

ASSESSING DROUGHT SEVERITY AND ITS IMPACT ON VEGETATION WITHIN OLTEНИA PLAIN USING NDVI FROM MODIS (2000-2010)

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ABSTRACT. - **Assessing drought severity and its impact on vegetation within Oltenia Plain using NDVI from MODIS (2000-2010).** Remote sensing is often used for detecting seasonal vegetation changes, treating a phenomenon both from a spatial and temporal perspective. Regional assessment of the drought has a huge importance in future studies and measures taken in order to diminish its negative effects in the agricultural sector. Considering this fact as a premise, the primary objective of our study aims at observing the impact on the vegetation of the well-known and, probably, the most severe meteorological risk in Oltenia Plain, the drought, using the NDVI analysis and several drought indexes and correlations. At the same time, one of our goals was to see the characteristic periods of the drought by consulting the effects it has over the vegetation. Although a lot of work has been devoted to examining the drought on a temporal and spatial scale, the results were conclusive, showing a direct relation between the values of the rainfall and the phenological state of the vegetation. Our interest was accomplished via a multi-indices assessment of the drought impact, according to which, the binome vegetation – humidity proved to be the best way to estimate the drought periods in Oltenia Plain, as well as drought exposure and vulnerability.

Key words: drought, NDVI, Oltenia Plain, "De Martonne" Index

1. Introduction

Drought is a risk phenomenon, characterized by a prolonged period of dry weather when the amount of rainfall is abnormally low and therefore causes a hydrological imbalance. Depending on the research interest, several definitions may be found, each of them attempting to measure drought severity and magnitude. The most versatile method for defining drought intensity is achieved by determining deviations from the annual mean rainfall, water balance, or river flow. Drought severity can be then measured by multiplying the drought intensity by the duration of the drought (Smith, 2001, 2006). There are several types of droughts:

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atmospheric droughts, pedological droughts and complex droughts. The atmospheric drought is characterized by partial or total absence of rainfall, increased temperatures and increased water consumption by the vegetation. In cases of prolonged atmospheric droughts, the moisture deficit affects increasingly deep layers of soil, thus causing the occurrence of soil drought. The combination of the two types of drought gives rise to mixed or complex droughts, which may compromise some or all crops (Ciulache, Ionac, 1995).

Drought, however defined, is associated with a number of outcomes. Impact assessments begin by mapping out the direct physical consequences of a climatic event or climatic change, such as: reduced crop yields, livestock losses, reservoir depletion, hydroelectric interruptions, drinking-water shortages or quality changes, dry land degradation or forest dieback. These direct outcomes can then be traced to social consequences (Ribot, 1996). The global climate change that has been taking place in the last decades, manifested by rising average temperatures and changes of the rainfall regime, was the main trigger for the expansion of areas affected by drought, both globally and in Romania. (Sandu, Mateescu and Vătămanu, 2010).

Oltenia Plain is located in the South-Western part of Romania, being bounded by the Danube to the South and West, by the Olt River to the East, and by the Getic Plateau to the North (fig. 1). The multiannual average temperatures in Oltenia Plain are between 10.9°C (Craiova meteorological station) and 11.9°C (D.T.Severin meteorological station), followed by Calafat with 11.8°C. The multiannual average rainfall ranges from 332.6 l/m² at the Bechet to 512.8 l/m² at D.T.Severin station. The highest values are recorded at stations located at higher than average altitudes (Craiova - 192 m, Caracal - 106 m, D.T. Turnu-Severin - 77 m, Calafat 61 - m, Băilești - 57 m, Bechet - 36 m).

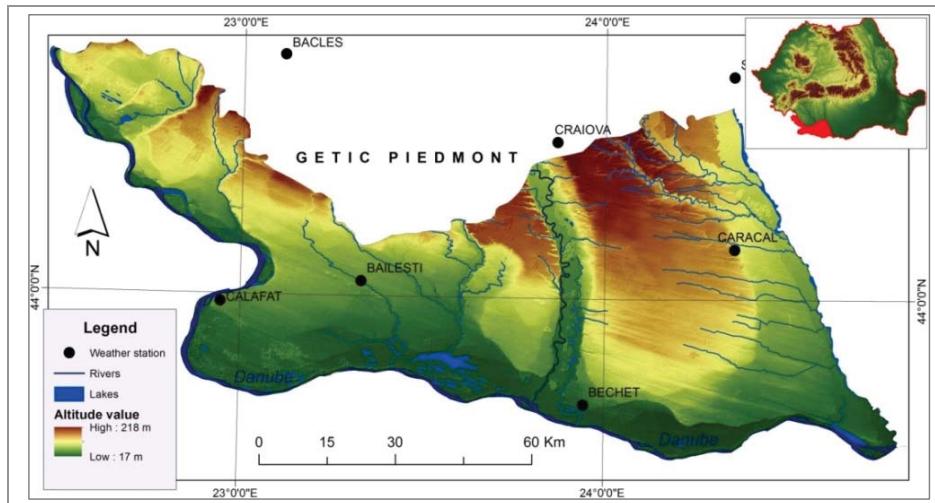


Fig.1. Location of Oltenia Plain

2. Data and methods

In this study we used meteorological data from six weather stations (Craiova, Caracal, Calafat, Băileşti, Bechet and D.T. Severin), in order to calculate the „De Martonne” Index and NDVI product from MODIS images with a resolution of 250 m and representing a synthesis of 16 days, as well as its percentage deviation ($\Delta \%$) compared to the mean. The MODIS products can be downloaded from the website (<http://daac.ornl.gov/MODIS/>) in GeoTIFF format and then processed with a software for processing satellite images.

NDVI (Normalized Difference Vegetation Index) is a quick and efficient way for estimating the amount of vegetation. Also, NDVI indicates the level of photosynthetic activity in the monitored vegetation, reflecting whether the vegetation is stressed or not. After a stress, a significant reduction in NDVI values of the field is to be expected (Tsiros, Dalezios, 2010). It is computed following the equation:

$NDVI = (NIR-RED)/(NIR+RED)$; where NIR is near infrared spectral band and RED is red spectral band.

NDVI values range from -1 to +1, with values near zero indicating no green vegetation and values near +1 indicating the highest possible density of vegetation. Areas of barren rock, sand and snow produce NDVI values of <0.1, while shrub and grassland typically generate NDVI values of 0.2–0.3, and temperate and tropical rainforests produce values in the 0.6–0.8 range (Belal et al, 2012).

The "De Martonne" Index is one of the indices frequently used in Romania (Gaceu, 2002, Dumitraşcu, 2006, Păltineanu, 2007, Vlăduț, 2010, Sandu, 2010), to characterize the climatic restrictions in a given region.

It is used for determining the demand for irrigation (WMO, 1975, Nastos, Politi, Kapsomenakis, 2013). Its monthly values are described by the following equation:

$$I_{DM} = \frac{P * 12}{T + 10}; \text{ where } P \text{ is the monthly mean rainfall (mm)} \text{ and } T \text{ (°C) is the respective mean monthly air-temperature.}$$

The purpose of this index is to identify the months for which irrigation is necessary, which in turn depends on both rainfall and ambient temperature. Thus, irrigation according to this index becomes necessary when $I_{DM} < 20$ (Shahabfar, Eitzinger, 2013).

3. Results and discussion

The gradual degradation of the irrigation system in the Oltenia Plain led to increased water addiction of crops from rainfall. Therefore, the aridity index variation between 2000 and 2010 was correlated with vegetation index variation.

A primary study was to analyze the months with the highest water consumption by vegetation (May - August), May-June for the autumn grain and July-August for the row crops. Afterwards, we analyzed the cumulative rainfall during the vegetation period of crop.

The lowest values of the „De Martonne” Index ($I_{DM} < 5$) were recorded in June 2003, July 2007 and August 2000 and 2008, with low values ($I_{DM} = 5 - 20$) also recorded in 2001, 2002, 2004, 2009 and 2010 (Fig.2).

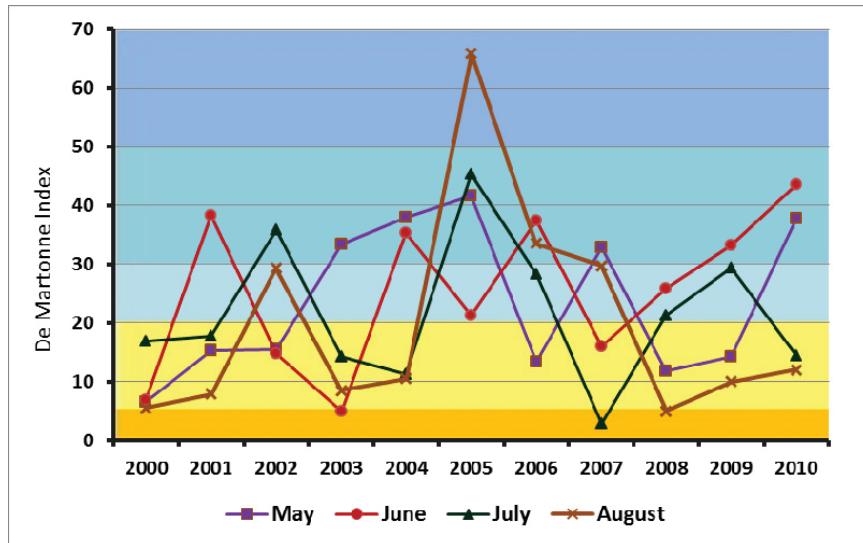


Fig.2.,„De Martonne” Index in Oltenia Plain (2000-2010)

According to the percentage deviation ($\Delta\%$), compared to the multiannual average, the lowest values of the NDVI were found in July 2007 (-29.2 %), May 2002 (-23.0 %), August 2000 and 2010 (-19.5 respectively -20.6 %). Also, low values (< -10 %) were recorded in 2000 (May, June, July), 2002 (June), and August 2001, 2003, 2008 and 2009 (Table nr. 1).

Table nr.1. NDVI percentage deviation ($\Delta\%$) compared to the multiannual average

Year	May ($\Delta\%$)	June ($\Delta\%$)	July ($\Delta\%$)	August ($\Delta\%$)
2000	-15.6	-17.8	-13.5	-19.5
2001	-4.6	3.5	-5.6	-11.5
2002	-23.0	-17.9	16.7	28.7
2003	11.4	2.0	-8.4	-12.3
2004	4.0	16.3	-0.5	-0.1
2005	13.5	11.0	13.3	22.2
2006	-6.3	9.1	9.9	14.2
2007	-1.5	-2.0	-29.2	25.3
2008	6.8	5.3	1.1	-12.3
2009	4.1	5.6	6.0	-14.1
2010	10.6	-15.0	9.8	-20.6
NDVI average (2000-2010)	0.6	0.5	0.6	0.5

The percentage deviation of NDVI was correlated with De Martonne Index value (2000-2010), resulting in a correlation coefficient of 0.66 (May), 0.34 (June) and 0.79 (July and August). According to the Bravais-Pearson statistical test, the value above which the coefficient can be considered statistically significant was 0.5214 for 10% error risk, 0.6021 for 5% error risk and 0.6851 for 2% error risk (Table 2). Therefore, the correlation coefficient was statistically significant for July and August with 10, 5 and 2% error risk, or May with 10 and 5% error risk. In June, the correlation coefficient was statistically insignificant, this situation being possibly explained by the vegetation stage of wheat crop. The reflection of wheat during this period is high, determining record low NDVI values.

Table nr.2. The correlation coefficient of NDVI percentage deviation ($\Delta\%$) and De Martonne Index within Oltenia Plain

Months	R ²	Correlation coefficient (r)	$\alpha = 10\%$	$\alpha = 5\%$	$\alpha = 2\%$
May	0.435	0.66			
June	0.1152	0.34	0.5214**	0.6021**	0.6851**
July	0.6267	0.79			
August	0.6251	0.79			

* α – error risk

** The threshold value of r above which can be considered statistically significant correlation according to Bravais – Pearson

Spatial distribution of the NDVI value depends on the soil texture, sandy soils showing low water holding capacity, so in the density of the vegetation within is lower. According to the NDVI average value, between 2000 and 2010, the lowest values were recorded east of the Jiu River.

According to the average (2000-2010), in May, most of the values of NDVI fall into the 0.6 – 0.7 class. The lowest values are registered in the eastern part of the Jiu River, precisely in the Leu-Rotunda Field (Fig.3). Compared to the average, in 2000 the preponderance of the NDVI values was in the 0.5-0.6 class, followed by the 0.4-0.5 class (Fig.4). Another year in which vegetation density decreased, was 2002. Even if in this year the „De Martonne” Index shows that the drought was less severe than in 2000, the cumulative rainfall in September-June (the vegetation period of autumn crop) was 254.6 l/m² in the Plain of Oltenia, while the cumulative rainfall in 2000 was 371.1 l/m² and in 2007 it was 306.6 l/m².

In 2002, the highest NDVI values could be found mainly in the 0.4-0.5 class, followed by those from the 0.3-0.4 class. The lowest values were recorded in Leu-Rotuda Field, Dăbuleni Field, Sălcuței Plain, Nedeei Field and Punghinei Plain (Fig.5).

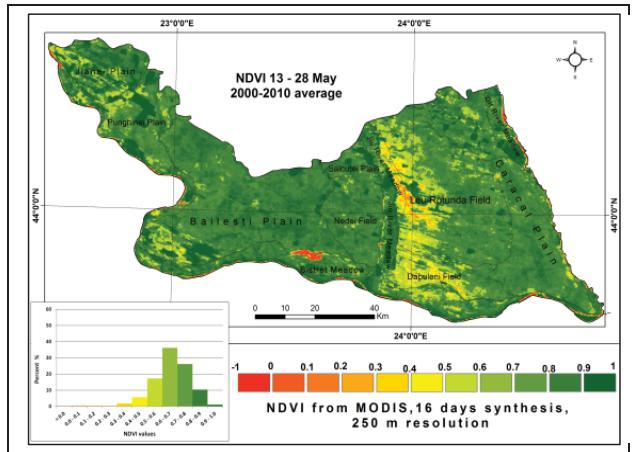


Fig.3. NDVI - May 2000-2010

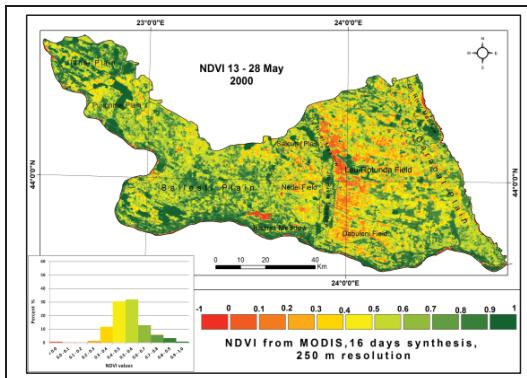


Fig.4. NDVI - May 2000

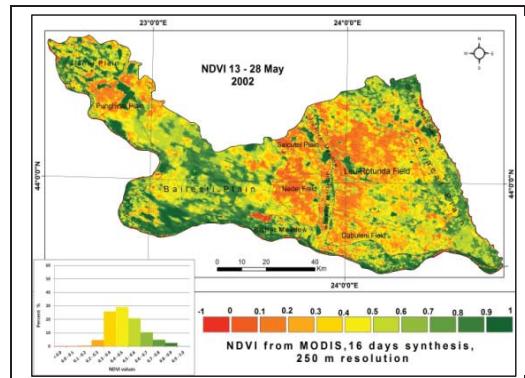


Fig.5. NDVI - May 2002

In June, according to the 2000-2010 average, values of the NDVI between 0.5 and 0.6 dominated (26.6%), followed by those in the 0.6-0.7 class, with a weight of 31.1% (Fig.6). In June 2002, as in May, the values of the NDVI were lower than average. The values lower than 0.3 were located in Nedeei Field and Sălcuței Plain and values between 0.3 and 0.4 were found to the Northwest and Southeast of the Leu-Rotunda Field and in the Bailesti Plain (Fig.7). The error risk regarding the drought impact on the crop is high during this month, because we did not have a spatial statistics with the distribution of the areas cultivated with autumn grain.

In July, according to the NDVI average, 54.3% of the values are between 0.5 and 0.6, the lowest values being recorded in southern Caracal Plain (Fig.8). In 2000, in terms of the distribution of NDVI values, Oltenia Plain was divided in two areas, the first one situated in the West and the second one in the East. The western area bordered

by the Danube to the West and Jiu River in the East (Jianei Plain, Punghinei Plain, Băileşti Plain, Sălcuţei Plain, Nedeeii Field and Bistreş Meadow), registered values between 0.5 and 0.7, while the eastern area (Leu-Rotunda Field, Dăbuleni Field and Caracal Field) registered values ranged between 0.2 and 0.5 (Fig.9).

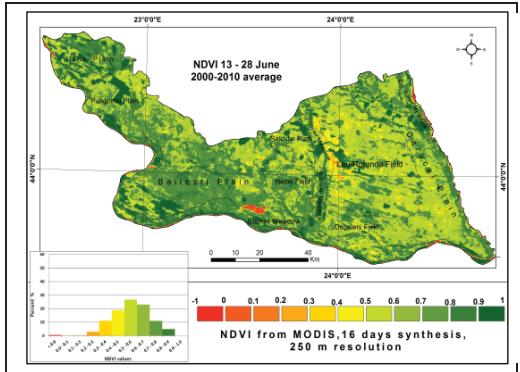


Fig.6 – NDVI June 2000-2010

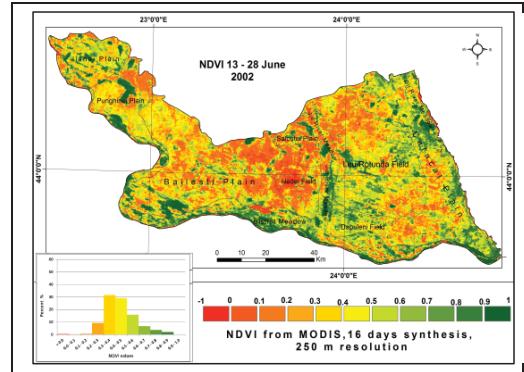


Fig.7 – NDVI June 2002

July 2007 was the driest month of the entire analyzed period, in which all the crops were compromised (Fig.10). The NDVI values were between 0.2 and 0.5, and the class with the highest weight was 0.3-0.4 (39.4%). This month was also characterized as excessively hot, with record temperatures. Furthermore, at the Calafat weather station a maximum temperature of 44.3 °C was recorded, higher than the national absolute maximum temperature for this month, registered at the Giurgiu weather station on 5 July 2000.

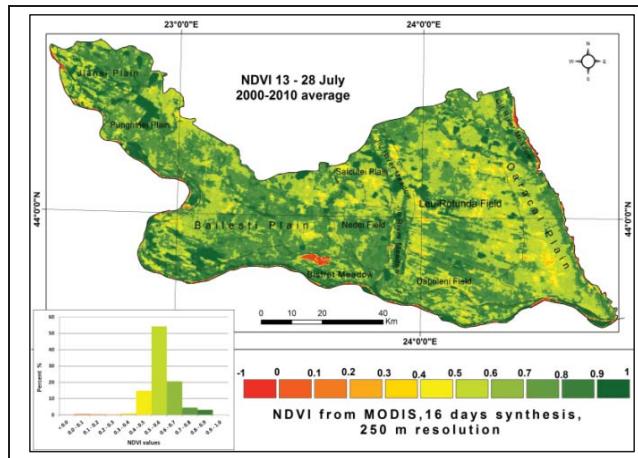


Fig.8 NDVI – July 2000-2010

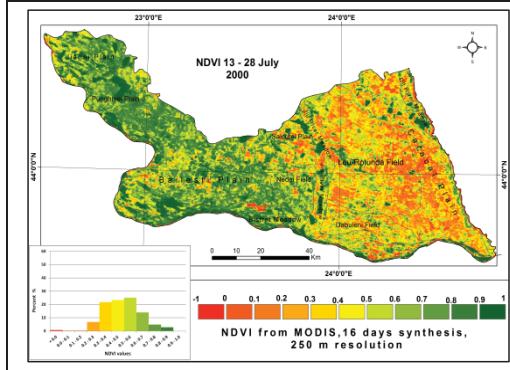


Fig.9 – NDVI July 2000

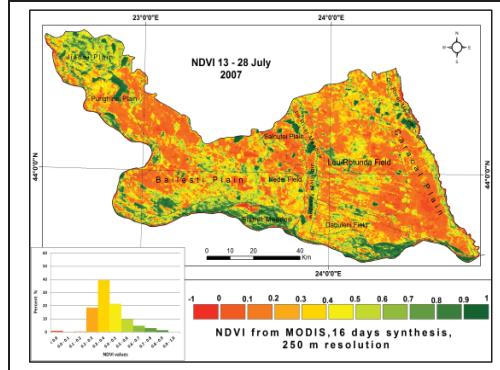


Fig.10 – NDVI July 2007

In August, the values of the NDVI are distributed approximately equally between 0.3-0.4 (17.8 %), 0.4-0.5 (22.9 %), 0.5-0.6 (21.3 %) and 0.6-0.7 (19.4 %). The lowest values are found in the Caracal Plain and in the eastern part of the Leu-Rotunda Field (Fig.11).

In 2000, most of the NDVI values were between 0.3 and 0.4 (37.2 %), followed by values between 0.4 and 0.5 (25.1 %) and values of 0.2-0.3 (15.9 %). The area most affected was located east of the Jiu River (Leu-Rotunda Field, Caracal Plain and Dăbuleni Field) (Fig.12).

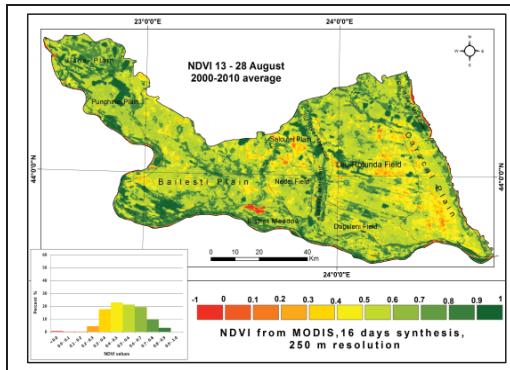


Fig.11. NDVI August 2000-2010

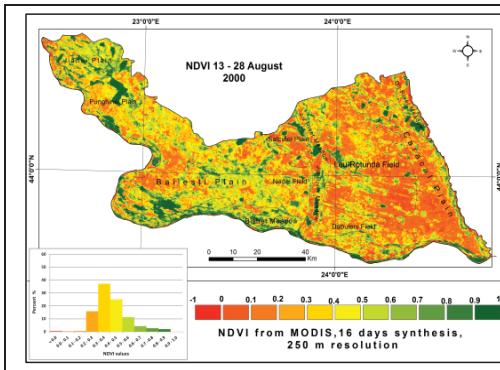


Fig.12. NDVI August 2000

4. Conclusion

The analysis of the drought severity and impact in Oltenia Plain between 2000 and 2010 revealed, through its complex approach, the years and months highly exposed to such a risk phenomenon.

In accordance with the results of the vegetation and aridity indexes used to quantify the consequences of the drought, we could notice that July and August

registered the most numerous cases of severe drought, whereas the driest years were 2000, 2002 and 2007. Neither less important nor negligible was the manifestation of the drought in the rest of the years, the impact consisting in crop production and vegetation changes in the long term. Conversely, the years more often found at shelter from the drought were 2005, 2009 and 2010, due to abundant precipitations sustaining the vegetation humidity requirements.

The mean values of NDVI indicating a drought (0.3 – 0.4) were predominant along the Danube River, namely Dăbuleni Field and Caracal Plain, but also for all the eastern part of Oltenia Plain, where most of the crops are found. The sandy substrata, vulnerable to deflation and very permeable for the water, also played a key role in the existence of low values of NDVI.

Last but not least, considering that the six weather stations have a unitary spatial distribution, the correlations made between "De Martonne" Index and the satellite images analysis on the basis of NDVI proved one more time the strong relationship between the main meteorological parameters and the vegetation response in terms of humidity.

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