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SATELLITE DERIVED PRODUCTS FOR VEGETATION STATE MONITORING IN THE LOWER MURES BASIN

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Abstract

Drought refers to a temporary decrease in water availability, for example, when it doesn't rain over a long period of time. On the other hand, water scarcity occurs when the demand for water exceeds the available sustainable resources. Most European countries are affected by the consequences of water scarcity, droughts and land degradation caused by water resources over-exploitation and exacerbated by climate change. The satellite systems present a wide range of new capabilities that can be used to assess and monitor the actual conditions of agro-ecosystems since information can be obtained on remote, wide area, non-destructive and/or real-time bases. Remote sensing data with low spatial resolution and high temporal resolution provide a useful tool for the monitoring of the vegetation activity from global to regional and local scale. The agricultural vegetation condition monitoring is currently possible, ranging from medium spatial resolution satellite derived - products, with daily revisit (NOAA-AVHRR, SPOT-VEGETATION, etc.) to high and very-high spatial resolution, offered by environmental satellites (LANDSAT, SPOT, FORMOSAT, IKONOS, QuickScat etc.) with longer revisit period. The most important parameters are: vegetation indices, maximum greenness during the growing season, total greenness during the growing season, fraction of photosynthetically active radiation and leaf area index.The study is focused on vegetation state assessment based on satellite derived products for drought monitoring (drought duration and intensity). This paper is based on the analysis of several vegetation indexes (NDVI, NDWI, etc) and biophysical parameters (LAI, fAPAR, land surface temperature, etc).The study area is focused on agricultural region situated in the western part of Romania, in the Romanian downstream of Mures River.

Key words: *drought, water scarcity, vegetation indexes, remote sensing,Mures*

INTRODUCTION

Climate change predictions point to a warmer world within the next 50 years, yet the impact of rising temperatures on rainfall distribution patterns in much of the world remains far less certain. Agriculture is currently accountable for 85% of the global water consumption, and irrigated areas are expected to rise by a factor of 1.9 by 2050, globally in the highest percentages where water-scarcity is most intense, namely South Europe Countries (Martindale, 2010).

For this reason, the need for improved crop, soil and water management practices, particularly in light of climate change, is growing.

Water scarcity and drought are different phenomena although they are liable to aggravate the impacts of each other. In some regions, the severity and frequency of droughts can lead to water scarcity situations, while overexploitation of available water resources can exacerbate the consequences of droughts. Therefore, attention needs to be paid to the synergies between these two phenomena, especially in river basins affected by water scarcity.

As in most European countries, Romania is affected by the consequences of water scarcity, droughts and land degradation caused by climate change. The situation is expected to worsen as further temperature increases are expected in Europe (between 1.0-5.510°C) by the end of the century, while the precipitation decreases. The physiographic and biophysical features of many regions change through time, due to natural and/or anthropogenic factors.

STUDY AREA

The basin of the River Mures is shared by Romania (upstream country) and Hungary (downstream country).
The study area is focused on agricultural region surrounding the Pecica town, in the Ier and Crac sub-basins and the Romanian downstream of Mures River (Fig 1). Mean altitude in the study area is between 100 m to 170 m with a mean slope less than 10°.

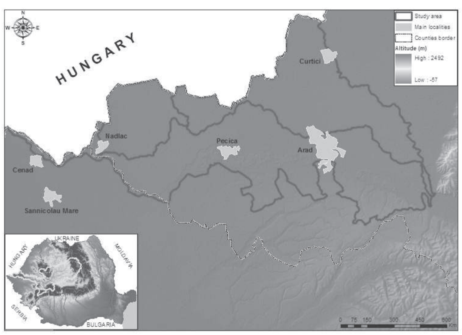

Fig.1. Study area location

DATA USED AND METHODOLOGY

In order to analyse and monitor the vegetation state different types of satellite images have been used: SPOT VEGETATION S10 NDVI products (10 days synthesis) for the year 2011; TERRA/MODIS (Moderate Resolution Imaging Spectroradiometer) vegetation indexes products (VI, NDVI, LAI) for the 2000, 2003, 2005 and 2010; LANDSAT 5 row data for the droughty years (2003, 2006 and 2010).
The methodology used includes the following steps: image geo-referencing, import in the GIS environment and obtain the final documents as cartographic, statistical and tabular and dissemination actions.

RESULTS

In order to monitor the vegetation statement, the medium and high resolution satellite images have been used to obtain the dedicated vegetation indexes. These indexes are good indicators of drought and they are used also by the scientific community (European Drought Observatory).

Normalized Difference Water Index NDWI Gao, 1996) is a satellite-derived index from the Near-Infrared (NIR) and Short Wave Infrared (SWIR) channels from LANDSAT images. The SWIR reflectance reflects changes in both the vegetation water content and the spongy mesophyll structure in vegetation canopies, while the NIR reflectance is affected by leaf internal structure and leaf dry matter content but not by water content. The combination of the NIR with the SWIR removes variations induced by leaf internal structure and leaf dry matter content, improving the accuracy in retrieving the vegetation water content.

The amount of water available in the internal leaf structure largely controls the spectral reflectance in the SWIR interval of the electromagnetic spectrum. SWIR reflectance is therefore negatively related to leaf water content (Tucker 1980).
NWDI holds considerable potential for drought monitoring because the two spectral bands used for its calculation are responsive to changes in the water content (SWIR band). As a result, NWDI is influenced by both the desiccation and wilting of vegetation and may be a more sensitive drought indicator than traditional remote sensing-based indices such as the Normalized Difference Vegetation Index (NDVI), which do not account for changes in the vegetation's water content. This index increases with vegetation water content or from dry soil to free water.

Table 1 reveals the NDWI distribution for the study area. The same drought hot-spots are easily identifiable this time with a lower intensity in the Central-Eastern part of the image.

Tabel 1. NDWI distribution per land-cover classes for the study area

Land cover (CORINE)		NDWI - 2003				NDWI - 2006				NDWI - 2010			
Code/Land classification	Area (sq. km)	Mean	Stdv	Min	Max	Mean	Stdv	Min	Max	Mean	Stdv	Min	Max
211	2525.09	0.30	0.13	-0.67	0.69	0.07	0.18	-0.71	0.67	0.08	0.18	-0.67	0.62
221	51.61	0.23	0.11	-0.60	0.56	0.00	0.12	-0.78	0.56	0.02	0.12	-0.64	0.50
222	16.34	0.16	0.16	-0.80	0.47	-0.06	0.14	-0.21	0.42	-0.06	0.13	-0.65	0.38
231	297.32	0.34	0.11	-0.67	0.72	0.08	0.13	0.02	0.67	0.08	0.14	-0.66	0.60
242	71.57	0.26	0.12	-0.56	0.61	0.03	0.13	-0.40	0.66	0.05	0.14	-0.58	0.64
243	59.01	0.26	0.15	-0.70	0.54	0.03	0.16	-0.71	0.51	0.03	0.16	-0.67	0.50
311	167.65	-0.03	0.15	-0.82	0.53	-0.13	0.12	-0.79	0.51	-0.13	0.09	-0.78	0.53
321	8.60	0.30	0.13	-0.22	0.55	0.06	0.14	-0.68	0.52	0.07	0.14	-0.33	0.52
324	10.87	0.20	0.18	-0.83	0.54	-0.04	0.14	-0.86	0.46	-0.01	0.16	-0.59	0.49

The distribution of NDWI per land classes illustrated in Table 1 confirms the conclusions of the NDVI values distribution per land classes: the pastures and natural grasslands are the most affected land-cover classes followed by the agricultural lands.

By combining the two indexes a drought "pattern" is recognizable: for the year 2003 most of the values are grouped in the upper left part of the chart (low NDVI and high NDWI). In 2006 and 2010 the largest number of values can be found in the lower right corner of the graph (high NDVI and low NDWI), (figures 2 and 3).

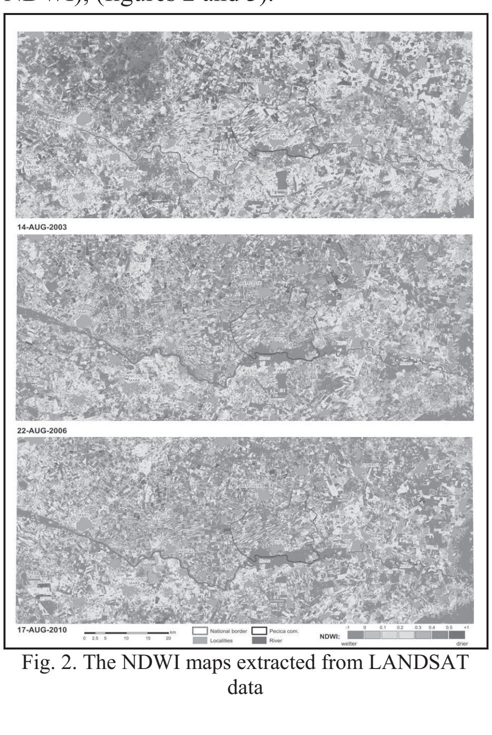

Fig. 2. The NDWI maps extracted from LANDSAT data

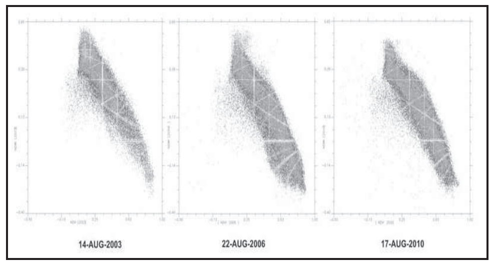

Fig. 3. Scatter – plots of the NDVI and NDWI

Leaf Area Index (LAI)

The LAI variable defines the number of equivalent layers of leaves relative to a unit of ground area. The LAI variable is used as satellite-derived parameter for calculating surface photosynthesis, evapotranspiration, and net primary production, which in turn are used to calculate terrestrial energy, carbon, water cycle processes, and biogeochemistry of vegetation. For MIDMURES Project study area TERRA/MODIS data have been used to obtain the LAI maps. The LAI values confirm the result obtained when observing the NDVI and EVI evolution during the phenophase. More visible this time, are the forest lands, noticeably with higher values of LAI (figure 4).

In order to highlight the plant water stress and drought (according to vegetation status), the LAI evolution has been monitored, starting from March 06, 2011 to October 16, 2011 in the study area. From May 25, 2011 LAI values began to decrease and lasted about 1 month until June 26, 2011 mark out the beginning of drought. This time period matches with latest phenological stages of winter crops (winter wheat), early milk and harvesting (end of June-beginning of July).

During this period were recorded small amount of precipitation that affected the crops and led to lower values of LAI.

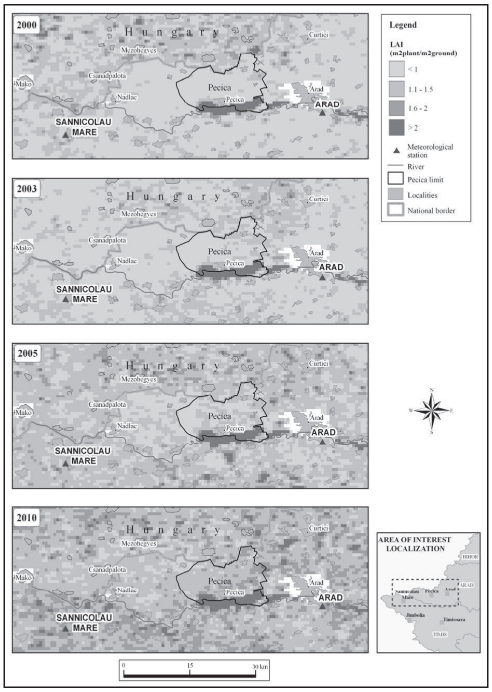

Fig. 4. Spatial variation of LAI values

A critical period can be observed from August to October when precipitation amounts were very low and soil moisture anomalies occurred thus setting up the droughts.

The MODIS LAI values have been validated using the field campaigns that were carried out in the agricultural area of Pecica town. In these campaigns the LAI values ware measured with specific devices (AccuPAR LP- 80). The LAI field measurements were taken for different crops like oats, sunflower, onion and watermelon.

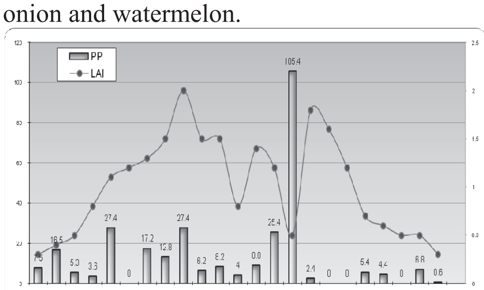

Fig.5. The correlation between LAI and precipitation

Normalized Difference Vegetation Index (NDVI) can be used for the determination of the beginning, the end and the duration of the vegetation season. These biological events play a key role in the interactions occurring at the soil-plant-atmosphere interface.

NDVI values have been extracted from SPOT VEGTATION, TERRA/MODIS and LANDSAT data.

The SPOT VEGETATION data have been used to monitor the vegetation state for year 2011. In figure 6 is shown an example of the NDVI obtained from SPOT VEGETATION data.

The NDVI values can be used in correlations with various agro-meteorological parameters using datasets provided by agro-meteorological models and agro - meteorological observation platforms. The GPS measurements and crop identification on the satellite data allow to correlate the NDVI values (for different crops) with the precipitation values recorded at Arad meteorological station.

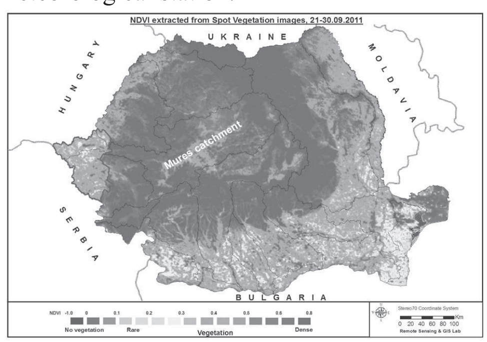

Fig. 6. The NDVI spatial distribution, extracted from SPOT VEGETATION, 21-30.09.2011

The TERRA/MODIS data analysis has been done for different four years (2000, 2003, 2005 and 2010), in order to evidence the drought years.

The difference between 2000 and 2003 on one hand and 2005 and 2010 on the other hand (except some wooded land along Mures) shows the effect of low precipitation and high temperature in 2000 and 2003. That is why NDVI values of more than 0,3 are sparse.

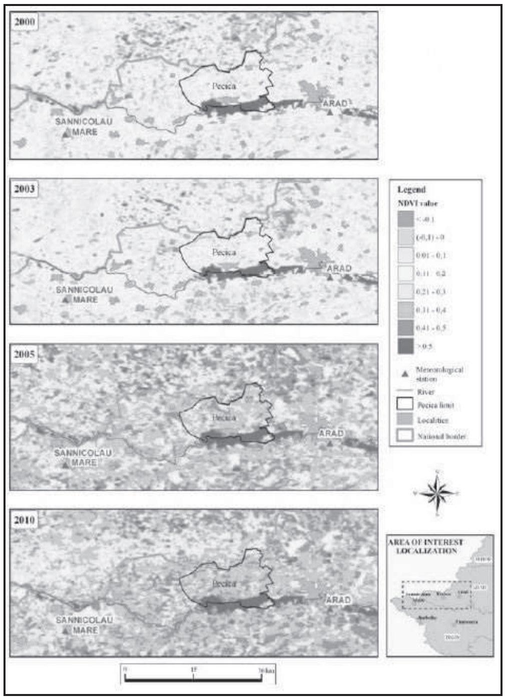

Fig. 7. Spatial variation of NDVI values from 10th of June to 28th of August

Table 2 aggregates the raw information and illustrates the NDVI percentage change between the 3 years under analysis. For the normal years (2006 and 2010), these changes don't exceed 10%. While for 2003 they exceed 30% for a considerable number of land-cover classes. As anticipated above, the pastures seem to be the most sensitive to drought occurrence with changes higher than 40%. The agricultural classes (CLC 211 and 243) suffer also major changes of 30%.

Table 2. NDVI changes (%) per land classes for the study area

Land cover (CORINE)		NVDI % of change		
Code	Area (sq.km)	2003-2006	2003-2010	2006-2010
211	2525.09	37.19	31.64	-8.84
221	51.61	27.45	25.34	-2.91
222	16.34	22.44	21.95	-0.63
231	297.32	46.13	40.94	-9.64
242	71.57	34.81	28.80	-9.22
243	59.01	35.97	31.02	-7.72
311	167.65	-0.60	-0.76	-0.15
321	8.60	38.05	31.28	-10.94
324	10.87	27.08	20.40	-9.16

The NDVI stretched colour scale includes sometimes too much information. In order to isolate only the parts affected by drought a 2 classes classification can be applied, using a "low-vegetation" NDVI threshold. In this regard, the NDVI value of 0.22 was used as "drought threshold". This bi-color representation excludes the "normal" NDVI values. Areas represented in orange in figure 8 can be therefore associated with dry land.

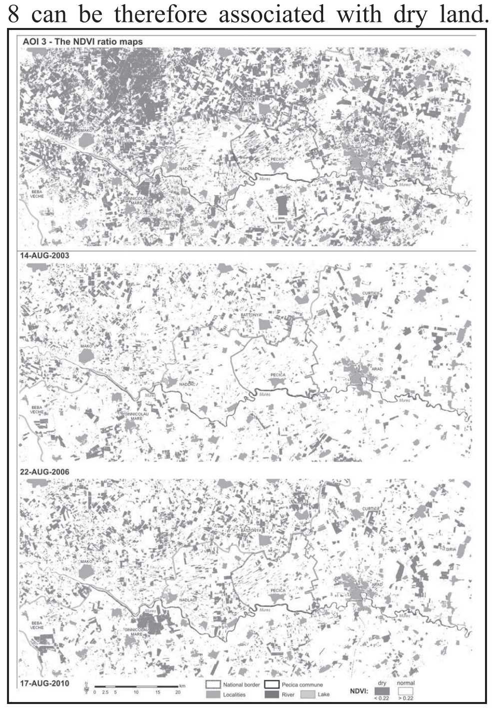

Fig. 8. The NDVI ratio maps

Another approach in evaluating the NDVI maps is by using the histograms (figure F.16). In statistics, a histogram is a graphical representation, showing a visual impression of the data distribution. Such a data evaluation offers the possibility of a general view for the entire set of data. The NDVI histograms can be divided in 2 zones: dry and normal. The values for year 2003 are grouped in the "dry" part while for 2006 and 2010 the opposite situation is recorded.

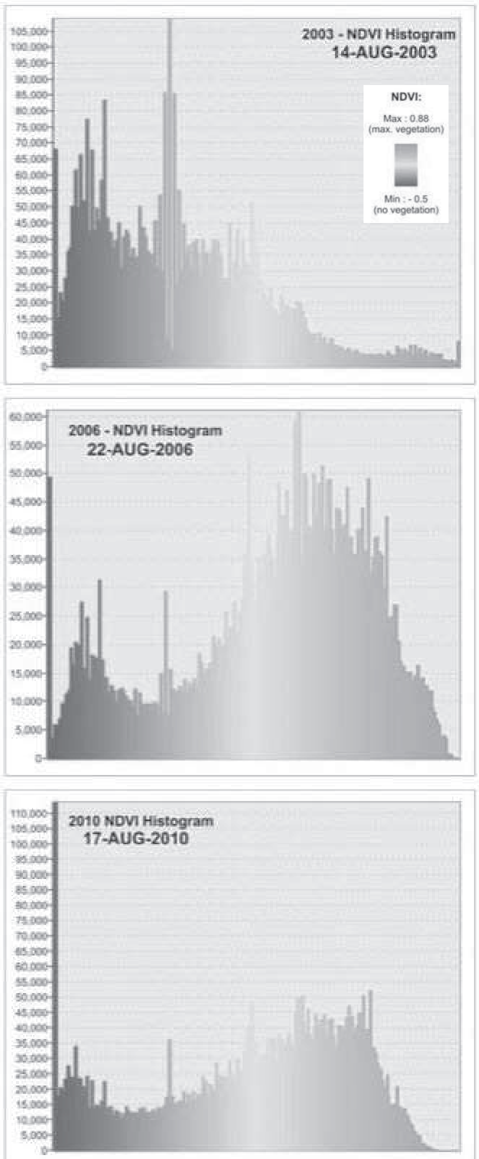

Fig. 9. NDVI histograms

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CONCLUSIONS

It proved that remote sensing techniques can enhance and improve the drought analysis, especially considering the scarce availability of measured ground truth data. The advantage of multi-annual imagery availability allows the overlay and cross-checking of doughty, normal or rainy years.

LANDSAT imagery proved to be a very useful tool in studying historical drought events. Its high spatial resolution enables a detailed observation of the Earth's surface, while its broad spectral resolution allowed the development of numerous LANDSAT drought-oriented current indexes.

SPOT VEGETATION and TERRA/MODIS imagery/products can be used for monitoring the vegetation state during the season (very good temporal resolution) for the large farms (medium spatial resolution).

GIS technologies offer the possibility of crossed-analysis between various data sources such as vegetation indexes.

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