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ANALYSIS OF RAINFALL DEFICIT AND ITS IMPACT ON THE OLTENIA PLAIN VEGETATION USING SATELLITE IMAGES FROM THE PERIOD 2000-2009

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Analysis of rainfall deficit and its impact on the Oltenia Plain vegetation using satellite images from the period 2000-2009

Irina Onţel

Análisis de los déficit de precipitación y su impacto sobre la vegetación de Oltenia Illano usando imágenes de satélite durante el período 2000-2009. Este investigación pretende evaluar el déficit de precipitaciones en temporada de verano y su impacto sobre la vegetación. Disminución de las precipitaciones en comparación con el valor medio representa el primer firme que precede el sequía. El análisis de los resultados de el Índice de Precipitación Estandarizado calculado por tres meses (SPI-3) y el mes (SPI-1), reveló que durante 2000-2009 en la Oltenia Illano tuvimos 5-6 años deficientes de precipitation de los cuales 2 años fueron calificados como los años secos y muy secos. Este déficit se observa en el análisis de satélite productos, NDVI y LAI obtenido por procesamiento de imágenes Spot-Vegetation y MODIS en la tercera década de cada mes de verano. Las imágenes de satélite revelan las diferencias temporales y espaciales de esta parametro meteorologico y el impacto que tiene en la vegetación de la llanura de Oltenia.

Palabras clave: sequía, la vegetación, SPI-3, SPI-1, NDVI, LAI, Oltenia Plain.

Analiza deficitului de precipitaţii şi impactul acestuia asupra vegetaţiei Câmpiei Olteniei cu ajutorul imaginilor satelitare în perioada 2000-2009. Lucrarea are ca obiectiv evaluarea deficitului de precipitaţii din anotimpul de vară şi impactul său asupra vegetaţiei. Scăderea cantităţii de precipitaţii raportată la o valoare medie reprezintă primul semn ce precede fenomenul de secetă. Din analiza valorilor rezultate în urma calculării Indicelui Standardizat de Precipitaţii pe trei luni (SPI-3) şi o lună (SPI-1), a rezultat faptul că în perioada 2000-2009 în Câmpia Olteniei am avut 5-6 ani cu deficit de precipiataţii dintre care 2 ani s-au încadrat în categoria anilor secetoşi şi foarte secetoşi. Acest deficit se observă şi prin analiza produselor satelitare NDVI şi LAI, obţinute prin prelucrarea imaginilor Spot-Vegetation şi MODIS din a treia decadă a fiecărei luni de vară. Imaginile satelitare pun în evidenţă atât diferenţieri temporale cât şi spaţiale ale impactului pe care acest parametru meteorologic îl are asupra vegetaţiei din Câmpia Olteniei.

Cuvinte cheie: secetă, vegetaţie, SPI-3, SPI-1, NDVI, LAI, Câmpia Olteniei.

1. INTRODUCTION

The decrease in rainfall relative to the mean, is the first sign preceding droughts. This decrease correlated with temperatures increased and poor irrigation system, leading to a temporary inability to meet agricultural water consumption generating food insecurity. This is today an important issue in the World.

Meteorological drought is a short lived, recurring natural disaster, which originate from the lack of precipitation and can bring significant economic losses [1]. It is not possible to avoid meteorological droughts, but it can be monitored, and their adverse impacts can be alleviated [2]. The success of the drought prediction depends on how well it is defined and identified. Because drought is intimately related with food security, therefore, study on drought hazards especially drought monitoring are essential for implementing mitigation to reduce drought impact in Oltenia Plain[3].

The purpose of this article is to evaluate the precipitation deficit in summer season and observing the impact it has this parameter on vegetation within Oltenia Plain. The drought estimation is conventionally based on indices for the identification of drought characteristics, such as its intensity or severity, duration and its extent surface.

The study area is Oltenia Plain which is located in South-West Romania, between the Danube to the South and West, Olt river to the East and Getic Plateau in the North (Figure 1).

This sector is well individualized as compared to the other sectors of the Romanian Plain because of a series of morphostructural elements. It is a typically piedmont-like plain, where all the valleys, including the Danube's, display well-developed systems of terraces. Its main feature is the presence of sand dunes, which covers almost half of the surface of the plain. The presence of the dunes is extremely important from the climatic point of view as sandy soils impose a series of restrictions. Within these areas, the precipitation amount is relatively low and the temperatures quite high, especially in summer; thus, due to the physical-chemical features of the soil the water deficit must be covered through irrigation [4].

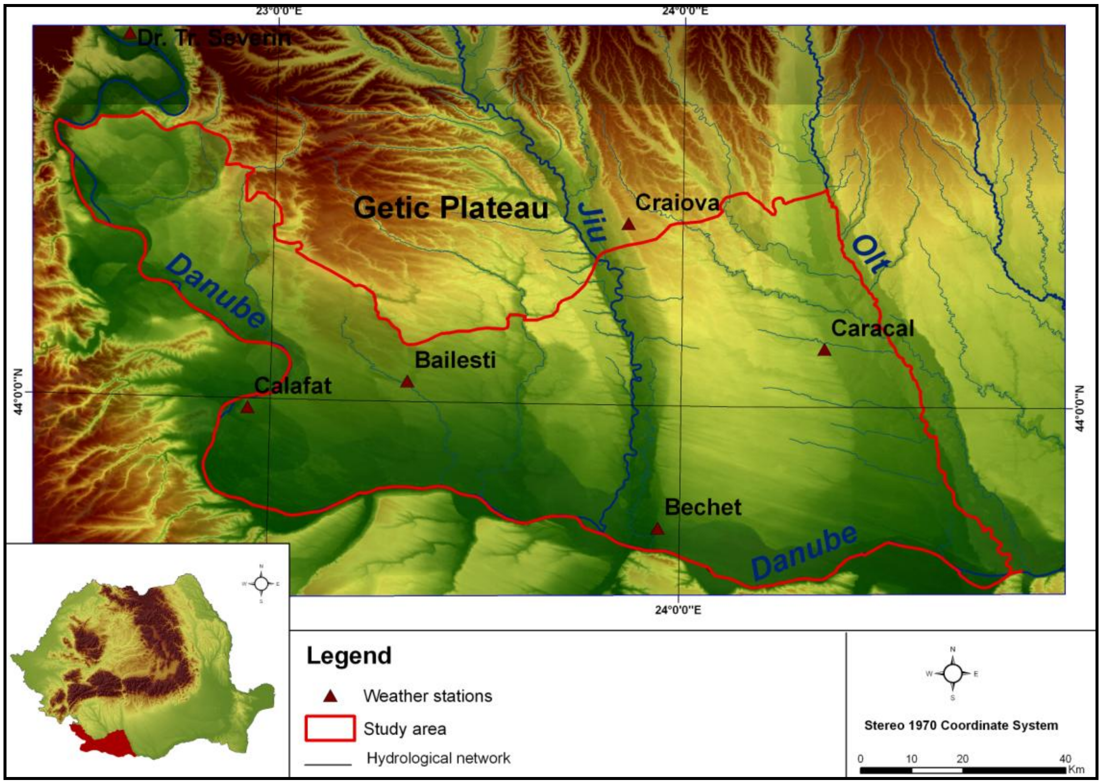


Figure 1. Location of the Oltenia Plain within Romania

2. DATA AND METHODS

The analysis of precipitation deficit was performed by calculating Standardized Precipitation Index for three months and one month, using data from weather stations within Oltenia Plain.

The SPI developed by McKee et al. (1993) is based on the concept of standardized precipitation, which is the difference between total precipitation for some period of time and historical mean total precipitation for the same period divided by the standard deviation. The use of flexible time scales, which can be obtained only by accumulating precipitation for a desired period of time, makes this index very important because different time scales are applied to different types of drought.

An analyst with a time series of monthly precipitation data for a location can calculate the SPI for any month in the record for the previous i months, where i=1, 2, 3, 12... 24... 48 ... depending upon the time scale of interest. Hence, the SPI can be computed from precipitation for 1 month to 48 month length [3].

SPI has been selected by the World Meteorological Organization as a key indicator for monitoring drought. As a result it is used by drought monitoring centres worldwide. There are many examples of its successful application in research oriented literature.

$$SPI = \frac{Pi - Pm}{\sigma}; \qquad \sigma = \sqrt{\frac{\sum(Pi - Pm)^2}{n-1}};$$

Pi = rainfall from current period;

Pm = the average annual precipitation from period i;

Φ = standard deviation;

n = number of values.

The negative values correspond of the periods with rainfall deficiency while the positive values correspond the periods with rainfall excess (Table 1).

Table 1. SPI Classification following McKee et al. (1993)

SPI Value	Class	Colour
SPI > 2,00	Extreme wet	
1,50 < SPI ≤ 2,00	Severe wet	
1,00 < SPI ≤ 1,50	Moderate wet	
-1,00 < SPI ≤ 1,00	Normal	
-1,50 < SPI ≤ -1,00	Moderate dry	
-2,00 < SPI ≤ -1,50	Severe dry	
SPI < -2,00	Extreme dry	

Impact on vegetation is observed used satellite data, SPOT VEGETATION (Normalized Difference Vegetation Index, 10 days synthesis, 1km spatial resolution) and TERRA/MODIS (Leaf Area Index, 8 days synthesis, 1 km spatial resolution). These products are provided free by the French Space Agency [5] and NASA [6].

Normalized Difference Vegetation Index (NDVI) is one of the most successful of many attempts to simply and quickly identify vegetated areas and their "condition," and it remains the most well-known and used index to detect live green plant canopies in multispectral remote sensing data.

The NDVI is calculated from these individual measurements as follows:

$$NDVI = \frac{NIR - red}{NIR + red}$$

Where: NIR and RED stand for the spectral reflectance measurements acquired in the visible (red) and near-infrared regions, respectively.

NDVI was introduced in literature by Rouse (1973), for vegetation mapping from U.S. plains using ERTS images, the first generation of Landsat images (MSS). The purpose of the first formula was to highlight the spectral signatures of the vegetation in near-infrared (the spectral area reflectance in the chlorophyll is highest), in relation to the area of red (chlorophyll absorbs light radiation which impose the green color to the healthy vegetation, located in high season) [7].

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 surface, clouds [8].

The Leaf Area Index (LAI), defined as half the total leaf area per unit ground surface area [9] is a key biophysical canopy descriptor, which play a major role in vegetation physiological processes and ecosystem functioning. Crop LAI estimation and its spatial distribution has grat importance for crop growth monitoring, vegetation stress, crop forecasting, yield predictions and management practices.The LAI estimation algorithms from satellite data are based on the analysis of multispectral and multidirectional surface reflectance signatures of vegetation elements [10].

$$LAI=(NDVI*1.71)+0.48$$

3. RESULTS AND DISCUSSION

According to the value to the Standardized Precipitation Index in three months (SPI-3), in 2000 and 2003 we had moderate dry summers in most of the Oltenia Plain and in the Caracal Plain we had severe dry (Figure 2). The summers from 2005 and 2006 were moderate wet, severe wet and extremele wet and the rest of the years we have had relatively normal summers. From rainfall point of view, June was moderate dry in 2000, 2002, 2003 and 2007, the July was in 2007 and the August was in 2002 and 2003 (Figure 3). Standardized Precipitation Index values is fluctuates in time and space acording to the movement of the air masses circulation across the continent.

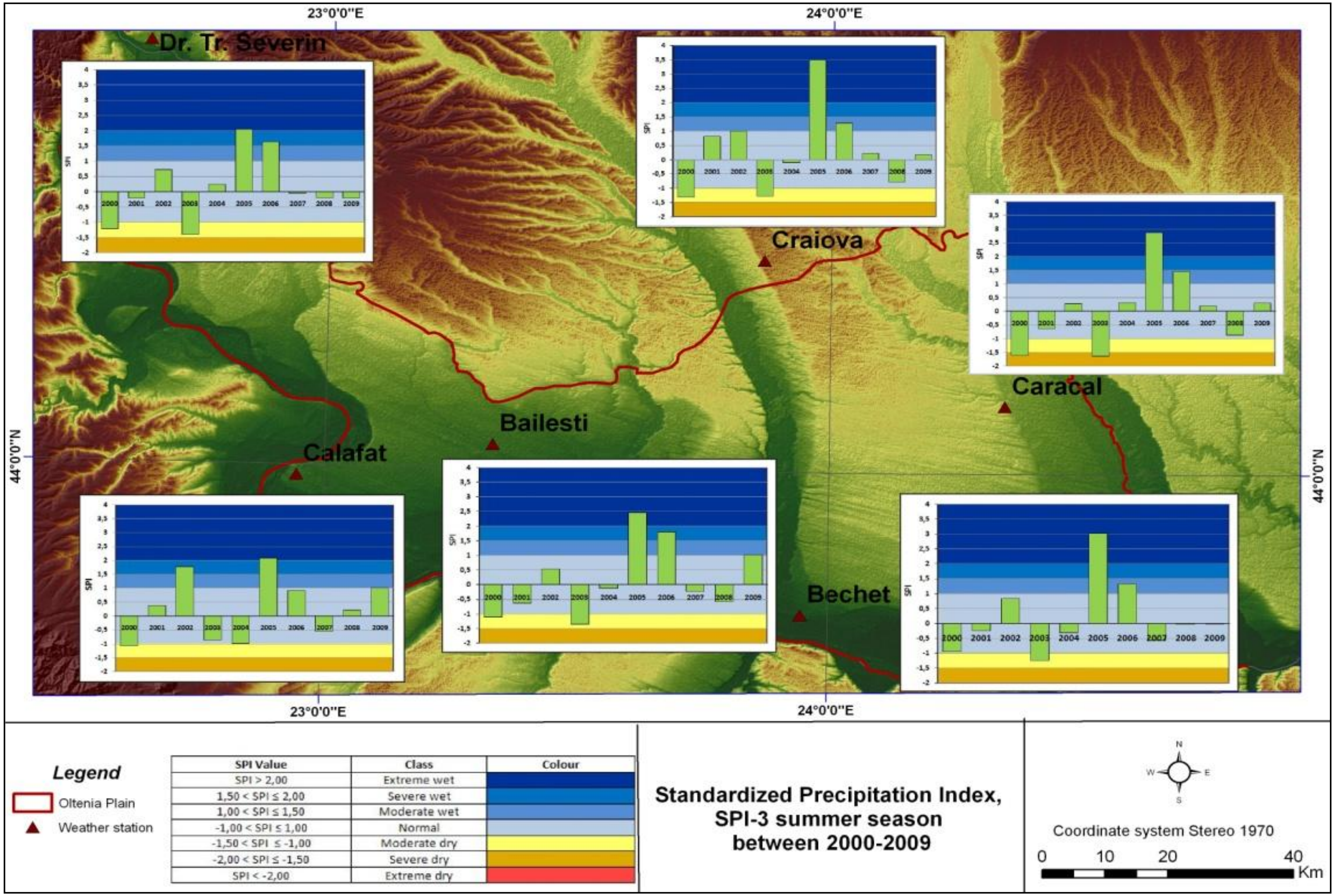
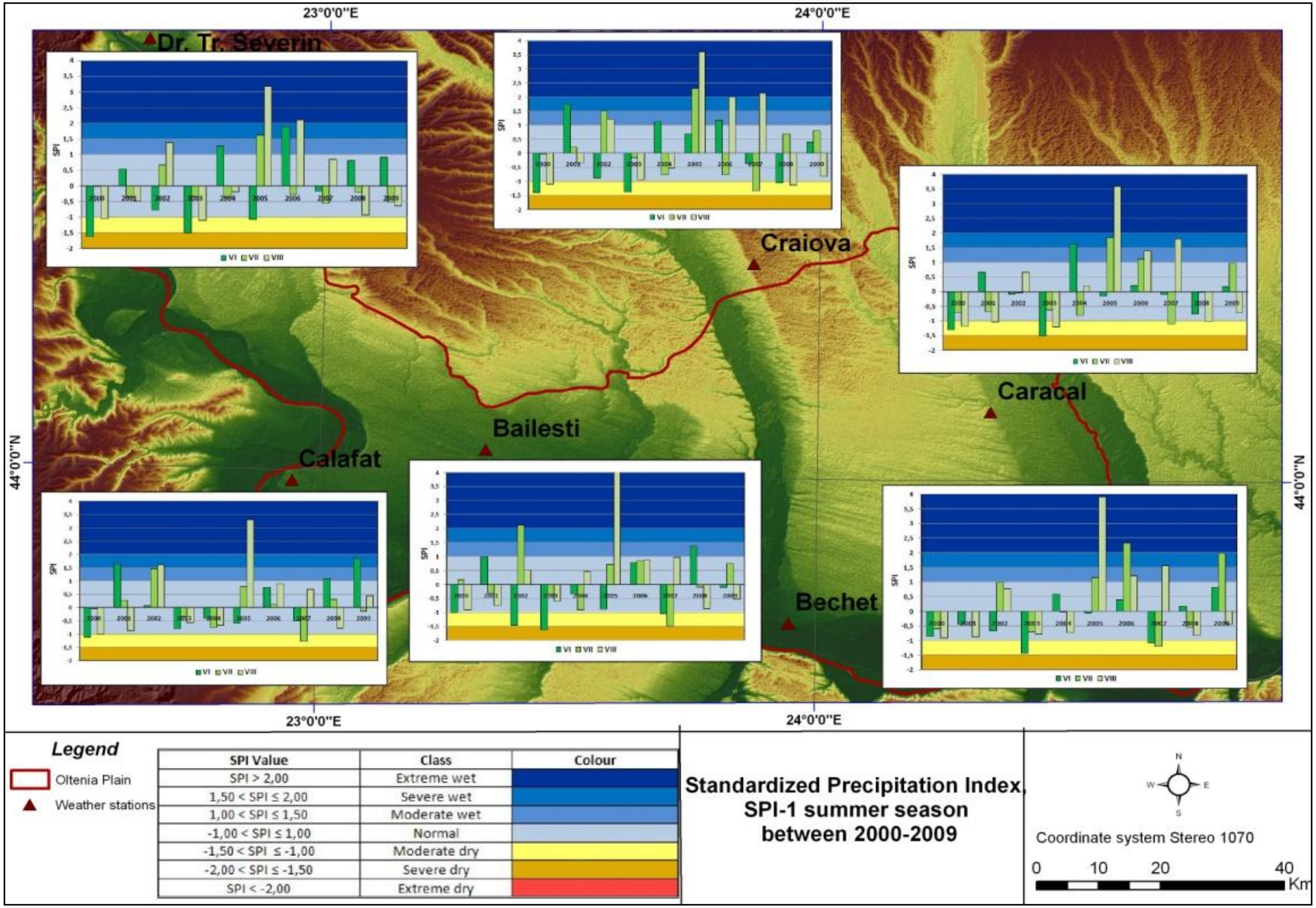


Figure 2. Standardized Precipitation Index (SPI-3)

Figure 3. Standardized Precipitation Index (SPI-1)



Even if the most years has been normals from the pluviometric point of view, this normality did not had asured enought water that the plant to develop. This thing can be obseved on the satellite images.

4. NORMALIZED DIFFERENCE VEGETATION INDEX

For June, a very dry year was 2000 and a result of that was the act that the vegetation density did not exceed 0.5 and in some areas was recorded values of 0.3 (Figure 4). Another remarkable year in terms of rainfall was 2002 and the value of the vegetation index was below 0.3. Although the June 2003 data recorded at stations in Oltenia Plain had indicated that this was a very dry month, the vegetation density was very high (Figure 5).

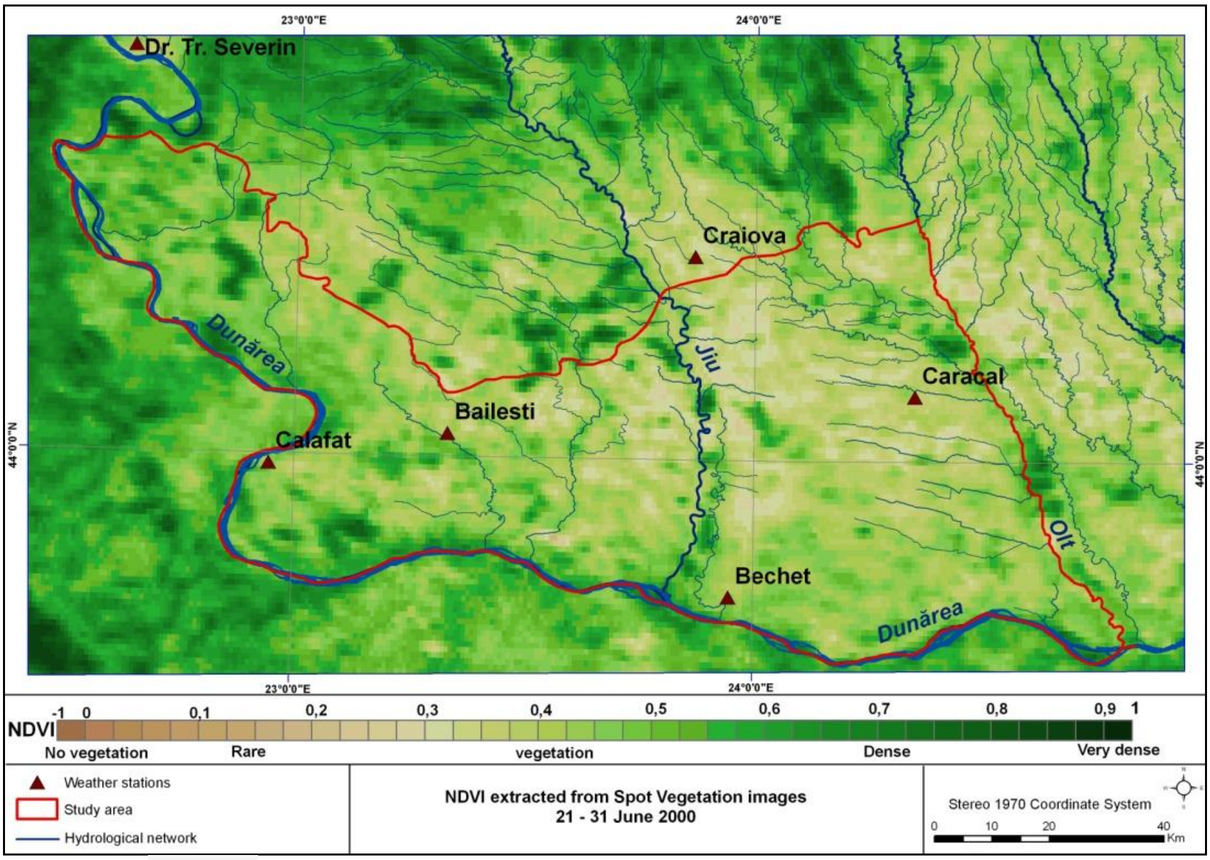


Figure 4. Normalized Difference Vegetation Index (NDVI), 21-31June 2000

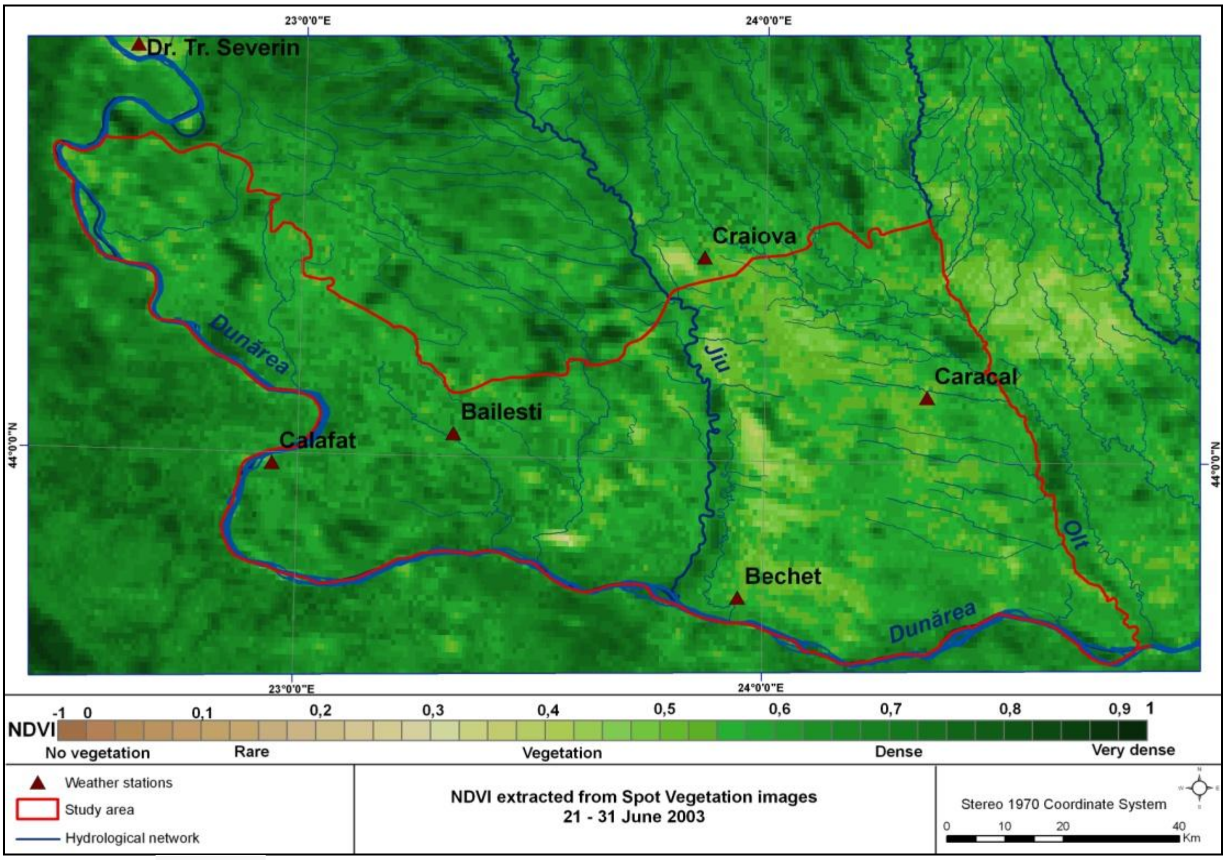


Figure 5. Normalized Difference Vegetation Index (NDVI), 21-31June 2003

In July 2000 can be seen a spatial differentiation of NDVI in witch recorded values are lower to the Est of Jiu river, and slightly higher to the West of it. In 2002 the higher values has been recorded to the West and the lower ones of the Est, which it is opposite of 2000. Due to low rainfall and because of the high temperature which was recorded in 2007, the NDVI values are lower to the entire study area (Figure 6).

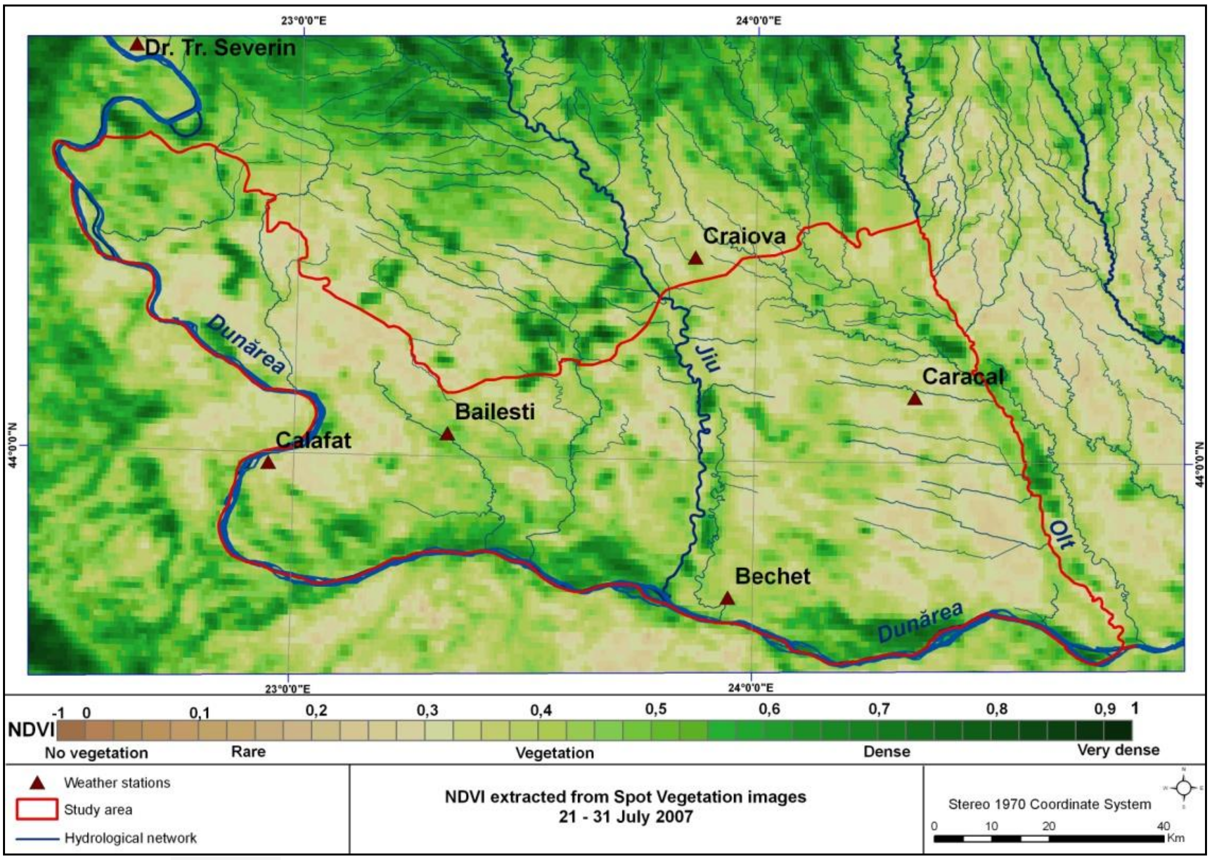


Figure 6. Normalized Difference Vegetation Index (NDVI), 21-31July 2007

In August, 2000 shared the same space as noted in previous months, with low values to the East than West Jiu (Figure 7). Another year with sparse vegetation was 2001. In 2003 they are higher than previous years, and the same thing is applied in the years 2008 and 2009. According to the National Statistics Institute, in 2000, 2002 and 2007 years, was recorded the lowest crop production.

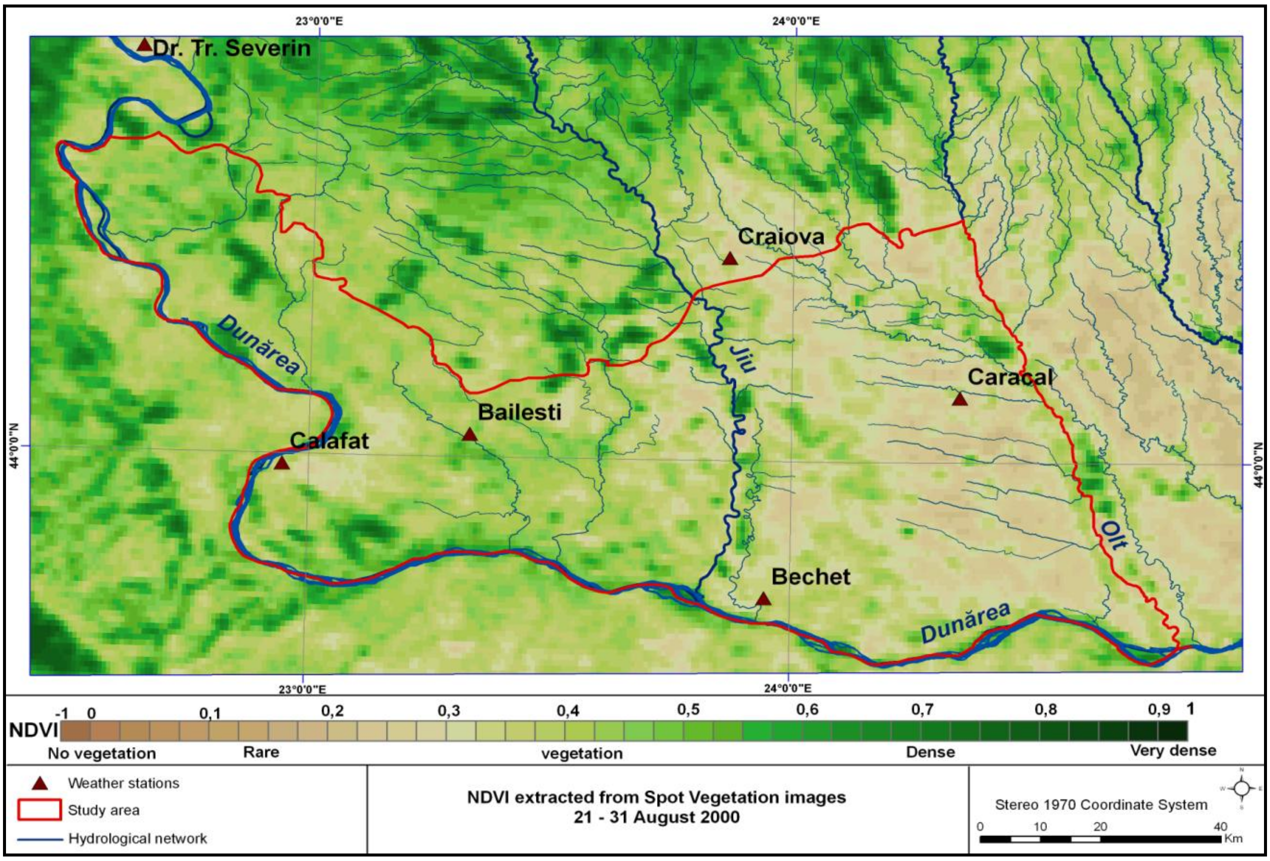


Figure 7. Normalized Difference Vegetation Index (NDVI), 21-31August 2000

5. LEAF AREA INDEX

Spatial and temporal distribution of the Leaf Area Index kept almost the same trends as in the case of the NDVI's. In June 2000, the value of Leaf Area Index is reduced East of the Jiu (Figure 8), in 2002 values between 0.3 and 0.5 are located in the central part of the Oltenia Plain (Figure 9) and in 2003 is the same exception as the index values above, the foliar surface is very high.

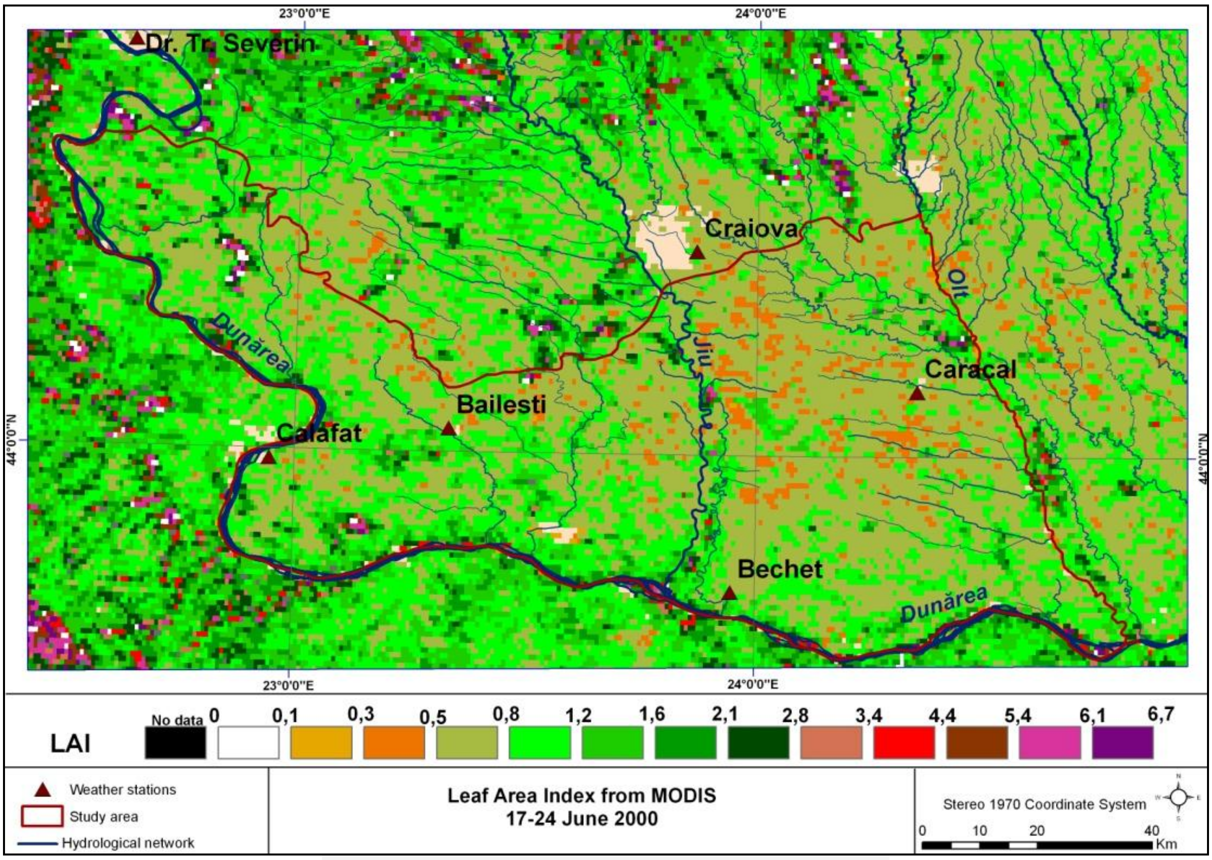


Figure 8. Leaf Area Index (LAI), 17-24 June 2000

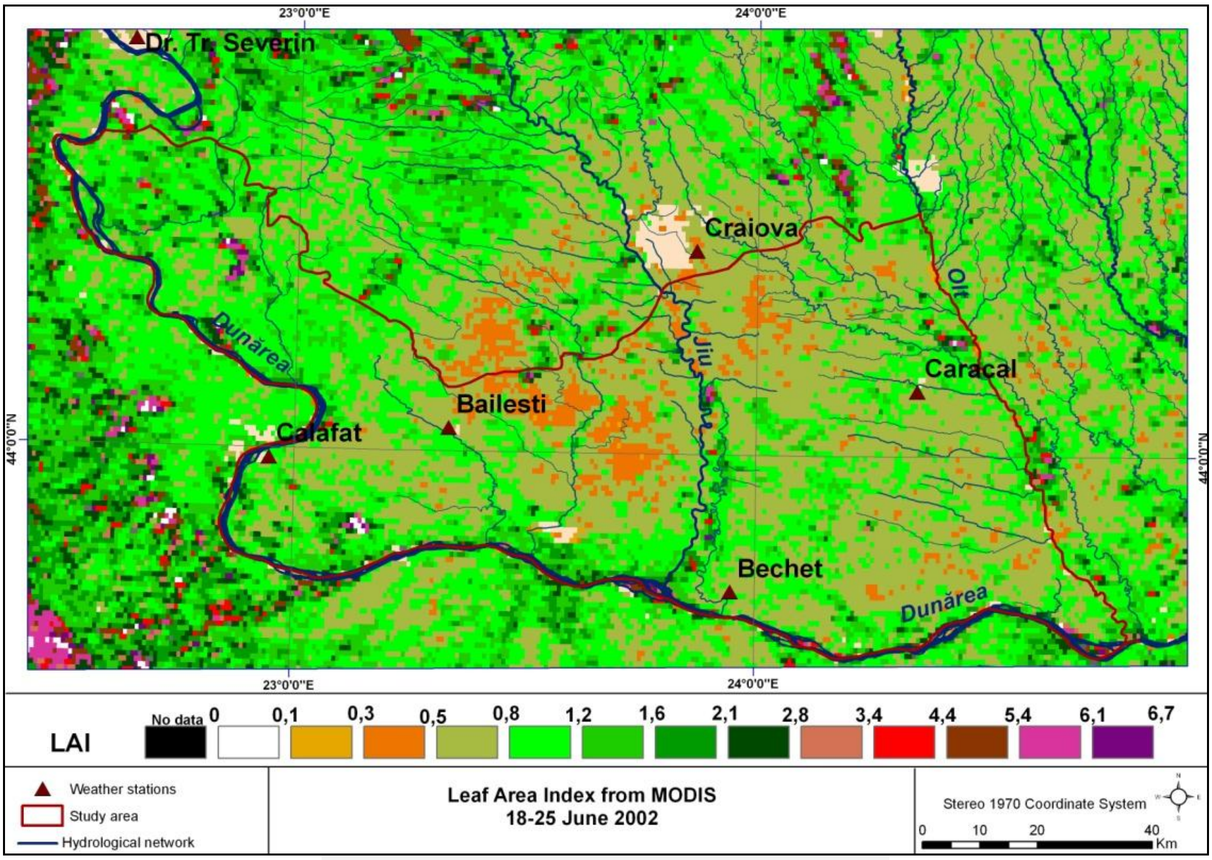


Figure 9. Leaf Area Index (LAI), 18-25 June 2002

In July the situation remains the same because of the phenological plant stage. A representative year for low values of index is 2007 (Figure 10), the predominant surface does not exceed 1 value, and highlighting the intensity of drought. In August, the index show low values on most images.

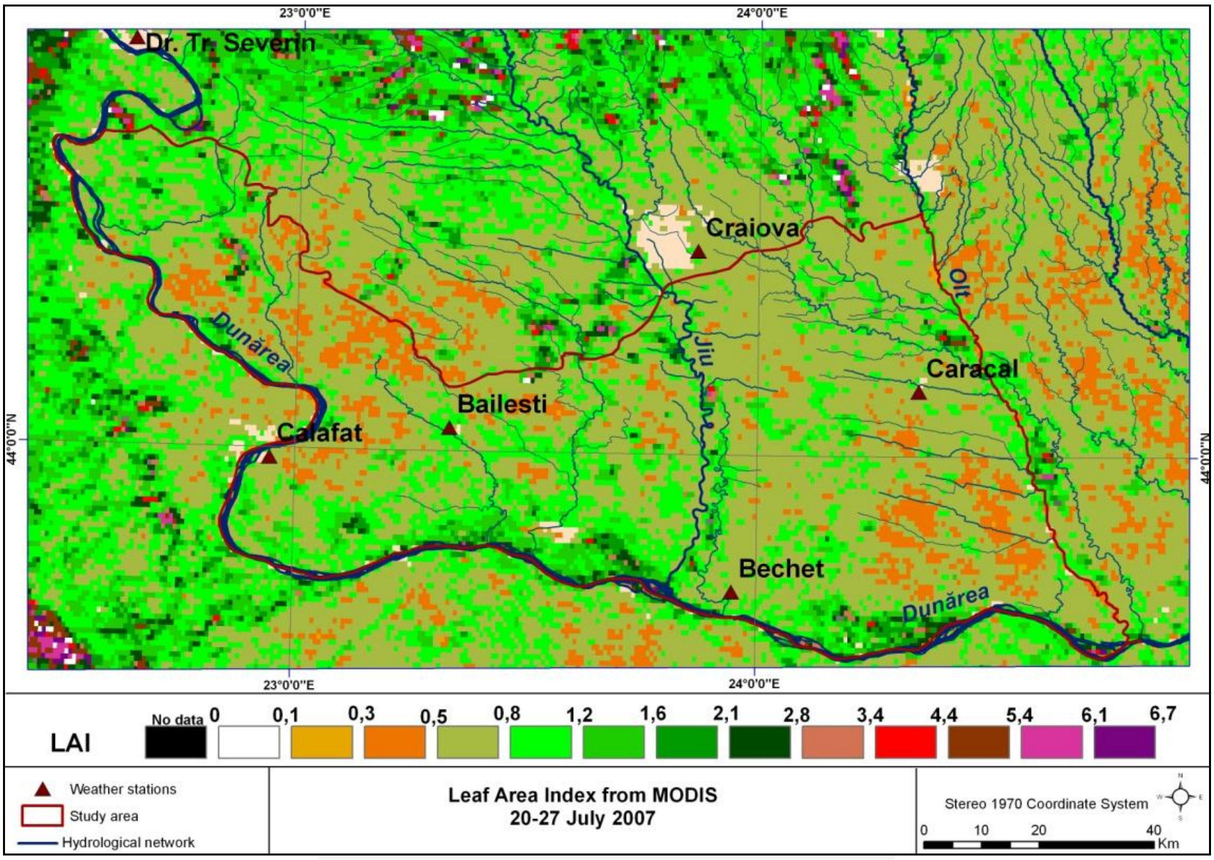


Figure 10. Leaf Area Index (LAI), 20-27 July 2007

6. CONCLUSION

Standardized Precipitation Index revealed dry periods of the years 2000-2009, the Oltenia Plain, emphasizing the summers of the years 2000, 2002, 2003 and 2007. In East, Oltenia Plain was more affected by drought than in West of its.

Spot-Vegetation images and Terra/MODIS were an important source of data for analysis of temporal and spatial evolution of vegetation, identifying the dry years. This images represents one of the most important type of satellite data available free of charge which can be successfully used in determining the vegetation status at one point or to predict the changes that may appear in plants activity.

The correlations between multispectral information provided by VEGETATION and MODIS sensors and the measurements of Oltenia Plain stations, highlighted the influence that rainfall have on vegetation.

The importance of such analysis is given of the use of land, which is predominantly agricultural, which requires constant monitoring of agricultural crops.

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