THE ANALYSIS OF MOISTURE DEFICIT BASED ON MODIS AND LANDSAT SATELLITE IMAGES. CASE STUDY: THE OLTENIA PLAIN

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ABSTRACT. The analysis of moisture deficit based on MODIS and LANDSAT satellite images. Case study: The Oltenia Plain. Satellite images are an important source of information to identify and analyse some hazardous climatic phenomena such as the dryness and drought. These phenomena are characterized by scarce rainfall, increased evapotranspiration and high soil moisture deficit. The soil water reserve depletes to the wilting coefficient, soon followed by the pedological drought which has negative effects on vegetation and agricultural productivity. The MODIS satellite images (Moderate Resolution Imaging Spectroradiometer) allow the monitoring of the vegetation throughout the entire vegetative period, with a frequency of 1-2 days and with a spatial resolution of 250 m, 500 m and 1 km away. Another useful source of information is the LANDSAT satellite images, with a spatial resolution of 30 m. Based on MODIS and Landsat satellite images, were calculated moisture monitoring index such as SIWSI (Shortwave Infrared Water Stress Index). Consequently, some years with low moisture such as 2000, 2002, 2007 and 2012 could be identified. Spatially, the areas with moisture deficit varied from one year to another all over the whole analised period (2000-2012). The remote sensing results was corelated with Standard Precipitation Anomaly, which gives a measure of the severity of a wet or dry event.

Keywords: moisture deficit, MODIS, LANDSAT, SIWSI, SPA, the Oltenia Plain

1. INTRODUCTION

The drought is a complex meteorological phenomenon, characterized by rainfall shortage or scarcity, high air-temperatures and high values of saturation deficit, extended over longer periods of time (weeks or even months). These conditions determine the depletion of soil water reserves and cause difficulties to plant growth and development (Ciulache and Ionac, 1995). Conventionally, drought monitoring is based on weather observations which sometimes lack the continuous temporal and spatial coverage needed to monitor its true extent and intensity. This is often the case provided that real-time meteorological data are difficult to be obtained, so that the existing drought monitoring procedures often lag behind the development of drought events. Satellite remote sensing provides

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systematic and consistent observations of terrestrial ecosystem dynamics. The increasing availability of satellite observations has been found to be a powerful tool to measure photosynthetic activity and phenology of vegetation/crops at local and regional scales (Thenkabail et al. 2004, Jiang et al. 2013).

The water content depletion is noticeable during the early stages, mainly in the 0.9–2.5 m (comprising the near infrared, NIR, and the short wave infrared, SWIR) spectral regions and more specifically in the bands centered on 1.45, 1.94, and 2.50 m (Carter, 1991). However, the decrease of chlorophyll content (Goerner et al., 2011) – noticeable in visible (VIS) wavebands – requires more prolonged periods of drought (Morelo A. et al., 2013).

The Oltenia Plain is located in the south-western part of Romania (Fig. 1). In this area, farmland represents the dominant land use type and cereals are the main crops being cultivated.

The autumn wheat report moderate moisture deficiency in most of the study area and locally, it reports high moisture deficiency both at the beginning and at the end of the growing season (the end of September and the end of June, respectively). The maize crop records moderate pedological drought on July-September and locally, severe drought during these summer months (Ion Sandu, 2010).

The purpose of this study is to identify the main periods with moisture deficit and the areas with the highest frequency of its manifestation, by means of remote sensing techniques

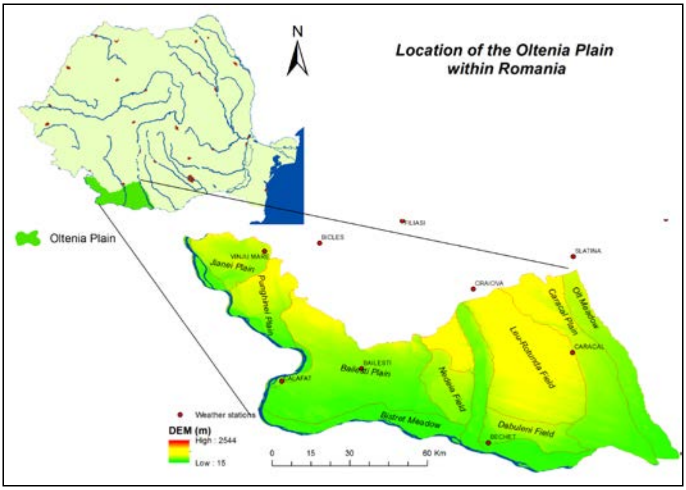

Fig. 1. Location of the study area (The Oltenia Plain)

2. DATA AND METHODOLOGY

In this study, the data we used for remote observation were the 8-day MODIS (Moderate Resolution Imaging Spectroradiometer) products of surface reflection (MOD09A1, 500 m), Landsat TM and (30 m resolution) provided by NASA Land Processes Distributed Active Archive Center (LP DAAC), respectively the U.S. Geological Survey (USGS).

We used a combination of the near infrared (NIR) and SWIR chanels, to derive the water sensitive index like SIWSI (Shortwave Infrared Water Stress Index).

The SIWSI is a normalized index and the values therefore theoretically vary between −1 and 1. A large absorption by leaf water occurs in the shortwave infrared wavelengths (SWIR) and the reflectance from plants thereby is negatively as related to the leaf water content (Fensholt and Sandholt, 2003; Fensholt et al., 2006).

$$SIWSI = \frac{SWIR - NIR}{SWIR + NIR};$$

where: NIR is the reflectance in near infrared, channels 2 (0.841–0.876 µm), SWIR is the reflectance in the shortwave infrared wavelengths, chanels 6 (1.628–1.652 µm).

We also used climatic data, represented by the rainfall, recorded at the weather stations: D.T. Severin, Calafat, Bechet, Băileşti, Caracal and Craiova and we calculated Standard Precipitation Anomaly to compare the drought phenomenon with remote sensing result.

The *Standard Precipitation Anomaly (SPA)* was computed by the formula of Gaceu (2002), Vlăduț (2006-2008):

$$SPA=(m_i - m)/\alpha;$$

where: m_i – amount of rainfall in a given period, m – multiannual average amount, α – standard deviation. The value of the SPA gives a measure of the severity of a wet or dry event, as summarised in Table 1.

Table 1. SPA Classification according to Gaceu (2002)

SPA Value	Class
SPA ≥ 2.00	Extremely wet
1.50 < SPA≤ 2.00	Severely wet
1.00 < SPA ≤ 1.50	Moderately wet
-1.00 < SPA ≤ 1.00	Almost normal
-1.50 < SPA ≤ -1.00	Moderately dry
-2.00 < SPA ≤ -1.50	Severely dry
SPA < -2.00	Extremely dry

3. RESULTS AND DISCUSSION

3.1. Shortwave Infrared Water Stress Index from MODIS

SIWSI, which use the channel 1.628–1.652 µm is more sensitive to moisture variability than NDWI which uses the channel 1.24 µm. There were pronounced differentiation of the SIWSI mean values with both negative and positive values. This is useful for the detection of subtle differences in the vegetation moisture. The type and land use plays an important role in the qualitative analysis of data obtained from satellite images. The phenological stages of crops can cause errors when interpreting the data recorded by remote sensing techniques. Following Corine Land Cover (2000, 2006, 2012) in the last 13 years (2000-2012), there were no major changes in land use. For this reason, was calculated a deviation of analyzed period from the multiannual average of the same vegetative stage. As a result, the deviation of June (26 June-03 July) was negative in 2000, 2001, 2002, 2007,and 2012 (Fig.2). According to the values of the SPA, calculated for the autumn crop period (IX-VI), there were registered dry and very dry years in 2000, 2002 and 2007 (Fig.2). The correlation between SPA (September-June) and SIWSI (26 June – 03 July) in 2000-2012 period was significant at the 0.01 level (Table. 2).

The results of studies obtained by other authors so far (Sandu, 2010; Vlăduț, 2013), these years had very dry summer seasons, recording low levels of agricultural production, not only in the Oltenia Plain, but also in most of the Romanian territory.

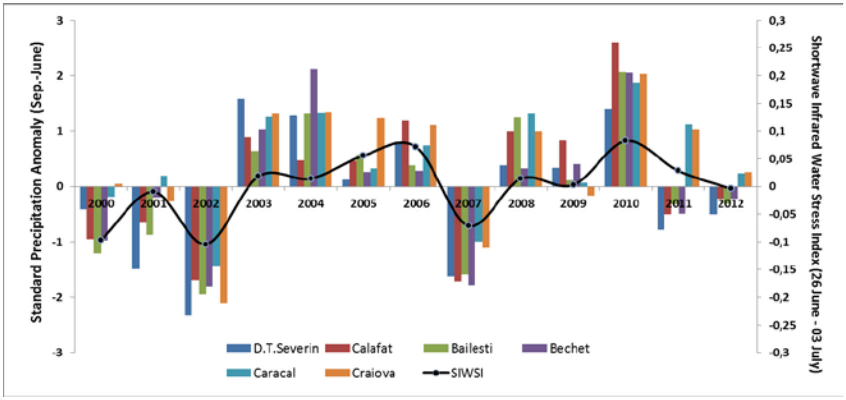

Fig. 2. The Shortwave Infrared Water Stress Index in the Oltenia Plain (2000-2012)

Table 2. Correlation between SPA (Sep.-June) and SIWSI (26 June – 03 July) in 2000-2012 period

Correlations			
		SIWSI	SPA
SIWSI	Pearson Correlation	1	0,848**
	Sig. (2-tailed)		0,000
	N	13	13
SPA	Pearson Correlation	0,848**	1
	Sig. (2-tailed)	0,000	
	N	13	13

**. Correlation is significant at the 0.01 level (2-tailed).

Spatially, the variability of the SIWSI values varied between -0.40 and 0.30 during the very dry years. The lowest values were recorded in the southern Caracal Plain and Băileşti Plain and the highest values were recorded in the floodplains of the Danube, Jiu and Olt rivers. On all of the images, we could notice that the highest values of this index is specific of areas covered by forests such as the south-western parts of the Băileşti Plain, the central parts of the Punghinei Plain and a few more isolated areas in the floodplains of the Danube, Jiu and Olt rivers (Fig. 3).

By analysing the MODIS images, we could not identify the areas with the most frequent moisture deficits as in the case of the sand-covered areas of the western Leu-Rotunda Field and the Dabuleni Field. Therefore, we can conclude that the moisture deficit is mainly influenced by rainfall, evapotranspiration and vegetation type.

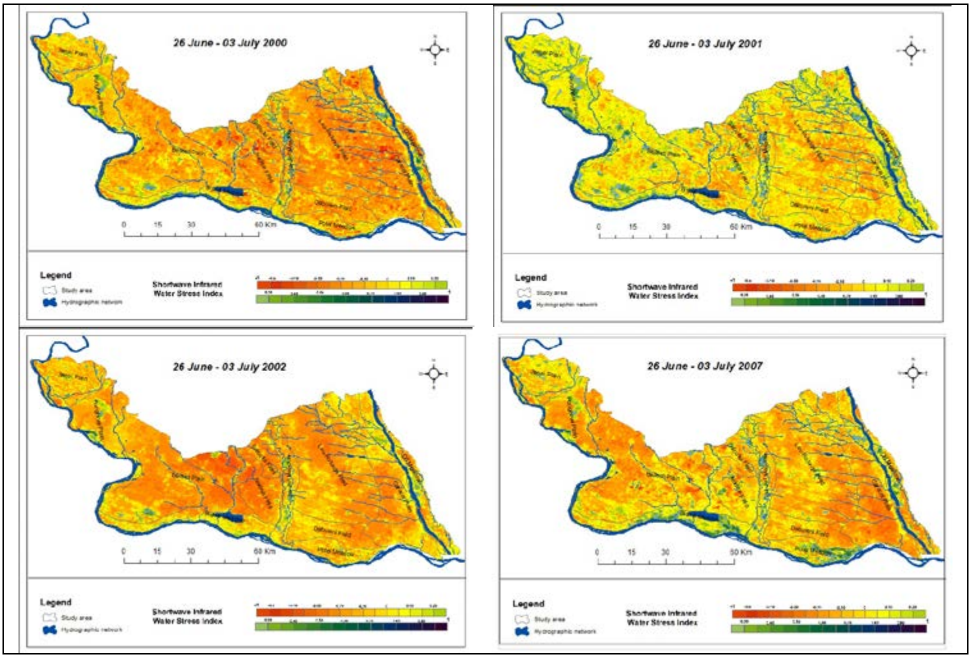

Fig. 3. The Shortwave Infrared Water Stress Index from MODIS in the Oltenia Plain

At the end of August (21-28) the SIWSI deviation has recorded negative values in 2000, 2001, 2003, 2004, 2008-2012. According to the values of the SPA, calculated for the spring crop period (IV-VIII), there were registered dry and very dry years in 2000, 2001, 2008, 2011 (Fig. 4). The relationship between the variability of the SIWSI and the climate phenomena was statistically significant according to the Bravais-Pearson test, but the correlation coefficient was lower than in the case of correlation autumn crops (Table 3). This is due to the influence of air temperature on evapotranspiration.

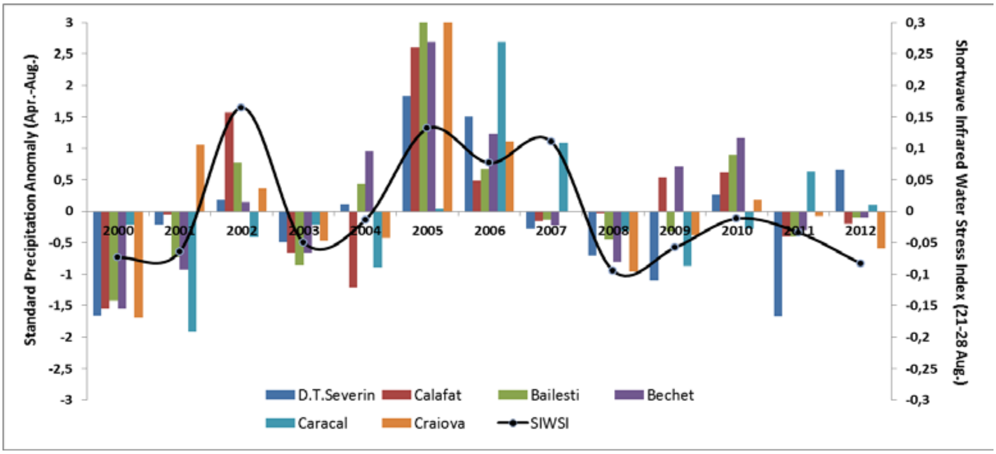

Fig. 4. The Shortwave Infrared Water Stress Index in the Oltenia Plain (2000-2012)

Spatially, the variability of the SIWSI values varied between -0.40 and 0.10 and the lowest values were recorded in the southern Caracal Plain and the eastern Leu-Rotunda Field (Fig. 5).

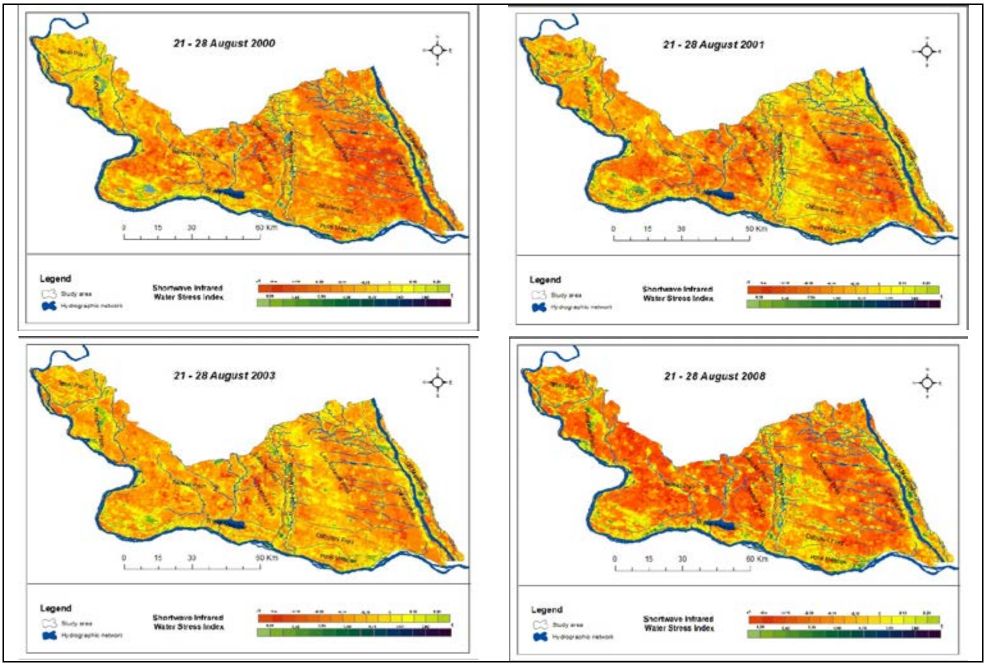

Fig. 5. The Shortwave Infrared Water Stress Index from MODIS in the Oltenia Plain

Table 3. Correlation between SPA (Apr.-Aug.) and SIWSI (21-28 Aug.) in 2000-2012

Correlations			
		SIWSI	SPA
SIWSI	Pearson Correlation	1	0,721**
	Sig. (2-tailed)		0,005
	N	13	13
SPA	Pearson Correlation	0,721**	1
	Sig. (2-tailed)	0,005	
	N	13	13

**. Correlation is significant at the 0.01 level (2-tailed).

3.2. The Shortwave Infrared Water Stress Index from LANDSAT

The Landsat satellite imagery with a resolution of 30 m, allows a more detailed analysis of moisture deficit in the crops, being able to distinguish between these specific and other land use types, although the temporal frequency of the Landsat images (2/month) does not allow either synthetic or case-study analysis on any time of the year. Moreover, their analysis is complicated by cloud-cover which may lead to errors of interpretation. Spatially, the variability of the SIWSI values from Landsat, varied between -0.50 and 0.30 in June 2000 and between -0,30 and 0,30 in June 2007. The lowest values were recorded in the southern Caracal Plain (24 June 2007) and the western Leu-Rotunda Field (28 June 2000), (Fig. 6).

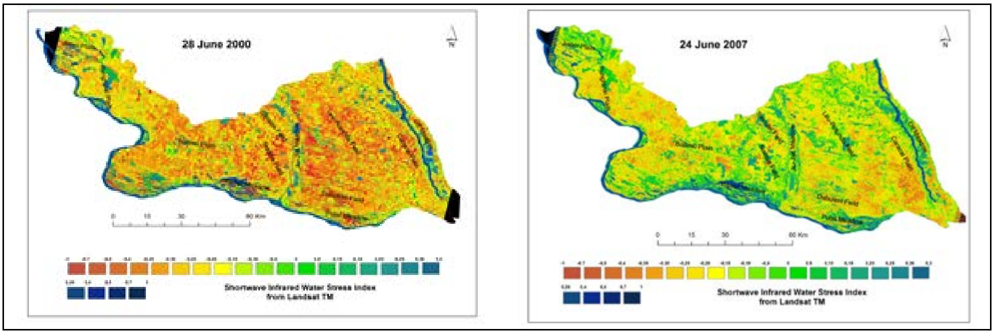

Fig. 6. The Shortwave Infrared Water Stress Index from Landsat in the Oltenia Plain

4. CONCLUSIONS

The moisture deficit can be efficiently analyzed by means of satellite images, which provide a pretty accurate picture on the spatial extent of the phenomenon, and on the areas that lack specific monitoring stations. The frequency with which the images are recorded allows a continuous monitoring of the risk phenomena, thus pointing to rapid intervention, even without field-observations which would cost more time and money.

According to the results obtained from the MODIS satellite images, moisture deficits were recorded in the 2000, 2001, 2002, 2007, 2008 and 2012 years and its intensity widely ranged spatially from one year to another.

In the analysis of risk phenomena by means of satellite imagery, one must take into account both the land use type and the phenological stage of the vegetation, together with cloud cover as well, especially in the case of Landsat images, in order to avoid errors of interpretation.

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