value between 0 and 8 of the global gridded database. The FPAR product will be an FPAR value between 0.0 and 1.0 assigned to each 1 km cell of the global gridded database. Leaf Area Index (LAI) is defined as the one-sided green leaf area per unit ground area in broadleaf canopies, or as the projected needleleaf area per unit ground area in needle canopies. The Fraction of Absorbed Photosynthetically Active Radiation (FAPAR, sometimes also noted fAPAR or fPAR) is the fraction of the incoming solar radiation in the Photosynthetically Active Radiation spectral region that is absorbed by a photosynthetic organism, typically describing the light absorption across an integrated plant canopy. This biophysical variable is directly related to the primary productivity of photosynthesis and some models use it to estimate the assimilation of carbon dioxide in vegetation [5].

The LAI and FPAR data are generated by MOD15A2 algorithm, which is a Level 4 product and is generated automatically every 8 days with a spatial resolution of 1 km in Sinusoidal projection.

Once generated, the values obtained are stored digitally with a scale-factor and offset applied to transform the values to their biophysical correspondence. The equation used to decode the digital values to their analysis form is the following [6, 7]:

$$\text{Analyticalpixel} = \text{scale factor} \cdot (\text{digitalpixel value} - \text{offset})$$

Research and Applications: LAI and FPAR are biophysical variables that describe canopy structure and are related to functional process rates of energy and mass exchange. Both LAI and FPAR have been used extensively as satellite derived parameters for calculation of surface photosynthesis, evapotranspiration, and NPP. These products are essential in calculating terrestrial energy, carbon, water-cycle processes, and biogeochemistry of vegetation. The LAI product is an input to Biome BGC (Biogeochemical) models to produce conversion-efficiency coefficients, which are combined with the FPAR product to produce daily terrestrial PSN (photosynthesis) and annual NPP [3, 4].

MOD15A2 provides global LAI and FPAR data derived from the atmospherically corrected BRDF (MOD 09) using up to 7 spectral ranges (0.47 µm, 0.555 µm, 0.688 µm, 0.588 µm, 1.24 µm, 2,130 µm).

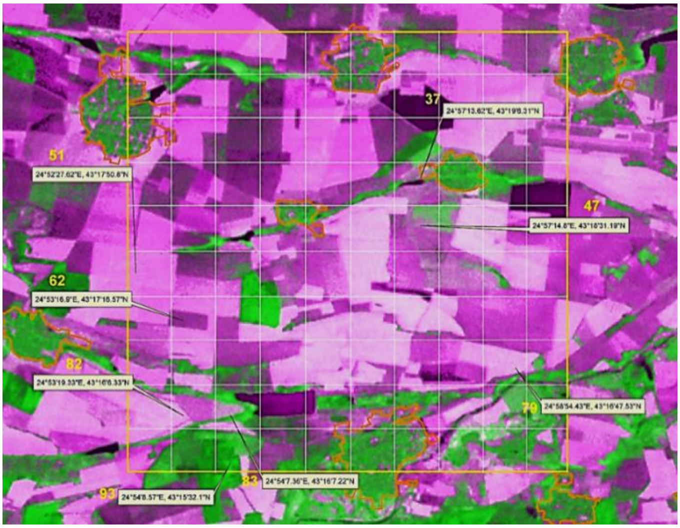

Fig. 5. Region 2 – Chirpan city area, Central Bulgaria
42°12'49,86"N, 25°21'9,08"E; 42°12'55,74"N, 25°28'13,90"E
42°7'33,89"N, 25°21'17,27"E; 42°7'39,76"N, 25°28'21,51"E

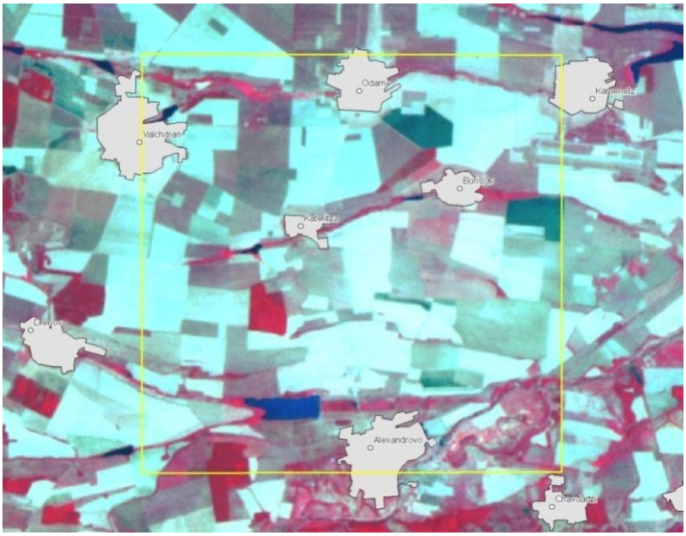

Fig. 6. Region1 – Central North Bulgaria, DMC image, 32 m, 2008
43°20'49,67"N, 24°52'4,91"E;   43°20'57,51"N, 24°59'17,44"E
43°15'33,86"N, 24°52'15,94"E; 43°15'41,67"N,24°59'27,85"E

The following charts (Figures 7, 8 and 9) show the relationship between the NDVI, LAI and FPAR. Theoretically, the relationship between NDVI/FPAR is linear, as FPAR is inherently derived from NDVI – electromagnetic radiation used to determine of NDVI, is used to determine of FPAR (photoactive radiation).

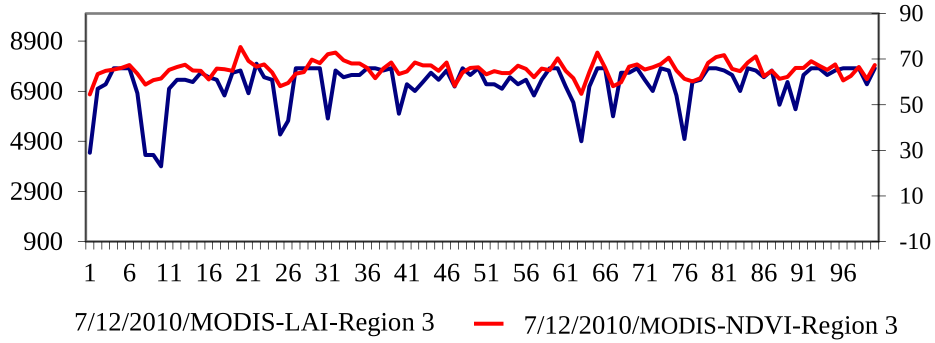

Fig. 7. Relationship between pixel values for NDVI and LAI for Region 3, July 2010. (Actual pixel values for NDVI: The values depicted on y-axis must be divided by 10,000)

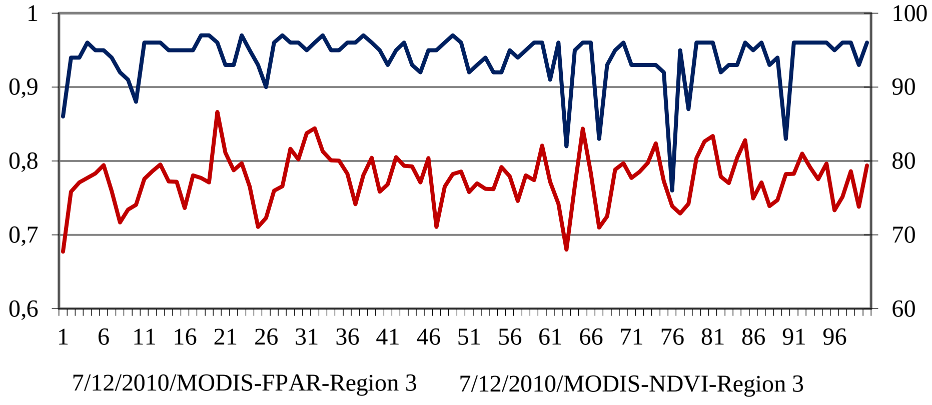

Fig. 8. Relationship between pixels values for NDVI and FPAR. Region 3, July 2010

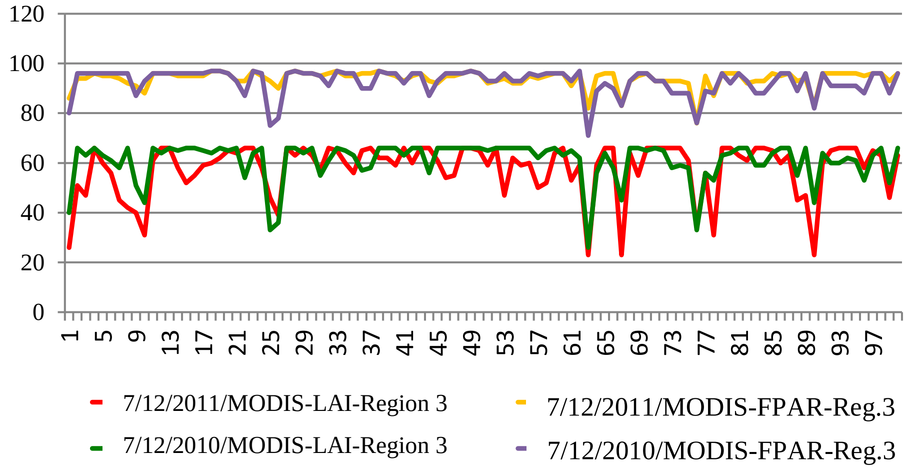

Fig. 9. Relationship between pixels values for LAI and FPAR. Region 3, July 2010 and 2011

It should be noted, in the areas lacking vegetation cover, NDVI and FPAR have very similar values. In areas with dense vegetation cover with maximum LAI values, FPAR also reach maximum values. It is obvious that the denser and "green" vegetation, result in the higher values of the vegetation indices. In our case, logically, the highest values for all indices are observed for the Rhodope mountain region.

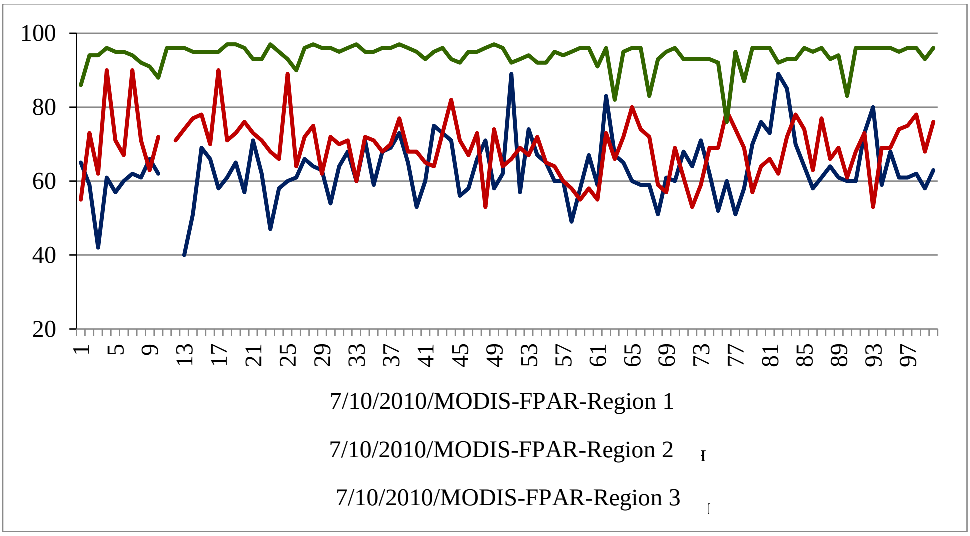

Fig. 10. Relationship between pixels values for FPAR indexes, July 2010

Applicability of remote sensing data in the risk management process of drought

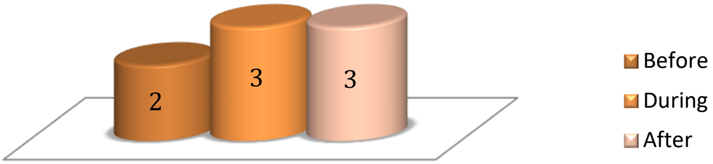

Fig. 10. Applicability of remote sensing data in the risk management process of drought; 1 – low; 2 – medium; 3 – high

Table 3. Applicability of remote sensing data in the risk management process of drought – land cover: "before" means – early warning, preparedness, risk and vulnerability assessment, (including modeling); "during" – monitoring and fast response; "after" – damage assessment, (including modeling); 1 – low; 2 – medium; 3 – high

Satellite	Instrument	Before	During	After	Resolution
High resolution	Camera system	1	1	1	2–10 m
Middle resolution	Camera system Radiometer	3	3	3	10–60 m
AQUA, TERRA	MODIS	3	3	3	250–1100 m
NOAA/POES	AVHRR/3	1	1	1	1100 m

Table 4. Applicability of remote sensing data in the risk management process of drought – water resources

Satellite	Instrument	Before	During	After	Resolution
High resolution	Camera system	1	2	2	2–10 m
Middle resolution	Camera system Radiometer	3	3	3	10–60 m
AQUA, TERRA	MODIS	1	2	2	250–1000 m
NOAA/POES	AVHRR/3	1	1	1	1100 m

Criteria selection for classification are divided in two broad groups. The first group covers the physical parameters related to particular natural hazards and risk process in the context of their study and investigation. On the other hand - the second group is connected with technical characteristics and operating parameter of the space platforms and technical equipment one the board.

Conclusion

The impact and negative effects of a drought depend on its duration, the severity and territorial distribution of the deficit, but also to a large extent on the environment and the socio-economic vulnerability of the affected areas. Desertification is largely caused by inadequate and unsustainable use of land in adverse climatic conditions, usually resulting from poverty and lack of livelihoods and livelihoods.

Land degradation and desertification resulting from prolonged droughts combined with the socio-economic impact and vulnerability of society are particularly evident in arid (dry) areas/areas. The global significance of the problem is underlined by the fact that dry regions cover about 41 % of the Earth's surface and that they are home to about 1/3 of the world's population.

Future climate change scenarios indicate that today's light/medium-sized drought and drought-related processes are likely to shift to future severe and prolonged droughts in less than 30 years.

The methodology for land cover monitoring and drought related processes related to the drought are discussed. It is based on the vegetation indices derived from satellite data and mathematical algorithms/"products" from satellite data. The main vegetation indices are considered, and the results of the calculations and comparative analyzes for several different cases are presented, including different vegetation indices showing the condition of the vegetation roof and having a direct relation to its condition and the processes of drought and drought.

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ИЗПОЛЗВАНЕ НА ДИСТАНЦИННИ ДАННИ ЗА МОНИТОРИНГ НА ПРОЦЕСИТЕ НА СУША И ЗАСУШАВАНЕ

А. Францова

Резюме

В настоящата статия се разглежда приложението на дистанционните изследвания за наблюдение на процесите, свързани със суша и засушаване. Начинът на тяхното приложение в практиката е показан чрез пример за мониторинг, извършен за три различни района в България, с различни географски характеристики и за един и същи времеви период – м. юли (за период от единайсет произволно избрани години от 1994 до 2009 г.). Използват се вегетационни индекси NDVI, LAI и FPAR. Според Междуправителствения панел по изменение на климата (IPCC) сушата и наводненията са най-тежките събития, застрашаващи територията на страната, поради което настоящето изследване обръща внимание на мониторинга на сушата.