ANALYSIS OF DROUGHT PHENOMENON WITHIN OLTENIA PLAIN, ROMANIA (1961-2010)

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Abstract. - Analysis of drought phenomenon within Oltenia Plain, Romania (1961-2010). Oltenia Plain, located in the south-western part of the Romanian Plain, is characterized by a moderate pluviometric regime (compared to the pluviometric patterns of plain areas from Romania) and, thus, each negative deviation generates certain complex phenomena, such as drought, that trigger perturbations of the natural environment and economic activities. Thus, determining the annual, seasonal and monthly negative deviations of precipitation at local scale is extremely important in order to establish accurate trends of drought phenomenon. We used 50-year time series (1961-2010) for six meteorological stations. The Standardized Precipitation Anomaly (SPA) and Weighted Anomaly of Standardized Precipitation (WASP) indicate a high predominance of normal years (>70%), both at annual and monthly levels. However, there clearly resulted a deterioration of the rainfall regime in the past three decades – normal years, but negative deviations in 80% of the cases; the driest years in the last five decades (1992, 1993, 2000, 2008); the wettest years (1999 and 2005). Linear regression emphasizes an obvious negative trend of the SPA values for the western and eastern parts of the plain (D.T. Severin, Caracal) and a positive trend for the northern extremity (Craiova); the rest of the region displays a slightly negative trend. At monthly level, the most exposed season is summer, even if drought affected the region in all the months of the year. For the last decade, the impact of drought was also assessed based on satellite images SPOT-VEGETATION and TERRA/MODIS. We used the products NDVI (Normalized Difference Vegetation Index), 10-day synthesis and 1 km spatial resolution and LAI (Leaf Area Index) 8-day synthesis, 1 km spatial resolution, data supplied by French Spatial Agency and NASA. The analysis of these products allowed us to emphasize a spatial and temporal differentiation of the density of vegetation within Oltenia, mainly induced by rainfall deficit and variability.

Key words: drought, SPA, NDVI, LAI, Oltenia Plain.

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1. Introduction

Its destructive impact makes drought be classified as one of the most problematic climatic risk phenomena all over the world. It is a recurring phenomenon displaying heterogeneous spatial and temporal features that vary significantly from one region to another (Tallaksen & van Lanen, 2004). There are four types of drought – meteorological, hydrological, agricultural and socio-economic drought (Fig. 2). According to Wilhite and Glantz (1985), the first three approaches refer to drought as a physical phenomenon, while the last one deals with drought in terms of supply and demand, underlining the effects of water shortfall on the socio-economic systems.

Oltenia Plain is located in the south-western part of Romania and it is limited by the Getic Piedmont in the north, by the Danube River in the south and west and by the Olt River in the east (Fig.1). Called by Nicolae Topor 'one of drought centres' (1964) and by Ion Marinică 'drought epicentre' (2006), the studied area is one of the most exposed to this climatic risk phenomenon regions in the country. Drought-induced problems are quite significant within Oltenia Plain as most of the population lives in the rural area where the main economic sector is represented by agriculture. Thus, usually, meteorological drought is accompanied by hydrological and agricultural drought, which first triggers food and economic insecurity, and then poverty. A poor production does not affect only rural population, but also urban population, which is forced to buy more expensive imported agricultural products.

Using the precipitations amounts as main meteorological element, we aimed at relating the obtained values of the SPA and WSPA to the normalized difference indexes NDVI and LAI, which emphasize the effects induced by rainfall deficit.

2. Methods and data

Standardized Precipitation Anomaly (SPA) is a mathematical method based on the precipitation amounts; it illustrates the pluviometric features of each year rendered in Table 1. It represents the difference between the precipitation amount from a specific period and the average multiannual amount for the respective period reported to the standard deviation. By weighting the SPA with the fraction of the month, resulted by dividing the monthly average to the yearly average (Croitoru, 2006), we obtained the values of the WSPA corresponding to each month. These methods are widely used both at national and international level.

Droughts effects are quite obvious mainly on vegetation cover. One of the monitoring methods is represented by remote sensing. Satellite products such as NDVI and LAI enable the analysis of the density and health state of the vegetation cover.

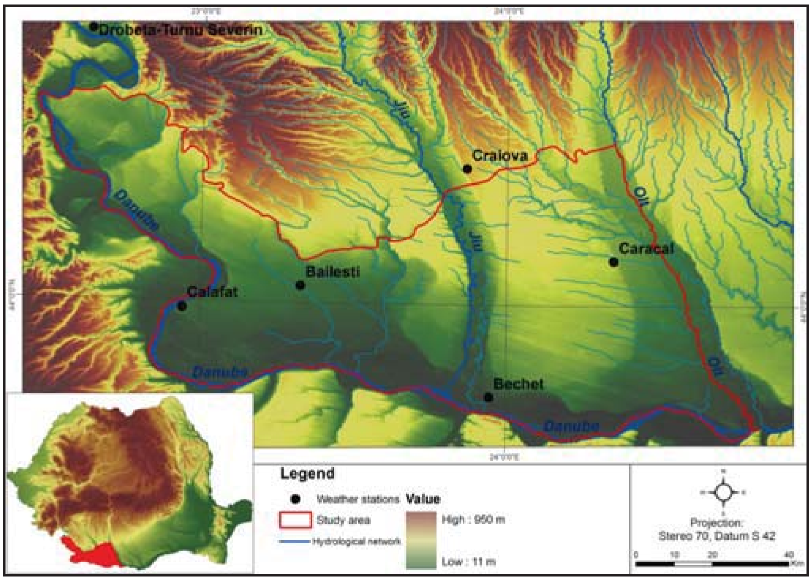


Fig. 1 Location of Oltenia Plain within Romania

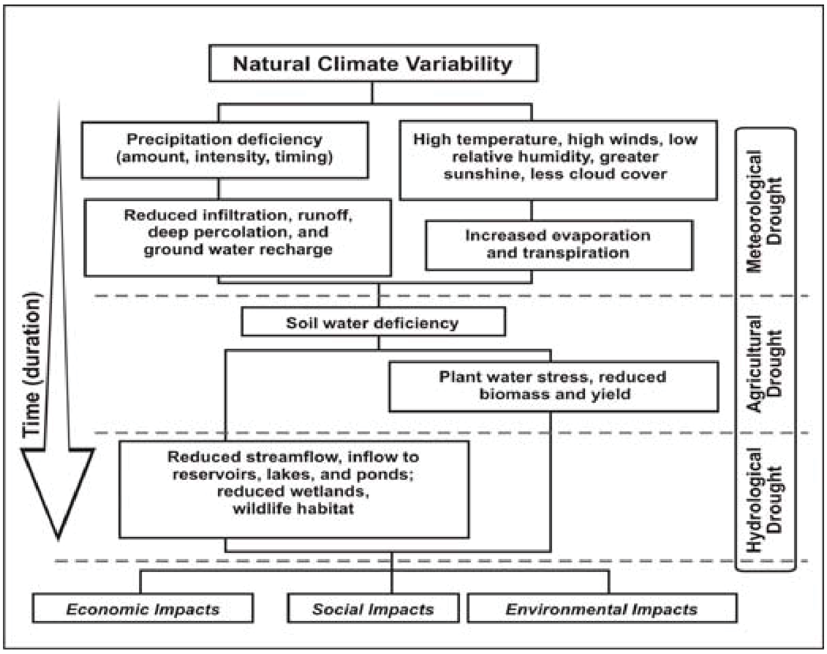


Fig. 2 Drought Impact (*Source: National Drought Mitigation Center, University of Nebraska, USA)*

The Normalised Difference Vegetation Index (NDVI) is computed as:

$NDVI = (b_{NIR} - b_{RED}) / (b_{NIR} + b_{RED})$ where b_{RED} and b_{NIR} are the red and near IR reflectances.

This formula is based on the fact that chlorophyll absorbs in the red part of the spectrum whereas the mesophyll leaf structure scatters NIR radiation. NDVI values ranges from -1 to +1, where negative values correspond to an absence of vegetation e.g. water surfaces, clouds (Myneni et al., 1995).

Table 1- Features of the years according to the SPA

SPA Values	Category	Risk category
> 2.5	Extremely Wet	Risk by excess
2 and 2.5	Very Wet	
1.5 and 2	Wet	
1 and 1.5	Moderately Wet	
1 and -1	Near Normal	Free by risk
-1 and -1.5	Moderately Dry	Risk by deficiency
-1.5 and -2.0	Dry	
-2.0 and -2.5	Severely Dry	
< -2.5	Extremely Dry	

Source: Gaceu, 2002

Leaf Area Index (LAI) measures the amount of plant leaf material in an ecosystem. It is typically expressed as a non-dimensional value giving the number of square meters of leaf material per square meter of ground. This variable plays important roles in models that represent processes, such as photosynthesis, respiration and rain interception, which couple vegetation to the climate system through radiation, carbon and water cycles. Hence, LAI appears as a key variable in many models describing vegetation-atmosphere interactions (Haboudane et al., 2004).

The data used in the present paper are represented by the precipitation amounts registered at six meteorological stations located within Oltenia Plain, belonging to the National Network of the National Meteorological Administration (Caracal, Bechet, Băileşti, Calafat, Drobeta-Turnu Severin and Craiova), for 50 years (1961-2010). The analysis of drought effects within this geographical area we used some satellite products: NDVI 10-day synthesis and 1 km spatial resolution, obtained from Spot – Vegetation images and LAI 8-day synthesis and 1 km spatial resolution, obtained from MODIS images.

3. Results and discussions

3.1. Distribution of the multiannual precipitation amounts

The mean annual precipitations amount reaches 573 l/m^2 within Oltenia Plain, varying from one meteorological station to another according to their position relative to predominant air masses and relief altitude. Thus, the highest precipitation amount of 674.2 l/m^2 is registered at Drobeta-Turnu Severin, a station located in the north-west of Oltenia Plain (Fig. 3). The minimum amount is noticed in the southern extremity of the plain, at Bechet, 521.6 mm. Between these extremes, there are not obvious differences, especially in the central and eastern sectors of the plain - Caracal 557.1 mm, Calafat 531.9 mm and 559.7 mm at Băilesti, taking into account the relatively homogenous altitudes and air mass exposure.

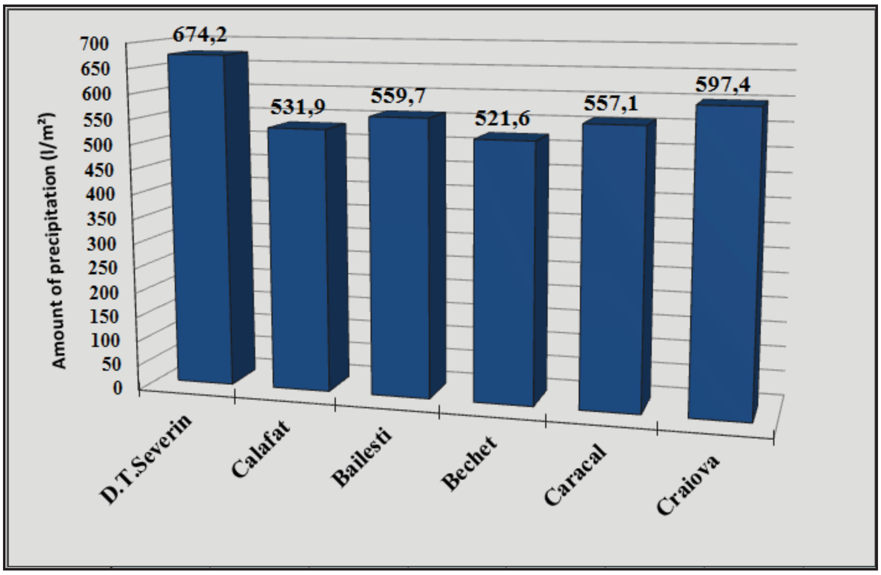


Fig. 3 Distribution of multiannual precipitations amounts

3.1. Standardized Precipitation Anomaly (SPA)

According to the values of the SPA, during the period 1961-2010, there were registered wet years in the first and last part of the analysed interval, while deficit represented the main feature of the middle part of the interval at all six meteorological stations. Thus, we remarked the years 1983, 1985, 1992, 1993, 2000 as dry and very dry and the years 1969, 1979, 1999 and 2005 as rainy and very rainy. Normal years predominated reaching more than 65% at all the stations.

Even if the analysed region does not cover a large surface compared to the territory of the country, there were emphasized a series of differences on north-south and west-east directions; the highest values of the SPA correspond to the northern and western parts of the plain, while the lowest are registered along the Danube Valley and in the central part of the plain. Thus, at Craiova, which is located in the northern part, most of the years display higher values than in the south, at Bechet (Fig. 4). In order to emphasize drought phenomenon we chose several years for comparison – 1983, when the annual value of the SPA was -1.90 at Bechet and -1.43 at Craiova; 1985 the same differentiation and the rest of the years were normal. In 1992, at Craiova, drought is emphasized by a greater value of the SPA, namely -2.30 (severely dry) compared to Bechet with -1.09 (moderately dry). In 2000, both stations display extremely low values, this year being severely or extremely dry within the entire plain. Starting with 2001, most of the years present positive deviations – normal years, except for 2005, when the SPA reached 3.68 at Craiova and 2.73 at Bechet.

From west to east, namely form Drobeta-Turnu Severin to Caracal, it was noticed that drought is more severe in the eastern sector of the plain due to the increased influence of the dry continental air masses compared to the west, where the penetration of tropical air masses is more frequent (Fig.5). Consequently, in certain years there occurred greater differences compared to the north-south direction. Thus, we remark the year 1999, which was very wet in the west (SPA: 2.07) due to some extremely heavy rainfalls registered in the summer months (mainly July – 331.4 mm, almost six times the normal amount of the month) and normal in the east (SPA: -0.04). However, in 2005, the SPA registered almost a double value at Caracal compared to D.T. Severin (2.69 in the east, which is extremely wet and 1.17 in the west, which is just wet).

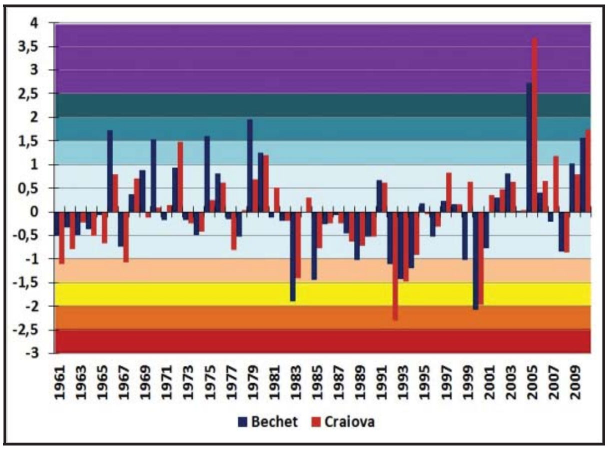


Fig. 4 Standardized Precipitation Anomaly at the stations Craiova and Bechet (1961-2010)

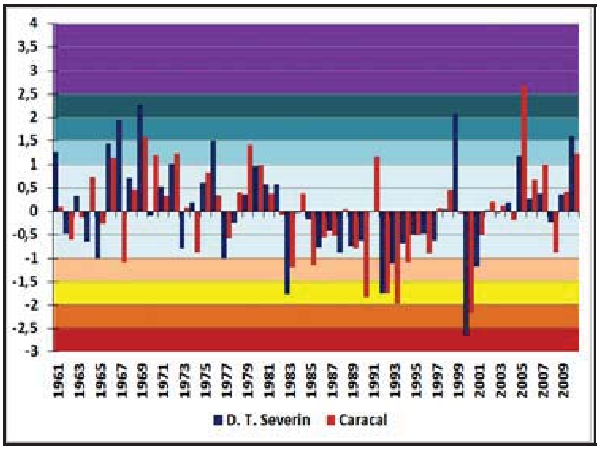


Fig. 5 Standardized Precipitation Anomaly at the stations D.T. Severin and Caracal (1961-2010)

On the whole, we remarked deficit increases from north to south (from 12% to 16%) and from west to east (from 10% to 16%), due to the more frequent and intense influence of dry continental air masses (Fig. 6). Normal domain covers the largest rate at all the six stations. The highest value was registered at Craiova, 78%, followed by D.T. Severin, 72%. In the north and west of the plain the precipitation amounts are generally higher, but, however, not sufficient to ensure a greater percentage of wet years, as only 18% at Severin, respectively 10% at Craiova of the 50 analysed years were surplus years. The rate of deficit years was higher at Craiova compared to Severin, as Mediterranean air masses contributes to the diminution of drought phenomenon and a certain moderation of climatic extremes in the area.

At Craiova we have an oscillatory regime, there is a cyclicity of the rainy years and the dry years, the share is 12% and 10% drought years and rainy years, while the percentage of Caracal station and Bechet is equal, the dry years with the rainy years, 16%. Some oscillatory regime is recorded from west to east.

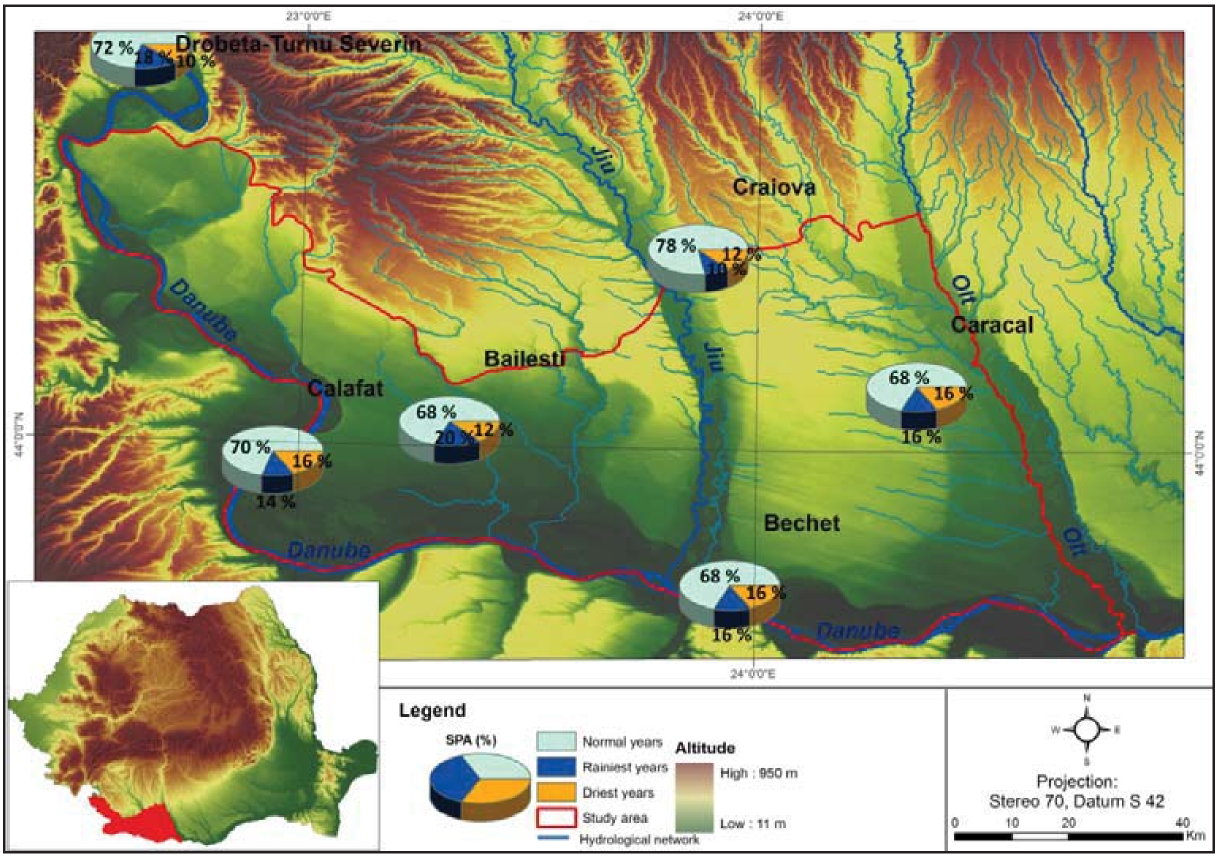
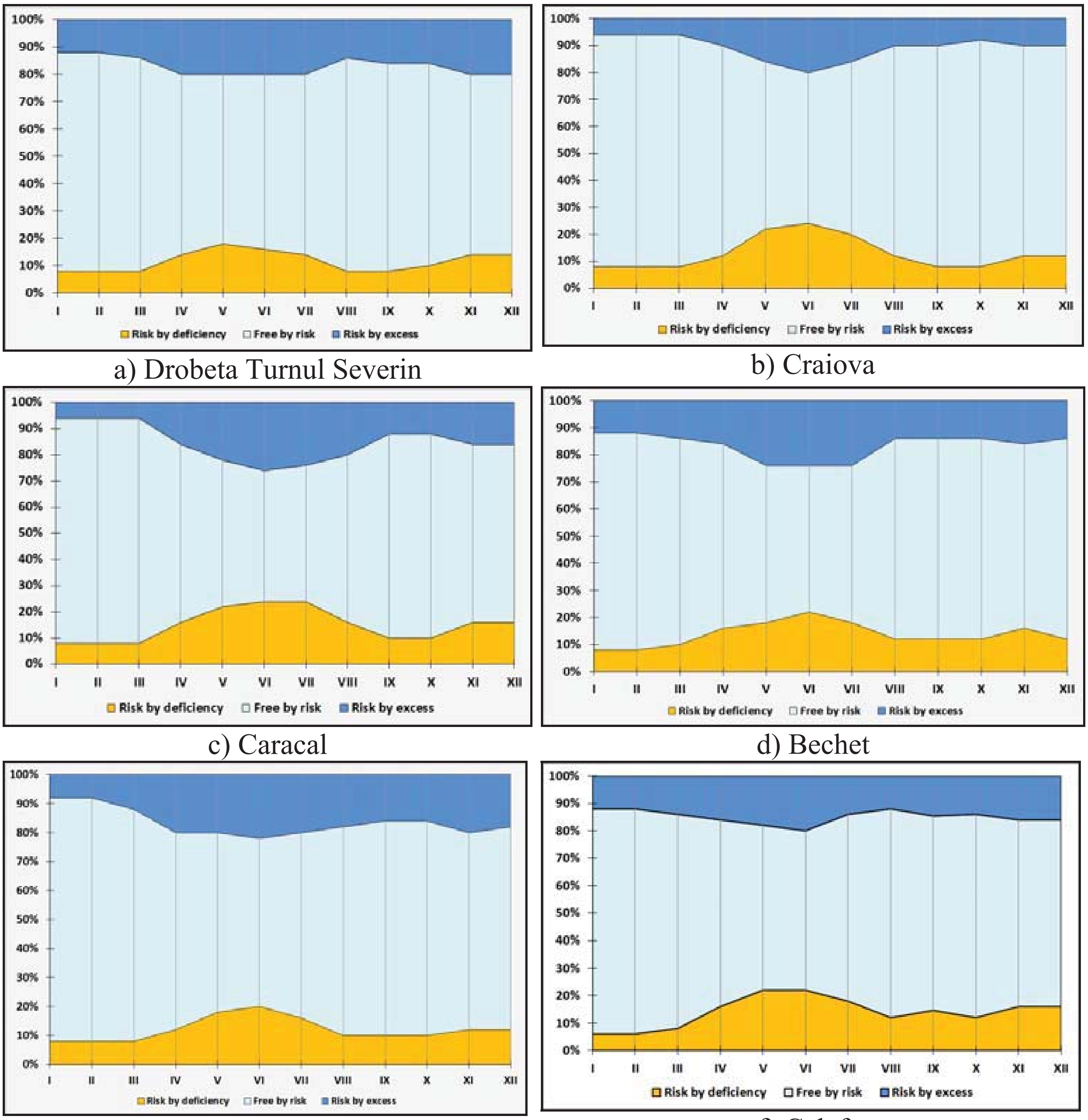


Fig.6 Rate of pluviometric domains according to SPA within Oltenia Plain (1961-2010)

3.2. Weighted Standardized Precipitation Anomaly (WSPA) compared with satellite products NDVI and LAI

If the analysis of the SPA values enabled us to emphasize drought at annual level, the WSPA helped us identify the months that contribute most to drought. The monthly values of WSPA indicated that May, June, and July display the highest drought risk (Fig.7). Rainfall deficit registered in these months is quite problematic as, usually, precipitation lack is associated with increased temperatures which affect crops. In the last decade of the analysed period, according to the values of the WSPA at monthly level, we remarked the years 2000 and 2008 as deficit years. 2000 was very dry at all the stations during all the 12 months, but the lowest values were registered in June and July.

In June, the values of the WSPA oscillated between -3.41 at Băileşti and -2.17 at Severin; also at the rest of the stations the values were very low: -3.20 at Calafat, -3.18 at Caracal, -2.95 at Bechet and – 2.87 at Craiova. The impact rainfall deficit had upon the cultivated and natural vegetation within Oltenia Plain can be noticed in the satellite images SPOT VEGETATION and MODIS, through the achievement of NDVI and LAI products.



a) Drobeta Turnul Severin b) Craiova

c) Caracal d) Bechet

e) Bailesti f) Calafat

Fig.7 Rate of pluviometric domains at monthly level according to WSPA within Oltenia Plain (1961-2010)

In the east of Oltenia Plain, in the third decade, the values of the Normalised Difference Vegetation Index (NDVI), varied between 0.2 and 0.3, which indicate rare vegetation, while in the west, the values were a little higher, varying between 0.3 and 0.4 (Fig. 8). Reduced values were also registered by the Leaf Area Index (LAI), which however displayed a random distribution within the analysed surface. Thus, in the east of Oltenia Plain, its values oscillated between 0.3 and 0.8, while in the west between 0.5 and 1.2 (Fig. 9).

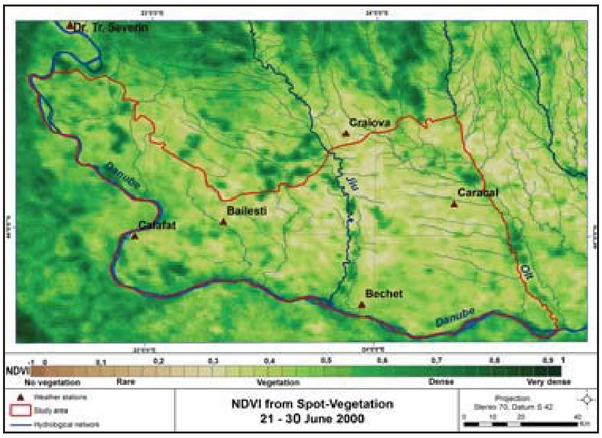


Fig.8 Spatial distribution of vegetation index (NDVI), June 21-30, 2000

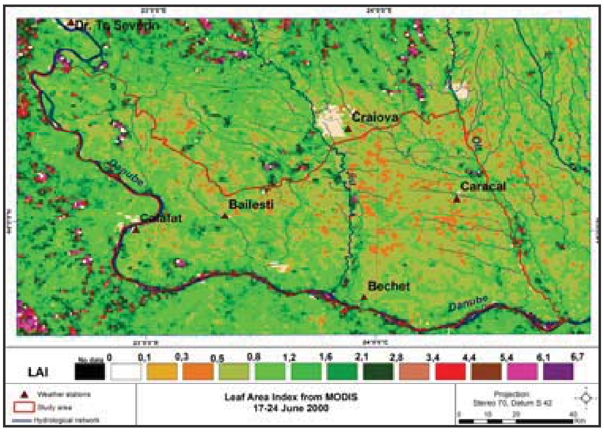


Fig.9 Spatial distribution of leaf area index (LAI), June 17-24, 2000

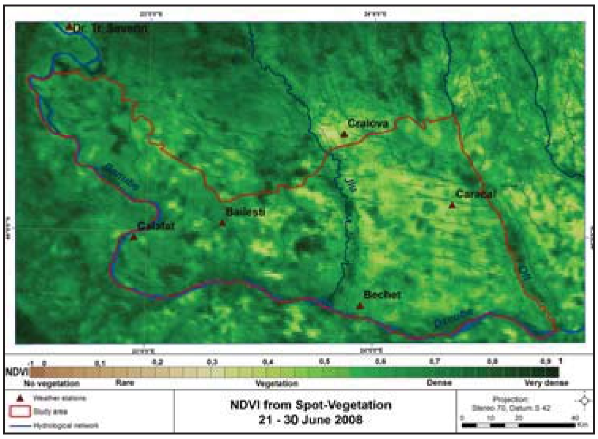


Fig.10 Spatial distribution of vegetation index (NDVI), June 21-30, 2008

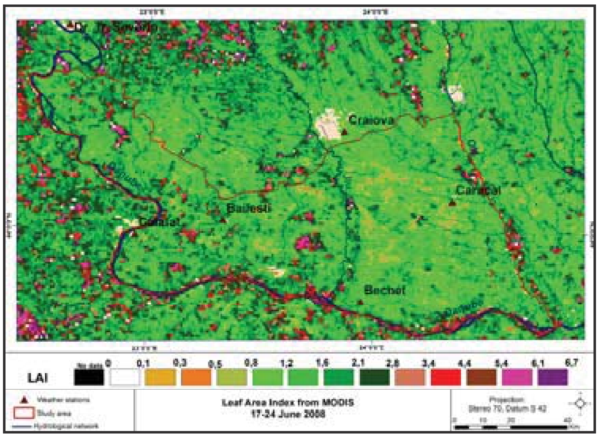


Fig.11 Spatial distribution of leaf area index (LAI), June 17-24, 2008

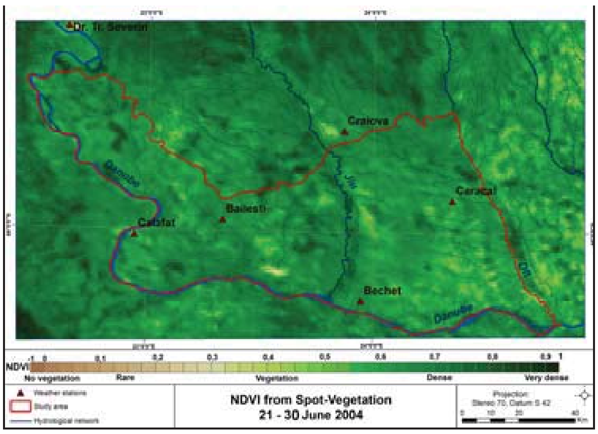


Fig.12 Spatial distribution of vegetation index (NDVI), June 21-30, 2004

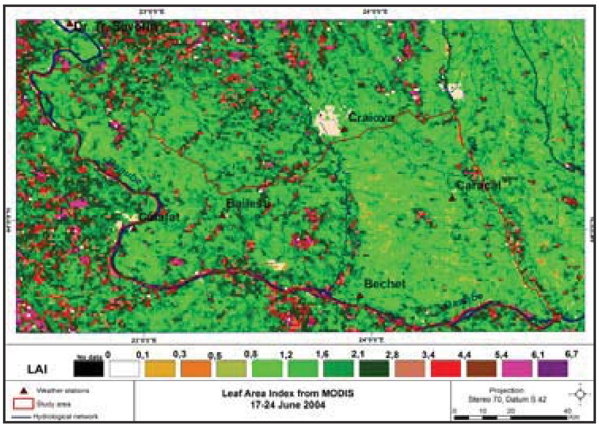


Fig.13 Spatial distribution of leaf area index (LAI), June 17-24, 2004

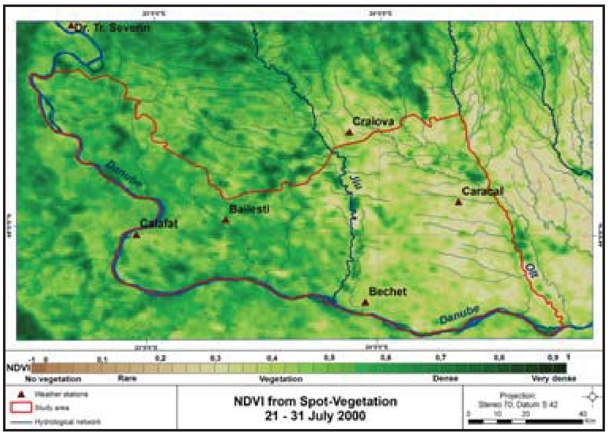


Fig.14 Spatial distribution of vegetation index (NDVI), July 21-31, 2000

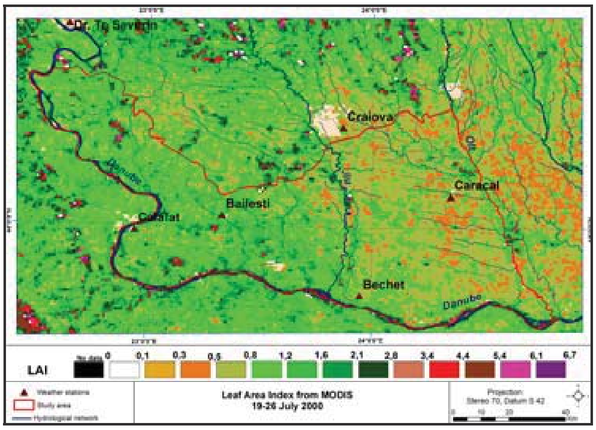


Fig.15 Spatial distribution of leaf area index (LAI), July 19-26, 2000

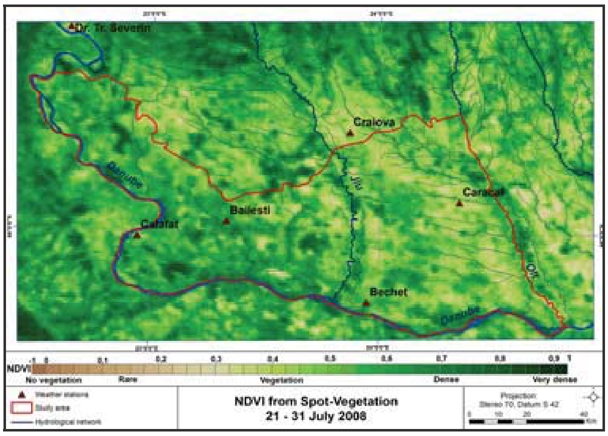


Fig.16 Spatial distribution of vegetation index (NDVI), July 21-31, 2008

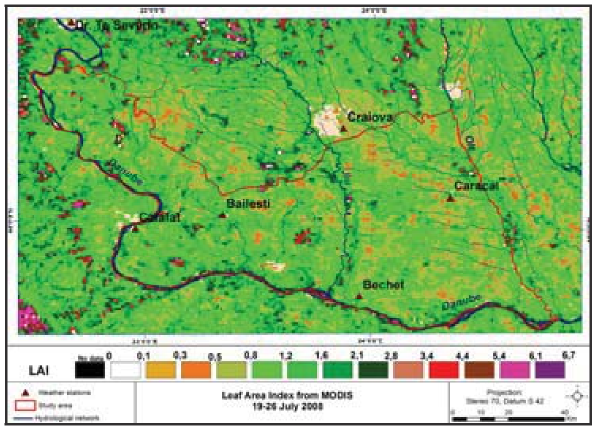


Fig.17 Spatial distribution of leaf area index (LAI), July 19-26, 2008

In June 2008, the values of the WSPA varied between -1.30 at Caracal and 0.05 at Calafat. Reduced values were also registered at Craiova (-1.25) and Bechet (-1.19). The intensity decrease of drought phenomenon compared to 2000 is also illustrated by the satellite products NDVI and LAI. In 2008, the values of the Normalised Difference Vegetation Index were comprised between 0.3 and 0.4 in the central-eastern part and between 0.4 and 0.6 in the western half of the plain (Fig.10). The same spatial distribution appears in case of Leaf Area Index, namely between 0.5 and 0.8 in the central-eastern part, 0.8 and 1.2 in the south-east and 1.2 and 2.1 in the western half (Fig.11).

In order to better render the rainfall deficit registered in 2000 and 2008, we also analysed 2004, considered a normal year according to both the values of WSPA and NDVI and LAI. In June, the values of WSPA at the meteorological stations from Oltenia Plain oscillated between -1.05 at Calafat and 0.22 at Severin, at the rest of the stations the values being quite close to 0 (0.06 at Craiova, 0.04 at Bechet, 0.16 at Băileşti and -0.27 at Caracal). Compared to 2000 and 2008, in

2004, the values of NDVI during the third decade of June exceeded 0.5 within most of the plain (Fig.12). LAI registered values above 0.8 within most of the plain, except for some small areas located in the eastern part, where it varied between 0.5 and 0.8 (Fig.13).

In July 2000, the values of the WSPA were even more reduced than in June (-2.92 at Caracal, -2.64 at Bechet, -2.51 at Craiova, -2.75 at Calafat, -2.93 at Băileşti and -2.85 at Severin), illustrating the severity of drought. However, the negative impact upon vegetation got more acute in the eastern part of Oltenia Plain. The values of NDVI were 0.2 and 0.3 in the east and 0.4 and 0.5 in the west (Fig.14). LAI also registered lower values compared to June, emphasizing the same trend, namely higher severity of drought in the eastern part of the plain, between 0.3 and 0.8 (Fig.15).

In 2008, the values of the WSPA varied between -1.19 at Caracal and 0.05 at Calafat. The decrease of the precipitations amounts from west to east is also emphasized by the values of NDVI (Fig.16) and LAI (Fig.17), which follow the same decrease tendency as those of the WSPA.

4. Conclusions

In the last 50 years, precipitation amounts displayed heterogeneous values within Oltenia Plain; it represents one of the meteorological parameters which is highly dependent on air masses circulation at the level of the European continent, thus explaining the great temporal and spatial differences. Drought is firstly related to the lack or insufficiency of precipitation within a certain region, which then can evolve and affect river network (reduced flows), vegetation (soil moisture deficit), and, implicitly, population's livelihood and welfare, in other words when 'the demand for economic good exceeds supply as a result of a weather-related shortfall in water supply' (National Drought Mitigation Center, University of Nebraska-Lincoln, U.S.A.).

According to the values of the SPA the territory of Oltenia Plain is mainly characterized by a normal pluviometric regime, as normal years present higher rates than 65%. However, there was emphasized a certain periodicity of wet and dry periods – precipitation surplus in the first two decades, deficit in the next two, and then again surplus in the last decade. The most severe drought periods were registered in the period 1980-2000, the maximum being reached in 2000, which is by far the driest year in the last 50.

At monthly level, the highest risk of drought occurrence is registered by the end of spring – beginning of summer, in May, June, and July, which also coincides with the critical vegetation period for most of the crops. Thus, the decrease of precipitation amounts and water shortage affects the density and health state of vegetation, both natural and cultivated, situation strengthened by the analysis of satellite images and associated products – NDVI and LAI.

5. Acknowledgements

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