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CLIMATIC VARIABILITY AND THEIR EFFECTS ON LAND USE IN ROMANIAN PLAIN (JIU-OLT SECTOR)

-Phd. Thesis Summary-

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INTRODUCTION

Against the background of climate variability and expand more extensive areas of agricultural land uncultivated and abandoned, we are witnessing record effects created by the increasing interdependence between two issues. Agricultural areas unaffected adversely by factors such as climate and the non-climatic registered lately an extension outstanding Jiu-Olt Sector of the Romanian Plain so that, within its areas with fragile equilibrium acquire a higher rate of increasingly.

Currently there are studies that emphasize that climate variability may have an impact on agriculture, it demonstrated the fact that from all sectors, the agriculture are the most vulnerable branch. Usually named ``Romanian Sahara``, this territory has been chosen as study area because of its socioeconomic and especially climatic fragile balance. Based on this finding, the present work is questioning the quantitative effects generated at the local level by high temperatures and low humidity contact surfaces fixing and defining the following objectives: a. *Recent climate variability capturing in the Central-Western Romanian Plain (Jiu-Olt Sector);* b. *Reflection of physical-geographical potential of the land use change;* c. *Evaluate the effects of climate variability through the recent change in the land use.*

In order to achieve the above objectives proceeded to merge data obtained through direct measurements with those provided by indirect measurements, which facilitated a comprehensive analysis of many factors such as climate and non-climate that contribute to recording a high degree of bioedafic impaired, economic implicitly, in the studied area.

Recalled appearance is a very little or no literature addressed in the Romanian profile and enroll more recent concerns arising between the world towards revealing extremely close connections between climate variability operating, land and harnessing their economic vulnerability.

Moreover, an important argument in the adoption of this research is the considerable stake economically (socially implicitly) of the theme, if we consider that in the past almost 30 years, major changes in vegetation cover classes was produced by 53.0% of the entire surfaces.

By using the method of extracting data, Normalized Differentiation Vegetation Indices (NDVI and MSAVI2) were used to detect changes due to deforestation and major changes occurred in the use of land within a time longer. Climate variability has affected the vegetation in the area studied in different ways due to a wide diversity of plants and soil types.

In terms of anthropogenic factors, over the last 30 years, in Southern Romania, there have been major changes in land use, some of them are due to the geopolitic context, while some other have been associated to climate variability. Thus, in the very next year after the communism collapse (December 1989), the legislation changed and imposed a transfer of land from common property of the state to individuals and private companies. Under these circumstances, the land division in areas smaller than 10 ha (the largest area that could be returned to one owner, according to the law) has been a long and a very time-consuming process.

Other results unprecedented that gives the present study, in our opinion, a certain originality and scientific consistency, consider that those relating to the identification of synoptic situations and analyses of the frequency of weather types, leading to the installation and the persistent drought phenomenon during the warm semester, which leads to impaired fertility soils. Thus, the most extensive areas of degraded soil were found in arable land and less in areas occupied by forest.

This paper is a result of a doctoral research made partial possible by the financial support of the Sectoral Operational Programme for Human Resources Development 2007-2013, co-financed by the European Social Fund, under the project **POSDRU/159/1.5/S/133391** - " *Doctoral and postdoctoral excellence programs for training highly qualified human resources for research in the fields of Life Sciences, Environment and Earth*" implemented by the University of Bucharest, as beneficiary -partner 2 Babes-Bolyai University, Cluj-Napoca..

Also, this thesis has benefited from partial support for the research project developed under the framework of the project: *Extreme weather events related to air temperature and precipitation in Romania*, project code PN-II-RU-TE- 2014-4-0736, funded by the Executive Unit for Financing Higher Education, Research, Development, and Innovation (UEFISCDI) in Romania, through which we were able to process the climatic data set and improve the quality of research results on extreme weather events associated with air temperature and precipitation in the studied area.

1. GEOGRAPHIC INDIVIDUALITY OF ROMANIAN PLAIN (JIU-OLT SECTOR)

1.1 Geographic location. Defining geographic characteristics of plain in the Jiu-Olt Sector

The study area is part of the Romanian Plain and is located in Southwestern Romania. It covers an area of 3904 km2 and extends between 44° 20′ 01″–43° 41′ 40″ of Northern latitude and between 23° 01′ 44″–24° 32′ 33″ of Eastern longitude (Fig. 1), with N, NV – S, SE orientation. From the administrative point of view belongs to the counties Dolj, Olt, and in the extreme south-east belongs to Teleorman.

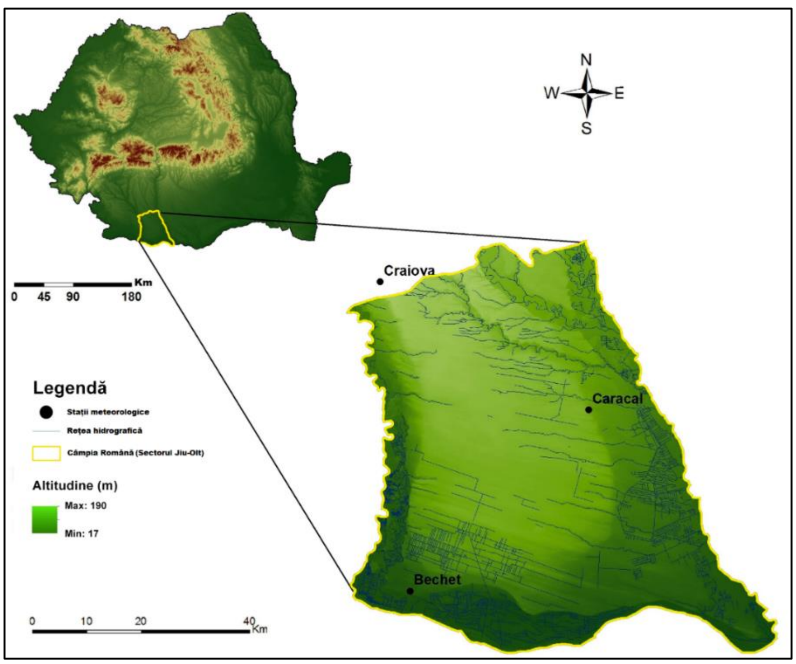


Fig. 1 Location of study area

In 1987, Grigore Posea described the Jiu–Olt Sector of Romanian Plain as looking like *a large amphitheater* with a high field in the middle, represented by Leu - Rotunda Field, joined by Caracalului Plain bordering on the Olt Valley, tilting towards the south of Dăbuleni subunit of the plain, which is bounded on the west by the Jiu river (Posea, 1987). Romanian Plain between Jiu and Olt River differs from other subdivisions by lack of permanent river network (especially in the south) and through the blanket that covers half the dune area. Amid these characteristics the two parts are different A line west-east, which starts in south of Drane (right bank of the Jiu) and passes through Apele Vii- Diosti-Caracal-Stoeneşti -South Daneasa (left bank of the Olt), divides the plain into two subunits: north and south plain (Coteţ, 1957).

2. DATA USED AND RESEARCH METHODOLOFY

2.1 Data used

2.1.1 Climatic data

Climatic data used are provides by archive of weather station from study area, as: Craiova, Bechet și Caracal. Besides the three weather stations belonging to the National Network of National Meteorological Administration were analyzed and data from Agro-Meteorological Station from Dabuleni, operating within the *Development Research Station for Plant Culture on Sands Dabuleni.*

Geographical coordinates of Weather Stations were founded in Table 1.

Table 1. Geographical coordinates of weather stations used in the study

Meteorological Weather Station	**Coordinates**			
	Latitud	**Longitud**	**Altitud (m)**	**Observations**
Bechet	43°47'	23°56'	36	located in meadow Danube, in the south of area
Caracal	44°10'	24°34'	106	located in central-eastern part of area, in Caracal Plain
Craiova*	44°18'	23°52'	192	at North of area
Agro-Meteorological Station Dabuleni	43°80'	24°05'	55	located by South of Dabuleni Field

* Meteorological Weather Station Craiova, is not integrant part of study area, being situated in the north side, but it was analyzed due of the short distance to the north of the studied area and due to the availability of data for the entire period;

The climatic data set of this study covers a period of 55 years (1961–2015). Climatic elements analyzed for the identification of climate variability are month quantities of atmospheric precipitation and monthly average value of air temperatures.

In addition to the data provided by the three Meteorological Weather Stations were used, available data from the international meteorological database: from database Reliable Prognosis - 5 days from Russia, (http://rp5.ru), from National Oceanic and Atmospheric Administration – (NOAA) (http://www.meteomanz.com) and the daily climatic database provided by ANM, ROmanian ClimAtic DAtaset - (ROCADA) (Dumitrescu and Bîrsan, 2015). For the days in which there were viable we used satellite images and other climate parameters observed at meteorological weather stations (daily amounts of precipitation, relative humidity, average and maximum temperature of the ground surface) in order to make a more detailed analysis of the situations.

2.1.2 Satellite data

The satellite data has been acquired from U.S. Geological Survey (http//:glovis.usgs.gov). Two satellite scenes have been used to cover the entire territory. They were recorded by the Landsat missions 5 and 7, and they can be identified as WRS 2-Path 184/Row 29 (44.6 N, 23.9 E) and WRS 2-Path 184/Row 30 (43.2 N, 23.4 E), respectively. The dataset covers a period between 1986 and 2015, in general from warm season (April to September), that overlap over the growing season for majority culture and natural plants. The details for the satellite data are presented in Table 2.

Table 2. Landsat imagery data used in this study

Sensor	Acquisition date	Acquisition Hour	Cloudiness (%)
ETM+	2.04.003	08:58:03	0.00
OLI_TIRS	11.04.2015	09:08:41	0.00
TM	29.05.1986	08:33:59	0.00
TM	14.06.1986	08:29:46	0.00
T M	28.06.1991	08:32:24	0.00
ETM+	28.06.2000	09:00:59	0.00
TM	24.06.2007	09:03:12	0.00
TM	19.06.2011	08:58:37	0.00
TM	11.07.1990	08:29:50	0.00
TM	23.07.2006	09:02:28	0.00
TM	26.07.2007	09:02:53	0.00
TM	15.07.2009	08:58:09	0.00
OLI_TIRS	26.07.2013	09:11:18	0.00
OLI_TIRS	16.07.2015	09:08:52	0.00
TM	4.08.1987	08:35:02	0.00
TM	12.08.1990	08:29:18	0.00
TM	22.08.2011	08:58:06	0.00
OLI_TIRS	14.08.2015	09:09:22	0.00
TM	18.09.1986	08:29:46	0.00
TM	17.09.2003	08:46:51	0.00
OLI_TIRS	2.09.2015	09:09:08	0.00

2.1.3 Reanalysis data

To detect the source areas of the air masses, the atmospheric backward trajectories of the air particles have been simulated by employing the online version of HYSPLIT model Realtime Environmental Application and Display sYstem (READY), developed by National Oceanic and Atmospheric Administration (NOAA) (Rolph 2011, 2016; Draxler and Rolph 2011; Stein et al. 2015). For synoptic analysis, the Europe’s maps with spatial distribution of air pressure at sea level and geopotential at 500 hPa level from Karlsruhe Weather Center e-archive (www.wetterzentrale.de) and (http://www1.wetter3.de/) have been used.

2.1.4 Other type of data

In category of other types of data were find vector and raster data, obtained from Geospatial database (www.geospatial.org), used for limit region reprezentation and relief units, and for the location of meteorological weather station. The soil type map has been provided by Corine Land Cover 2006 project (www.geospatial.org), also we used soil map 1:200.000.

In the analysis were used the surfaces occupied with sandy soils at the unincorporated area of localities, and data about the surfaces occupied with afforestation and deforestation in U.P. VIII and IV, Dabuleni and Sadova for the period 2003-2015. Among this data sets were used the irrigated surfaces at the level of 1990 and 2008 years. This data sets was proceeded after the archived of A.N.I.F Dolj (http://www.anif.ro/).

2.2 Research Methodology

For performing this work, we used a varied methodology applied to various data sets. It appealed to Google Earth Plus database to which were added GPS measurements.

2.2.1 Statistic methods

Research methodology consist in applied statistical methods, general and specific statistical methods.

2.2.1.1. General statistical methods

General statistical methods were used to determine the percentage deviation and standard deviations, but also to calculate the prevailing trends in the parameters of the two elements-climate weather. They used statistical correlation methods (functions linear, logarithmic and quadratic) calculated using SPSS software, version 19.0.0. The correlations between variables were made so direct measurements from weather stations with those obtained indirectly based on the application of satellite indices and between estimated indirect variables.

2.2.1.2. Statistic methods of detection climatic trend line

Change points in climatic data sets were detected by using homogeneity tests (Pettitt's, Buishand, von Neumann's and SNHT) for warm and cold semester. For trend detection we used Mann-Kendall test and Sen’s slope estimator for two types of statistical analyses.

2.2.1.3. Indices and complex variables to evaluate hydric balance

Highlighting climate variability in terms of the hydric balance was based on new methods, existing literature and recommended worldwide by specialized organizations of the O.N.U (FAO, O.M.M, etc.) These are *Reference Evapotranspiration* (ET_0) and *Standardized Precipitation Evapotranspiration Index* (SPEI) calculated for short and medium periods of time.

SPEI has the great advantage unlike SPI or other similar indices that take into account evapotranspiration values and temperatures (Vicente-Serrano, 2010) in addition to the precipitation. Subsequent analysis was made on the basis of the amount of time that has accumulated deficit or surplus of precipitation. Step for a month characterized by short-term droughts, while up to 12 months characterized the medium term droughts. Step up to 6 months was specifically calculated as the values in the analysis were taken accumulated warm months semester, analyzed vegetation cover in the territory.

2.2.2. Remote sensing methods

Results obtained to establishing climate variability based on direct measurements were completed through indirect measurements of the products analyzed using satellite remote sensing and GIS techniques.

2.2.2.1. Collecting and processing satellite images

Satellite products were satellite imagine recorded by the Landsat TM, ETM+ and OLI in wich was applied preprocessing operations, radiance and reflectance calibration, using ERDAS software, version 2014, ENVI, version 5.1 and ArcMap 10.2. RMSE was calculated using ERDAS software and it was values between 2.5 and 3 m. Two satellite scenes have been used to cover the entire territory. Creating a mosaic dataset for the entire study area was not possible for all the images because adjacent satellite scenes from the same day were not available. A small part of the area under study is not covered by the data (it was between 2 -5 %). For further calculations and analysis for the three study cases, the total area of the region considered has been diminished by the percentage of data uncovered area.

2.2.2.2. Indices calculated based on satellite images

The algorithm to calculate LST used is based on a procedure developed in few steps by different authors (Markham and Barker 1986; Xie et al. 2012; Imbroane et al. 2014; Herbel et al. 2015, Rosca et al. 2016). The general scheme of processing satellite data is presented in Fig. 2.

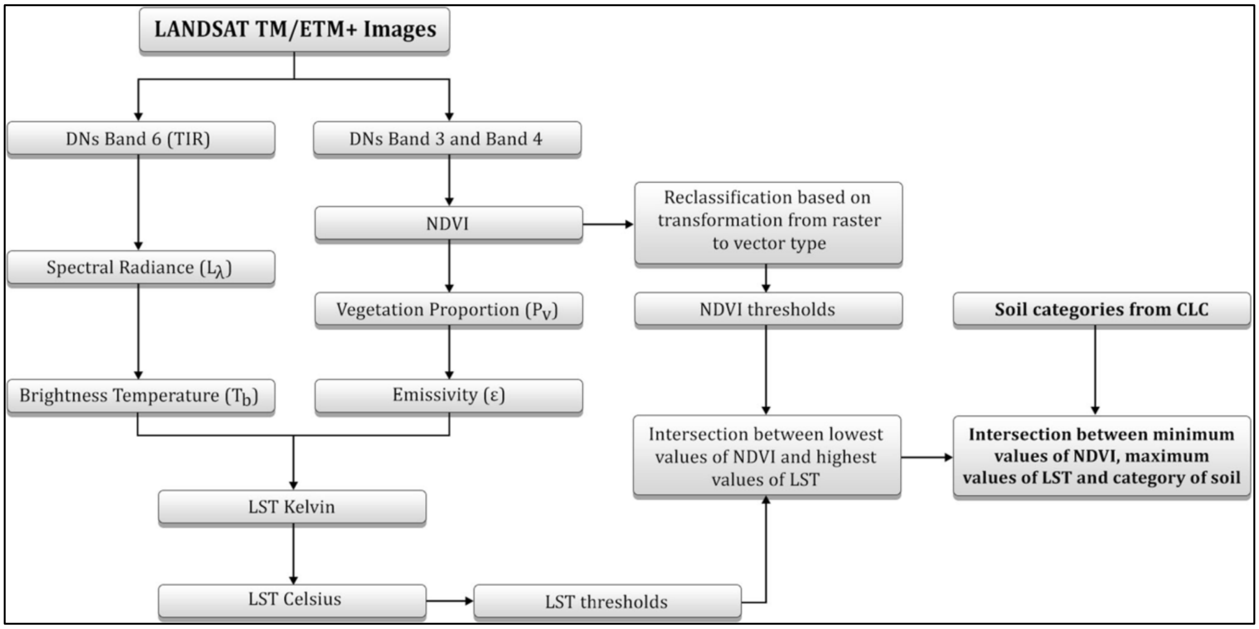


Fig. 2 Algorithm for satellite data processing (after Roșca et al., 2016)

Step 1. **Conversion of digital number (DN) in spectral radiance.**

Because the thermal radiation received by the satellite is affected by the atmosphere, an accurate temperature cannot be obtained directly from the sensors. Therefore, the calibrated digital numbers have to be converted to radiance values. In this model, we used the equation developed by Markham and Barker (1986) to calculate the spectral radiance (1).

$$L_\lambda = L_{\min(\lambda)} + \left(L_{\max(\lambda)} - L_{\min(\lambda)}\right)Q_{dn}/Q_{max} \qquad (1)$$

where Lλ is the spectral radiance for wavelength λ; Qdn is the gray level of each pixel; Qmax is the maximum numerical value of the pixel; Lmax(λ) and Lmin(λ), respectively, are the minimum and maximum spectral radiance for Qdn = 0 and Qdn = 255. The Lmax(λ) and Lmin(λ) values vary for each Landsat scene. These specific values can be found in the metadata file downloaded with the images.

Step 2. **Conversion of radiance to temperature**

The next step is to convert the spectral radiance into satellite brightness temperature. We used a simplified procedure to compute the blackbody temperature adapted for Landsat satellites imagery by Markham and Barker (1986). Assuming surface emissivity being equal to that of the black body, the formula for conversion is similar to Plank's equation calculated based on two free parameters (Xie et al. 2012), as in (2):

$$T_b = \frac{K_2}{\ln\left(K_1 / L_\lambda + 1\right)} \qquad (2)$$

where T_b is the blackbody temperature (in Kelvin); L_λ is the spectral radiance derived above; and K_1 and K_2 are the calibration constants (given by the sensors producer):

i. for Landsat 5: K_1 = 607.76watts/(meter squared × ster × µm) and K2 = 1260.56 K

ii. for Landsat 7: K_1 = 666.09 watts/(meter squared ×ster × µm) and K2 = 1282.71 K

iii. for Landsat 8, exist two thermal bands (B10 și B11): $K_1(_{B10})$= 774,89 K; $K_2(_{B10})$= 1321,08 K and $K_1(_{B11})$ = 480,89 K; $K_2(_{B11})$=1201,14 K.

For OLI satellite scenes type was used a mediation process between the two values of calibration constants.

Step 3. **Extraction of vegetation coverage**

We have calculated NDVI in order to determine the raster emissivity and after that to determine the LST. The reflectance in red and near infra-red has been combined to get the relationship between the radiometric response of the crops and their vegetative structure. Thus, NDVI has been calculated as in (3):

$$NDVI = \frac{B4 - B3}{B4 + B3} \qquad (3)$$

Were

B3 – band 3 (Red) for Landsat TM/ETM+;

B4 – band 4 (Near Infra-Red) for Landsat TM/ETM+.

For OLI imagines the formula has been calculated as in (4); $NDVI = \frac{B5-B4}{B5+B4}$, were B5 – Near Infra Red and B4 is RED. Based on this procedure, raster data ranging from −1 to 1 are issued. Positive values indicate areas with vegetation, while negative values indicate areas without vegetation such as bare soil, human settlements, or water.

Step 4. **Calculation of the proportion of vegetation**

Furthermore, based on NDVI values, the method proposed by Carlson and Ripley (1997) has been employed to calculate the proportion of vegetation for every pixel in the study area, as in (5).

$$Pv = [(NDVI - NDVI_{min})/(NDVI_{max} - NDVI_{min})]^2 \quad (5)$$

where Pv is the vegetation proportion; NDVImin is the NDVI values for bare soil pixels; and NDVImax is the NDVI values for fully vegetated pixels.

Step 5. Calculation of the land surface emissivity (LSE)

The calculation of land surface emissivity (LSE) is an important step to get LST, and the final emissivity raster has been obtained according to procedure developed by Sobrino et al. (2004) (6):

$$\varepsilon = 0{,}004Pv + 0{,}986 \quad (6)$$

where ε is the LSE values of the pixel and Pv is the vegetation proportion from (5).

Step 6. **Calculation of LST**

The LST in the study area was then computed by performing emissivity corrections on the brightness temperature obtained from (2). The method used for scaling the blackbody temperature was the one developed by Artis and Carnahan (1982) and recently used by Feizizadeh and Blaschke (2013), as shown in (7).

$$LST = \frac{T_b}{1 + (\lambda T_b / \rho)\ln \varepsilon} \quad (7)$$

where Tb is the black body temperature;

ρ = is the h × c/σ (1.438 × 10−2mK);

h is the Plank's constant (6.626 × 10−34 J s);

σ -is the Boltzman's constant (1.38 × 1023 J/K);

c is the light velocity (2.998 × 108 m/s);

λ is the wavelength of emitted radiance (11.4 μm for Landsat TM and ETM+ bands, respectively 10.8 for Landsat OLI_TIRS);

and ε is the LSE (emissivity)

Step 7. **LST conversion from Kelvin to Celsius degrees**

Since the LST value obtained in (7) is given in Kelvin, the final step for LST retrieval is to convert LST from Kelvin to Celsius degrees (8).

$$LST_C = LST - 273{,}15 \qquad (8)$$

where LST_C is the temperature in °C and LST is the temperature in °K.

Step 8. **Reclassification based on NDVI, LST values, and soil types**

After obtaining the raster results for NDVI, LST, and soil types, reclassifications have been performed for each parameter.

Thus, for NDVI, three classes have been established:

i. High density vegetation (NDVI values from 0.6 to 1.0);

ii. Low density vegetation (NDVI values from −0.5 to 0.5);

iii. Lack of vegetation class (NDVI values from −1.0 to −0.6), which was considered the most appropriate to be used for this study.

The LST values have been divided in intervals of 5.0 °C, but for established the impact factors was performed a major class for summer months (June, July and August).

i. High-temperature class (LST≥ 40.0 °C);

   For the rest of the months was used two other classes, according with the specific climatic conditions of those months:

   i. LST≥ 30.0 °C (April);

   ii. LST≥ 35.0 °C (May and September).

The soil types have also been reclassified in four main classes:

i. Sandy soils;

ii. Brown soils;

iii. Chernozems;

iv. Other soil types

On the maps, we identified a class of waterbodies.

For further analysis, one class has been retained both for NDVI and LST (lack of vegetation class and high-temperature class, respectively), as well as all soil classes.

Step 9. **Intersection of polygons derived from NDVI, LST and soil categories reclassification**

A transformation from raster to vector files was followed in the algorithm, in order to calculate the area of polygons with high-temperature and lack of vegetation for different soil class. First, the intersection of high-temperature and lack of vegetation polygons has been performed and further on the resulting polygons have been intersected by those resulted from soil reclassification. Under these circumstances and in order to get more accurate results, we have decided to use more than one correlation type for analysis of correlation between different pairs of variables considered: area without vegetation and area with LST ≥ 40.0 °C; LST and ground level temperature, TG mean, and TG max). Thus, Pearson product moment correlation coefficient, logarithmic, and quadratic correlation coefficients have been calculated. The data have been processed by using SPSS statistical software, version 19.0.0.

The method utilized in calculation of moisture of contact surfaces used the formula (9):

$$NDMI = \frac{(NIR - SWIR)}{(NIR + SWIR)} \qquad (9)$$

were:

NIR- spectral band Near Infra-Red;

SWIR- spectral band of Mid Infrared

After obtaining the resulted raster of NDMI product (Normalized Difference Moisture Index), it passed to the reclassification process for determining major classes on the principle established in NDVI. Thus, by intersection method has been established on the one hand the share overlapping areas with humidity over each class determined of vegetation cover, and secondly the share overlapping areas with humidity over higher temperatures of equal than 30.0 °C, 35.0 °C, and 40.0 °C respectively.

2.2.2.3 Methods and techniques for detecting changes in land use

Throught complex formula developed by Qi et. al. (1994b), MSAVI2 put in evidence better areas with vegetation cover. MSAVI2 used the formula presented in as (10):

$$\boldsymbol{MSAVI2} = \frac{[2*NIR+1-\sqrt{(2*NIR+1)^2-8*(NIR-R)}]}{2} \qquad (10)$$

NDVI using a common extraction data, the value thresholds method, based on the idea that the disturbing phenomena occured in the same time with the decrease of NDVI values, under the threshold („lack of vegetation”).

Mahmoud et al. (2016) shown that MSAVI is most indicated than NDVI, when the vegetation cover is almost lack, lower than 40%. Thus, MSAVI2 is considered like a particular index (Gaitán et al., 2013).

In order to compare data were established for the main classes MSAVI2 index. They were noted suggestive way:

i. Lack of vegetation - 0
ii. Moderate vegetation -1
iii. Healthy vegetation - 2

Subsequently, based on the major classes of MSAVI2 obtained differences were noted between the two indices of vegetation after having been detained classes 0 and 2 for establishing vegetation cover major changes in land use.

2.2.3. Synoptic analysis methods

2.2.3.1 Field analysis of sea level pressure and geopotential field at 500 hPa

This type of analysis has provided useful information that helped to explain some temperature variation.

2.2.3.2. Analysis trajectories of air masses

We have used, for this paper, backward trajectories detected at three levels, from near-ground level (2, 30 and 1000 m above ground level—AGL) up to mid-troposphere (1500 and 3000 an 5000 m AGL, respectively). These levels have been chosen in order to allow the identification of possible different source region of air masses and the existence of different air masses in low and middle troposphere, respectively, over the considered region.

The backward trajectories have been run for 72 h, ending at 09.00 UTC (i.e., 12.00 Romanian Summer Time—RST). Before choosing the time-span to run the trajectories, we have performed few trials, but finally we have retained the times pan of 72 h before the ending point. We have found it long enough to allow the identification of the air masses origin, especially in higher altitude where the velocity of the air flow is much higher compared to that of near-ground level.

The vertical transport has been modeled at every 6 h, by employing the vertical velocity option of HYSPLIT application, and thus five maps have been derived, with source point in Caracal city, Romania (44.10 N, 24.34 E), located approximately in the middle of the region. The ending time is very close to the satellite image capture and thus our analysis could provide useful information on the air masses generating the highest LST in the considered region. The changes in the air parcel height, along its trajectory, have also been investigated.

3. THE MAIN RESULTS AND CONCLUSIONS

3.1 CLIMATE VARIABILITY EVIDENCED ON THE BASIS MAIN SIMPLE CLIMATIC PARAMETERES

In terms of climate, the temperate continental climate is dominant, but quite frequent the Mediterranean climate influences are present in the Southwestern Romania. High values of monthly absolute maximum air temperature in the summer, measured in standard weather station conditions (35.0–43.0 °C), reference evapotranspiration higher than precipitation rate (550–700mm/vegetation period, 100–235 mm/summer), and low precipitation over the entire year, but especially in summer (less than 549.6 mm/year, and 173.3 mm/summer season) lead to frequent drought episodes. They occur especially in the summertime when they are associated to heat waves (Roşca 2012; Croitoru et al. 2013, 2015; Burada 2013, Piticar et al. 2016), stress the crops, and make from this area one of the most fragile in terms of agriculture use.

3.1.1 Analysis of interanual variability in time series air temperatures

Warm season in Southwestern Romanian Plain is experiencing changes in both climatic conditions and land use. The complex of the analysis was presented by table format and consist in trend detection in which we used Mann-Kendall test and Sen's slope estimator. The results showed that the change points in climatic data sets for summer months are 1991, 1986 and 1992 and are common to both weather station Bechet and Caracal (Table 3).

In June month in the 1961-2015 period was registered increasing from 1.0 °C at Bechet and 1.2 °C for Caracal Weather Station. The trend line for the period after change point (1995-2015) was negative (Bechet: -0.412 and Caracal -0.235 °C). The period of change in July was 1987-2015 and registered an increase trend line (0.191 °C for Bechet and 0.075 °C for Caracal). An increase trend line was registered in August for the change interval 1992-2015, (0.368 °C for Bechet Weather Station and 0.625 °C Caracal Weather Station).

Table 3. Mean values of air temperature (warm semester) before and after change points (CP) detected by using Pettitt test (the values represent the mean per temporal units) and slopes[a] detected by Mann-Kendall test combined with Sen slope

Month	*Change Year*		**Bechet**		**Caracal**		**Craiova**	
Temperatures	*Bechet and Caracal*	*Craiova*	**before CP (°C)**	**after CP (°C)**	**before CP (°C)**	**after CP (°C)**	**before CP (°C)**	**after CP (°C)**
April			12.25	-	11.77	-	11.47	-
May			17.74	-	17.37	-	16.88	-
Iune	**1992**	**1990**	20.90	21.90	20.60	21.80	19.88	21.15
			-0.095	**-0.412**	**0.087**	**-0.235**	**-0.001**	**0.000**
Iuly	**1986**	**1986**	22.40	24.00	22.2	23.90	21.66	23.38
			-0.700**	**0.191**	**-0.500***	**0.075**	**-0.007****	**0.003**
August	**1991**	**1984**	21.70	23.30	21.80	23.60	21.01	22.83
			-0.231	***0.368***	***0.000***	***0.625***	**-0.009+**	**0.005**
September			17.63	-	17.79	-	17.47	-
Warm semester	**1992/ 1991**	**1984**	18.76	19.57	18.55	19.46	17.87	18.94
			-0.150	***0.010***	***-0.060***	***0.260***	***-0.500****	***0.180***

[a] Slopes are given per decade in °C

3.1.2 Analysis of trend line evolution of rainfall quantities

Even if exist general decreasing trend line of average mean rainfall quantities the situation may by analyzed considering local conditions, because against the background general patterns of evolution occurring features action imposed by local factors. The situation of September deserved one detailed analysis, because the trend line registered. Thus, the rainfall quantities were registered a salt in the average per unit in all the weather stations. The year of change point (CP) was 1994

(Table 4). The period after CP have an increase of 31.5 mm at Caracal Weather Station, registered a negative trend line (-18.606 mm/decade), due in principal of the small values registered in the period of 2009-2013 (21.0 mm respectively 34.8 mm).

Table 4. Mean values of rainfall quantities (warm semester) before and after change points (CP) detected by using Pettit test (the values represent the mean per temporal units) and slopes[a] detected by Mann-Kendall test combined with Sen slope

Month	Change Year		**Bechet**		**Caracal**		**Craiova**	
Rainfall	Bechet and Caracal	Craiova	**before CP (mm)**	**after CP (mm)**	**before CP (mm)**	**after CP (mm)**	**before CP (mm)**	**after CP (mm)**
April	**1961-2015**		46.44	-	46.49	-	51.2	-
May			57.92	-	58.83	-	68.06	-
Iune			63.51	-	69.15	-	73.26	-
Iuly			54.01	-	60.46	-	63.74	-
August			38.89	-	45.68	-	47.42	-
September	**1994**	**1994**	40.24		29.20	60.70	32.67	67.26
			without CP		**-7.429***	**-18.606**	**-0.057**	**-0.102**
Warm Semester	1961-2015		301.09		320.73		350.00	

[a] Slopes are given per decade in mm

4. CLIMATE VARIABILITY EVIDENCED ON THE BASIS MAIN COMPLEX CLIMATIC PARAMETERS

4.1 Climatic variability by hydric balance

4.1.1 Evapotranspiration (ET_0)

Increase in evapotranspiration during the months when the plants registers the maximum water requirement, can only express critical level facing the vegetation in the area studied. By recording the change points, which showed significant increases in mean values in the two temporal units reveals changes in climatic parameter values (Fig. 3, Table 5). Years in which recorded the change points were 2002, 1992, 1995, 1997 and 2005 (Fig. 4).

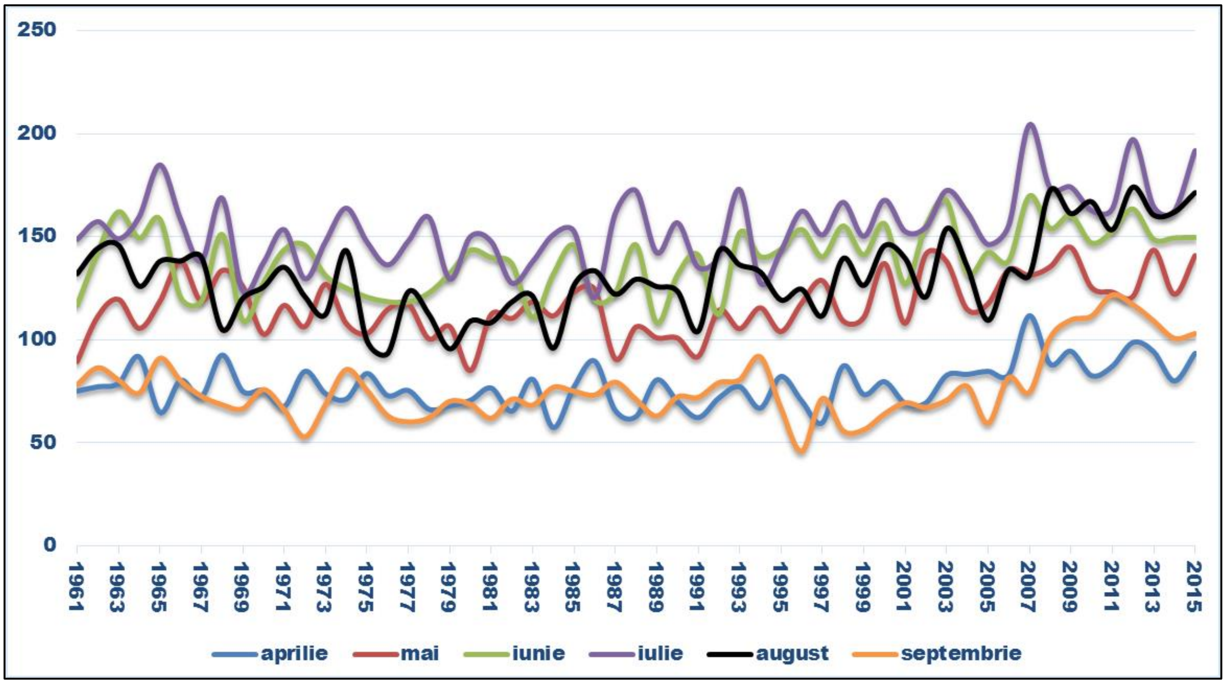
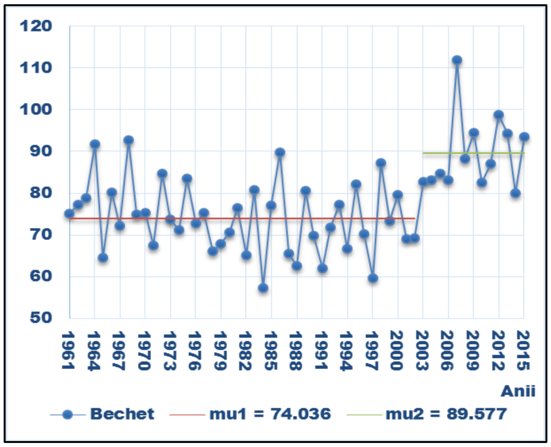
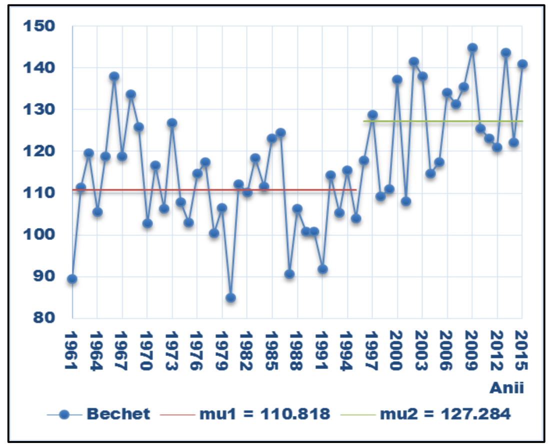


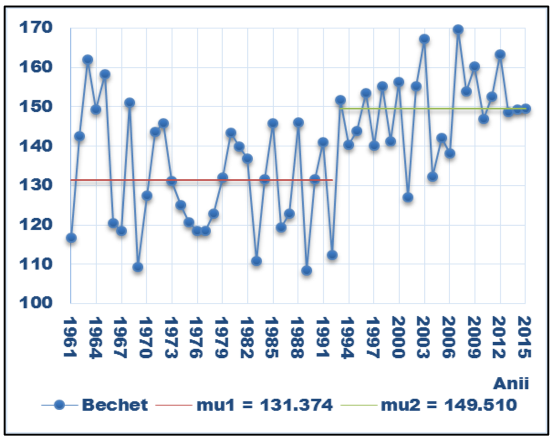
Fig. 3 Values of ET_0 in warm semester at Bechet Weather Station



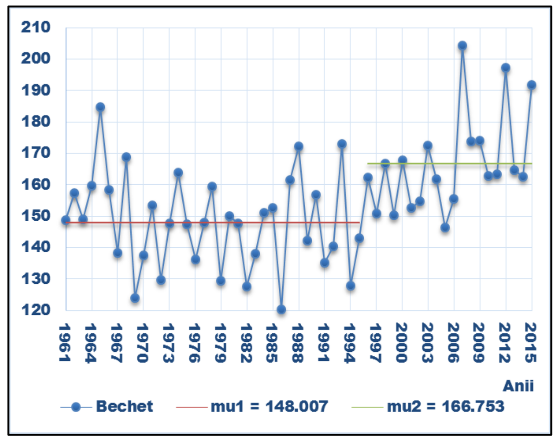
April



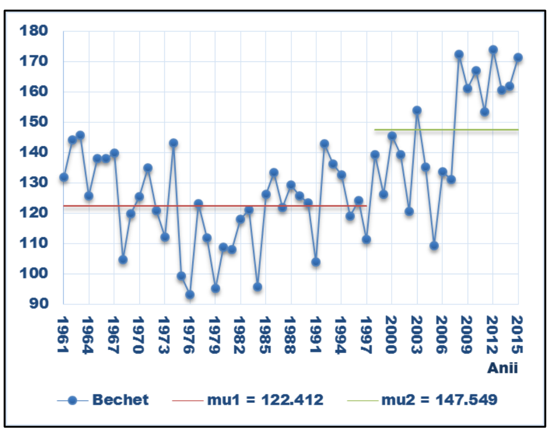
May



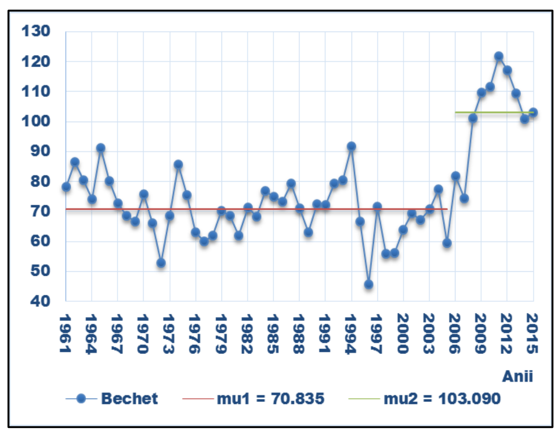
June



July



August



September

Fig. 4 The change point in dynamics values of ET_0 in warm semester month at Bechet Weather Station

Table 5. Trend line results according Mann-Kendall test combined with Sen slopes for average monthly evapotranspiration values of warm semester (1961-2015) (mm/decade)

Month	Weather Station		
	Bechet	**Caracal**	**Craiova**
April	2.3*	0.6	0.8
May	3.8**	0.9	1.0
June	4.9***	2.2+	1.5
July	4.6**	2.5*	1.2
August	6.3**	3.1*	2.3
September	2.4+	0.5	1.0

+ α= 0.1; * α= 0.05; ** α=0.01; *** α= 0.001

4.2.1 Standardized Precipitation Evapotranspiration Index (SPEI) – the characteristic of short and long period of time

At 12 months step SPEI results revealed an almost normal feature of the years analyzed, with the first period (1961-1985) where feature is part of the surplus, so that in the second period (1986-2015) surplus areas note alternation of excedentar and deficit domain (Fig. 5).

Like characteristics seen from the analysis of the 12 month period are those from 6 months step, which keeps the two relatively large periods of time. Since 1985 takes on another form chart values, index values as time variability SPEI (Fig. 6).

After characterization of the analyzed period of 55 years at annual and semester level we considered necessary to highlight for one-month time step, six-months' time step the characteristics according SPEI for all 21 satellite imagines used in the study (Table 6). From this analysis was eliminated the values for Craiova Weather Station, because this is not covered by satellite imagines.

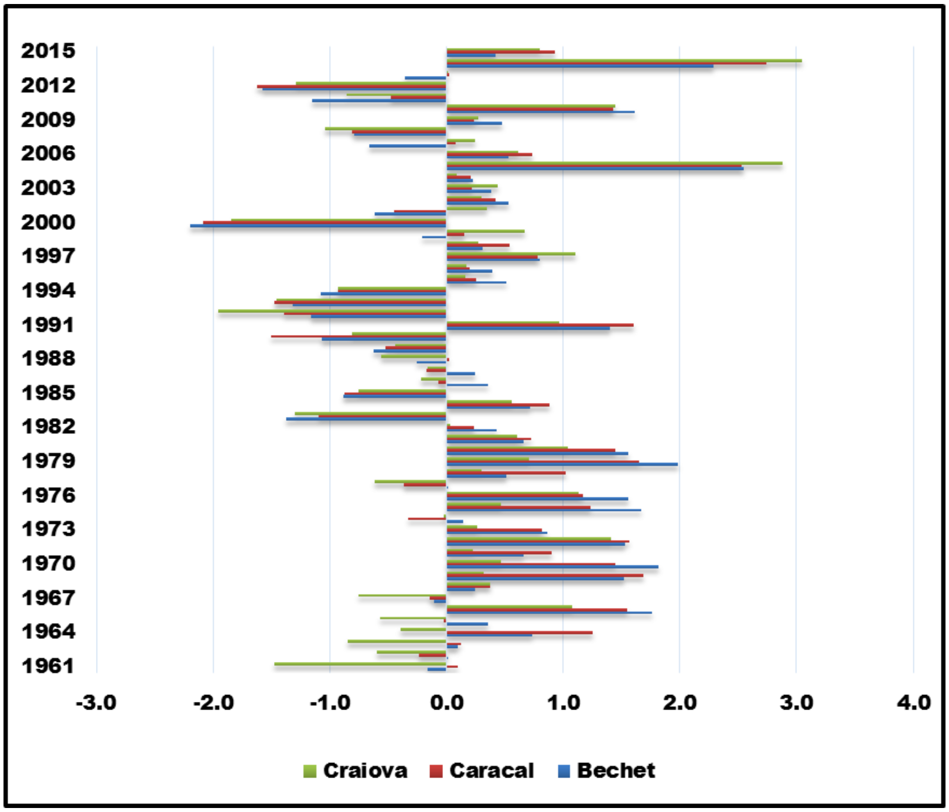


Fig. 5 Values of SPEI for 12 months (period of January – December)

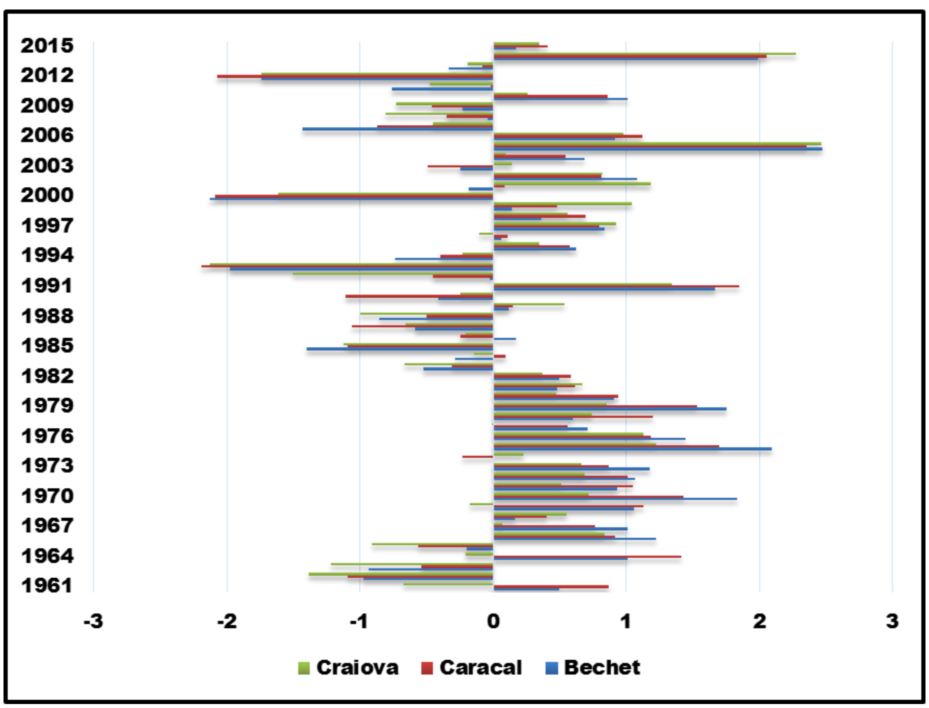


Fig. 6 Values of SPEI for 6 months (period of April-September)

Table 6. SPEI values and conditions calculated for one time steps

Acquisition date of satellite imagine	***Bechet***		***Caracal***	
	One-month time step *	**Characteristics**	**One-month time step ***	**Characteristics**
2/04/2003	1,11	moderately wet	1,10	moderately wet
11/04/2015	-1,31	moderately drought	-0,43	near normal
29/05/1986	-1,02	moderately drought	-1,75	severe drought
14.06.1986	1,10	moderately wet	0,88	near normal
28.06.1991	0,44	near normal	0,07	near normal
28.06.2000	-1,56	severe drought	-1,75	severe drought
24.06.2007	-1,40	moderately drought	-0,61	near normal
19.06.2011	0,10	near normal	0,69	near normal
11/07/1990	-0,85	near normal	-0,77	near normal
23/07/2006	1,56	severe wet	0,94	near normal
26/07/2007	**-2,23**	extremely drought	**-2,33**	extremely drought
15/07/2009	1,03	moderately wet	0,95	near normal
26/07/2013	-0,61	near normal	-0,12	near normal
16/07/2015	-1,70	severe drought	-1,34	moderately drought
4/08/1987	0,27	near normal	-0,41	near normal
12/08/1990	-0,24	near normal	-0,86	near normal
22/08/2011	-0,86	near normal	-0,65	near normal
14/08/2015	0,11	near normal	0,18	near normal
18/09/1986	-1,20	moderately wet	-1,03	moderately drought
17/09/2003	1,29	moderately wet	1,14	moderately wet
2/09/2015	0,98	near normal	1,74	sever umed

* the accumulated value for the acquisition date of satellite imagine

Overall, the entire series of satellite images feature percentage recorded near normal in six months' time step was 81.8% for the Bechet Weather Station and 72.7% on Caracal Weather Station. Although the studied area is relatively homogeneous, differences were noted in SPEI index values at the two weather stations (Table 7).

Table 7. SPEI values and conditions calculated for six time steps

Acquisition date of satellite imagine	***Bechet***		***Caracal***	
	Six-months time step *	**Characteristics**	**Six-months time step ***	**Characteristics**
2/04/2003	0,64	near normal	0,64	near normal
11/04/2015	0,68	near normal	1,33	moderately wet
29/05/1986	0,32	near normal	-0,10	near normal
14.06.1986	0,98	near normal	0,49	near normal
28.06.1991	1,07	moderately wet	0,89	near normal
28.06.2000	-1,77	severe drought	-1,90	severe drought
24.06.2007	-1,71	severe drought	-1,33	moderately drought
19.06.2011	-0,36	near normal	0,29	near normal
11/07/1990	-0,63	near normal	-1,09	moderately drought
23/07/2006	0,78	near normal	0,89	near normal
26/07/2007	**-2,01**	extremely drought	-1,76	severe drought
15/07/2009	0,25	near normal	0,09	near normal
26/07/2013	0,44	near normal	0,50	near normal
16/07/2015	0,22	near normal	-0,04	near normal
4/08/1987	0,15	near normal	-0,30	near normal
12/08/1990	-0,65	near normal	-1,27	moderately drought
22/08/2011	-0,17	near normal	0,36	near normal
14/08/2015	0,23	near normal	-0,08	near normal
18/09/1986	0,17	near normal	-0,25	near normal
17/09/2003	-0,24	near normal	-0,49	near normal
2/09/2015	0,17	near normal	0,41	near normal

* the accumulated value for the acquisition date of satellite imagine

5. **ANALYSIS OF SOME CLIMATIC PARAMETERS OBTAINED BY INDIRECT MEASUREMENTS**

5.1 Land Surface Temperature (LST) in the warm semester months in correlation with vegetation cover (NDVI) and soil categories

The main purpose of this paper is to investigate the relationship between high LST, its generating synoptic conditions and air masses origin, vegetation cover, and soil type in one of the driest region in Romania, based on five summertime case studies. The most important findings are: strong correlation between land surface temperature derived from satellite images and maximum ground temperature recorded in a weather station located in the area, as well as between areas with land surface temperature equal to or higher than 40.0 °C and those with lack of vegetation; the sandy soils are the most prone to high land surface temperature and lack of vegetation, followed by the chernozems and brown soils; extremely severe drought events may occur in the region.

5.1.1 Spatial-temporal analysis of land surface temperature (LST) and the impact of climatic and non- climatic factors

The maximum soil temperature recorded in Caracal weather station for 28th of June was 61.0 °C (Table 8), which is supposed to have been recorded few hours later, in the afternoon, after satellite image capture. The LST derived from the satellite image rose to more than 42.0 °C, at 9:00 am, in the pixel where the weather station is located. Under these circumstances, by the end of June, the total area with LST equal or higher than 40.0 °C reached almost 60 % (Fig. 7a, b, Table 8), while the lack of vegetation area extended over 71.45 % of the region (Fig. 7c, d, Table 8). Those conditions were specific to a severe drought event, which began in May and lasted for few months afterwards. The backward trajectories analysis revealed that in the 3 days before the time of the satellite image capture, an air mass coming through a ridge extended over North Atlantic from Azores High, was identified in higher layers (3000 and 5000 m AGL, respectively) (Figs. 9c and 8a). In the three previous days, the air masses at lower level characterized by a considerably slower velocity toward southeast, warmed significantly under clear sky and high solar. When high LST values, lack of vegetation and soil type polygons were overlapped (Fig. 7e, f), we found that about half of areas or even more in case of some main soil categories was characterized by lack of vegetation and high LST. The most affected was vegetation on brown soils (65.9 %), followed by those on sandy soils (54.2 %) and chernozems (49.6 %). It worth mention that the disastrous situation may be due also to lack of irrigation in the region, since at that period the irrigation system was completely damaged and out of work (Fig. 7 e, f).

Table 8. LST values registered in the pixel of Bechet and Caracal Weather Station versus there registered by direct measurements and areas without vegetation (NDVI) and LST ≥40.0 °C (%) in period of June 1986 – August 2015

Date	Time of satellite image *	LST (°C) Bechet	LST (°C) Caracal	Interval of measurement	Ground temperature in Bechet (°C)		Ground temperature in Caracal (°C)		Area without vegetation (%)	Area with LST ≥ 40.0 °C (%)
					T med.	T max.	T med.	T. max		
14.06.1986	08:29:46	27.8	25.9	00:06-18:00	25.9	44.6	26.0	38.6	15.6	9.9
28.06.1991	08:32:24	28.6	31.1	00:06-18:00	31.6	56.0	33.1	56.0	40.6	30.3
28.06.2000	09:00:59	36.8	42.4	00:06-18:00	30.3	58.5	33.3	61.0	71.5	59.6
24.06.2007	09:03:12	36.1	33.6	00:06-18:00	32.3	52.5	28.9	42.2	33,0	17.2
19.06.2011	08:58:37	31.9	27.8	00:06-18:00	28.9	63.0	28.3	42.0	11.2	8.6
11.07.1990	08:29:50	37.1	47.9	00:06-18:00	29.4	29.4	30.5	30.5	41.7	32.0
23.07.2006	09:02:28	28.9	33.5	00:06-18:00	33.2	59.8	31.0	61.6	6.3	1.6
26.07.2007	09:02:53	40.8	46.9	00:06-18:00	34.2	64.2	31.1	59.0	59.9	34.9
15.07.2009	08:58:09	32.2	38.6	00:06-18:00	27.7	41.0	28.1	33.0	36.8	10.6
26.07.2013	09:11:18	34.1	37.8	00:06-18:00	33.2	57.0	30.7	40.0	19.4	13.4
16.07.2015	09:08:52	39.6	45.3	00:06-18:00	24.9	51.0	25.8	33.0	40.2	25.2
4.08.1987	08:35:02	30.4	36.1	00:06-18:00	32.6	32.6	32.5	32.5	58.6	49.8
12.08.1990	08:29:18	30.2	33.9	00:06-18:00	25.1	25.1	25.6	29.2	39.2	29.2
22.08.2011	08:58:06	38.3	32.1	00:06-18:00	30.7	56.0	29.3	44.0	21.0	14.2
14.08.2015	09:09:22	29.8	33.2	00:06-18:00	26.4	54.0	27.5	35.0	19.0	15.2

* The time is given in UTC

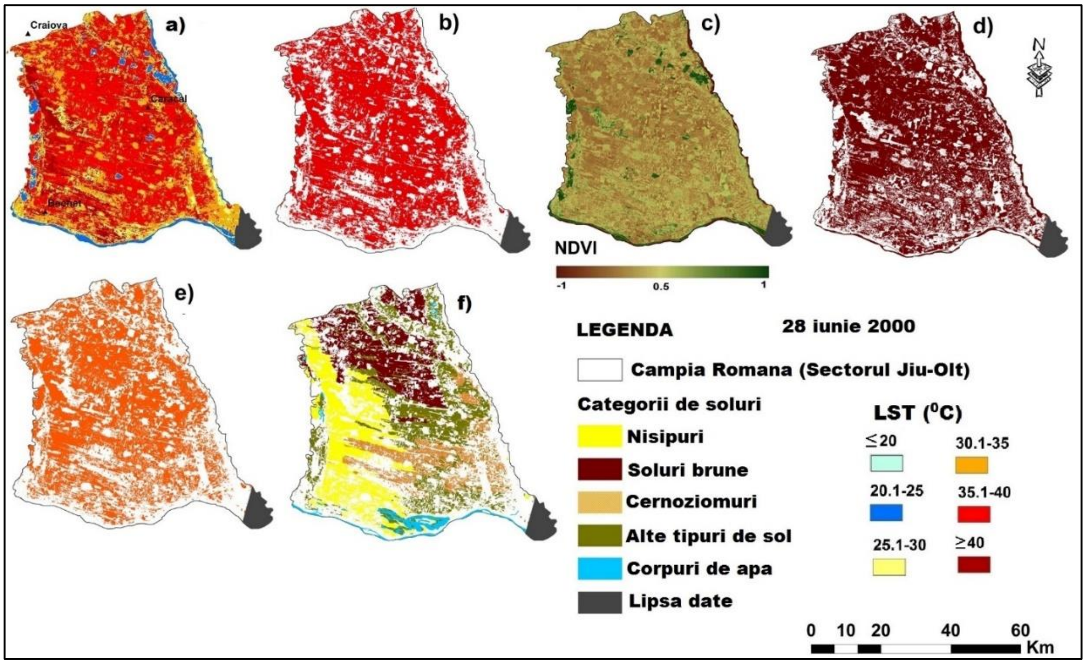


Fig. 7 LST, NDVI, and soil types on the 28th of June 2000 (a LST; b polygons with LST ≥ 40.0 °C (%); c NDVI; d polygons with lack of vegetation; e. polygons with intersection between lack of vegetation and LST ≥ 40.0 °C; f polygons with intersection of (e) and soil categories)

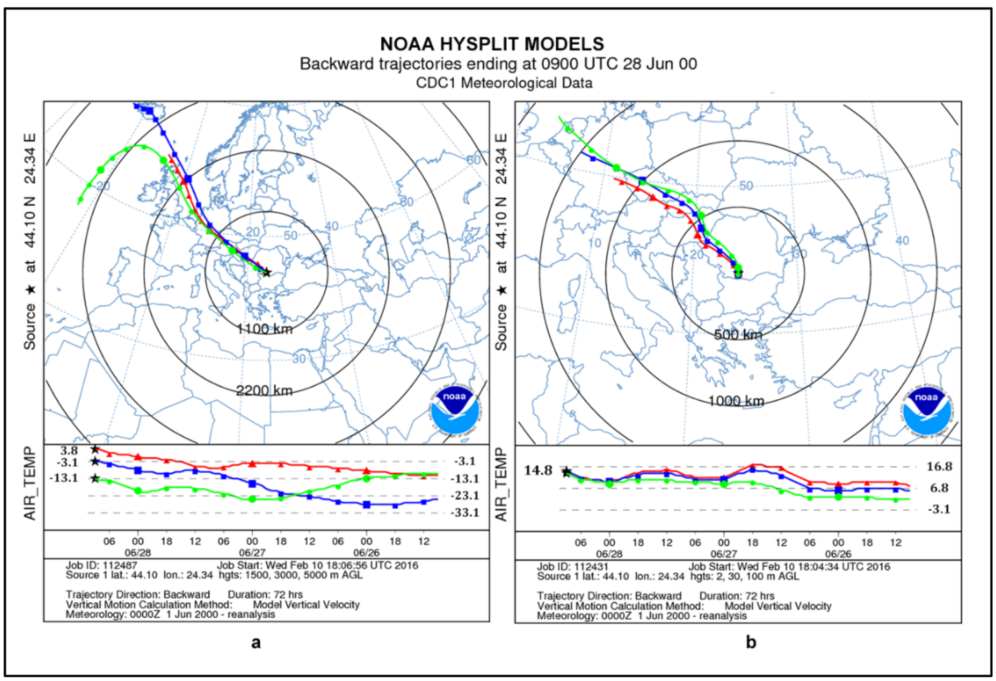


Fig. 8 Backward trajectories of air particles for the interval of 72 h before satellite image capture time, based on NOAA HYSPLIT Model for 28 June 2000

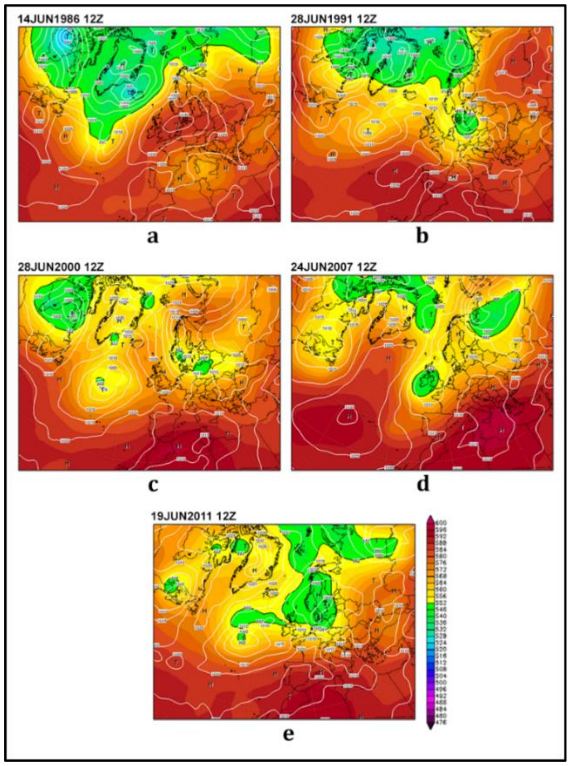


Fig. 9 Sea level air pressure and geopotential at 500 hPa level over Europe at 12:00 UTC hour (Source: http://www.wetterzentrale.de/, Roșca et al., 2016)

At the level of summer month, in which the temperature is higher or equal with 40.0 °C, the coefficient of correlation between two variables was higher for the three types of correlation (being between 0.927-0.856) (Table 9). The area with lack of vegetation derived from NDVI values increases with the increase of the area with high temperature class detected based on LST values (Roșca et al., 2016).

Table 9. Corelation between areas occupied by areas without vegetation (%) and areas with LST ≥40.0 °C (%) in June, July and August, respectively period June-August

Corelation value between Corelation type (r)	Areas without vegetation (%) and areas with LST ≥40.0 °C (%)			Areas without vegetation (%) and areas with LST ≥40.0 °C (%) – June- August period
	June	July	august	
Linear (Pearson)	0.981	0.883	0.989	0.927
Logaritmic	0.984	0.842	0.969	0.848
Quadratic	0.997	0.852	0.987	0.856

5.2 Normalized Difference Moisture Index (NDMI) in warm season months

5.2.1 Spatial-temporal analysis of moisture surfaces derived by NDMI and the affected degree for principal vegetation classes and LST

At July coverage according to the three classes chosen revealed different situations, which shows the influence of many factors involved in this analysis. On the one hand vegetation coverage, which this month recorded the highest level and, on the other hand climatic conditions offered through parameter values and analyzed climatic origins and transformations air masses analyzed situations. Not least due to the effects of changing the land use which contributes to maintaining, increasing or decreasing the degree of moisture in the soil.

The situation on the 11th July 1990 has played 46.9% of the area as occupied by a lack of moisture, while this lack of moisture recorded at contact surfaces overlapped areas with no vegetation over 38.7% (Fig. 10, b). The crops were affected by lack moisture areas with an area of 7.8% and healthy vegetation in very small proportion, 0.2% (Fig. 10 c, d, Table 10).

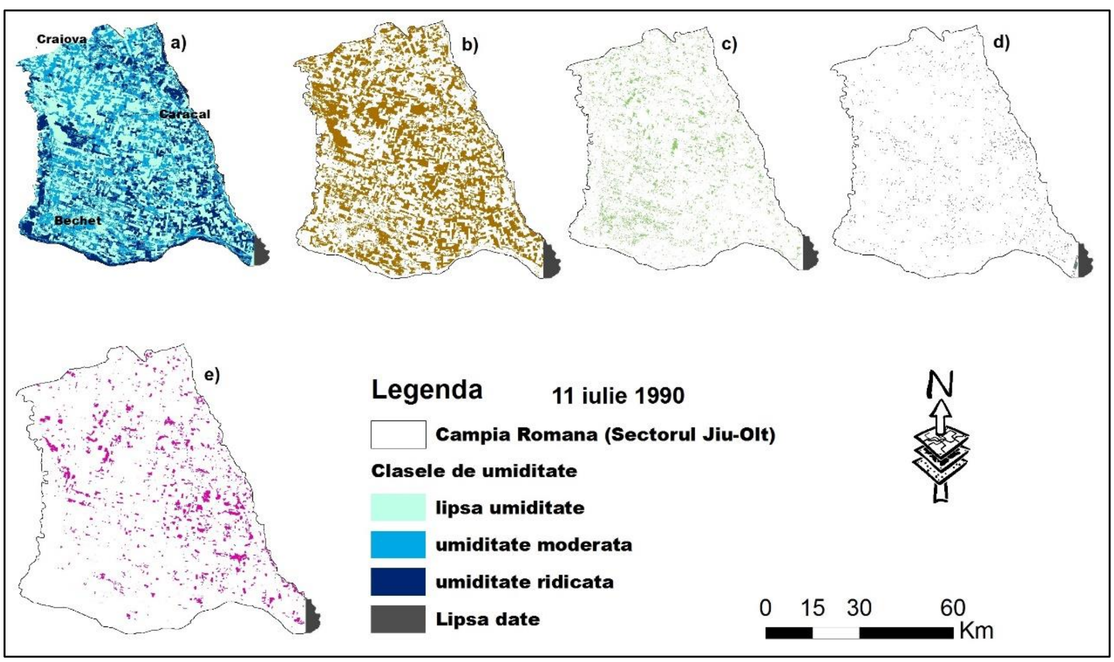


Fig. 10 NDMI, NDVI, LST 11 July 1990 (a. NDMI; b. polygons with intersection between lack of moisture and lack of vegetation class; c. polygons with intersection between lack of moisture and moderate vegetation class; d. polygons with intersection between lack of moisture and healthy vegetation class; e. polygons with intersection between lack of moisture and LST ≥ 40.0 °C)

Table 10. Intersection of surfaces with lack of moisture, lack of vegetation, moderate vegetation and healthy vegetation and LST ≥ 40.0 °C, July (%)

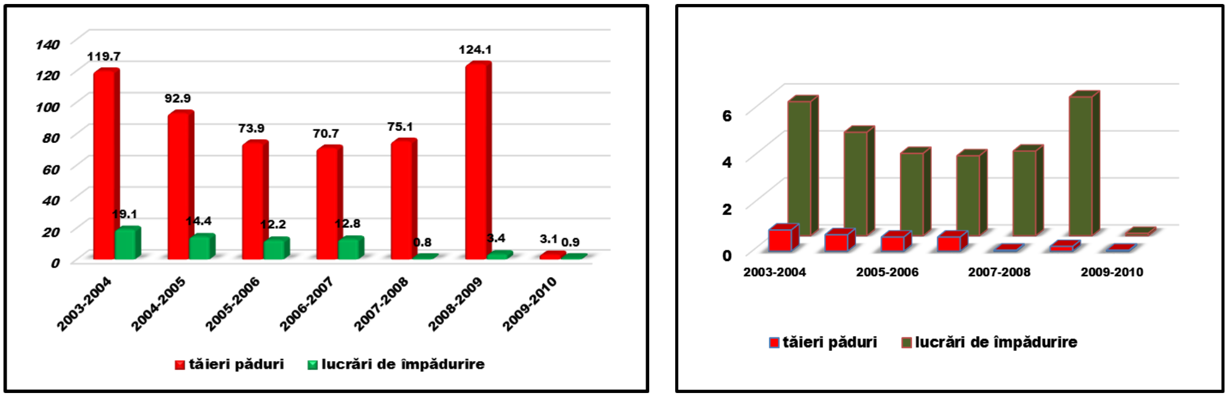
Polygons with intersection	**1990 Surface (%)**	**2006 Surface (%)**	**2007 Surface (%)**	**2009 Surface (%)**	**2013 Surface (%)**	**2015 Surface (%)**
lack of moisture with lack of vegetation	38.7	0.9	53.6	23.8	8.3	24.6
lack of moisture with moderate vegetation	7.8	47.7	6.5	19.9	10.0	11.2
lack of moisture with healthy vegetation	0.2	1.1	0.1	0.2	0.2	0.1
lack of moisture with LST ≥ 40.0 °C	6.1	2.8	30.0	2.4	7.2	7.8

6. THE MAIN RESTRICTIVITY FACTORS IN AGRICULTURAL DEVELOPMENT AND RECENT CHANGES IN THE LAND COVER

In terms of anthropogenic factors, over the last 30 years, in Southern Romania, there have been major changes in land use, some of them are due to the geopolitics context, while some other have been associated to climate variability. Thus, in the very next year after the communism collapse (December 1989), the legislation changed and imposed a transfer of land from common property of the state to individuals and private companies. Agricultural landscapes are prevailing, but the specificity is given by the presence of numerous sand dunes of different type: fixed, mobile, or semi-mobile. Their genesis is attributed to the Danube and Jiu Rivers in early Quaternary and more than 51 % of the considered area is covered by sandy soils (Irimus, 2003).

Under these circumstances, the land division in areas smaller than 10 ha (the largest area that could be returned to one owner, according to the law) has been a long and a very time-consuming process. Under existing natural (soil and precipitation) conditions, it is impossible to develop a sustainable and competitive agriculture without irrigation in the region. Because it is an aridity prone area, in the mid-1970s, some vegetal windbreakers were planted to protect against the moving sands and heavy blizzards, and an irrigation system was implemented in order to improve the agriculture yields and variety.

At the end of the 1990s, the high cost for operating and maintenance on the one hand, and the impossibility of individual owners to pay for water supply for plants on the other hand, led to discontinuous use of the irrigation system and then, to its gradually degradation and destruction. Moreover, in less than one decade (2003–2010), the forested area diminished by 22.6 % (559.47 ha), while only 3.02 % of the region (64.26 ha) were afforested (Fig. 11) (Roşca and Petrea 2014).



a) surfaces in ha

b) surfaces in %

Fig. 11 Situation of forestation works and cutting forest (a-ha) și (b-%) (after Roșca și Petrea, 2014)

6.1 Changes in land use identified by major vegetation classes resulted by Modified Soil-adjusted Vegetation Index2 (MSAVI2)

For the two moments (1987 and 2015) were observed changes in coverage of vegetation of the areal. From the results using the method of the major classes of vegetation cover changes occurred in 53.0% of the analyzed surfaces.

Thus, 47.0% of the complex has not been no change (Fig. 12). Major changes were considered those where the missing surfaces covered with vegetation were found in 2015 covered by vegetation healthy and vice versa. These changes were quantified by relief units, which make up the area of the Romanian Plain, Sector Jiu-Olt (Fig. 12 Table 11). Major changes in the period of 1987-2015 have been noted over a 53% of the analyzed surfaces and to the relief subunits areas most affected were encountered in: Caracal Plain, Leu-Rotunda and Dăbuleni Fields.

Afforested surfaces with protective curtain of acacia and compact bodies forest in special climate conditions and specific of soil texture these relief units were largely compromised. The changes consisted in replacements so that the areas occupied in 1987 by plantations of fruit trees (apple and apricot) were replaced from 2007 by acacia plantations. The Danube Floodplain changes were caused the economic interests of the newly established associations, which were used for good quality soil that allow optimal development of cereals and technical plants.

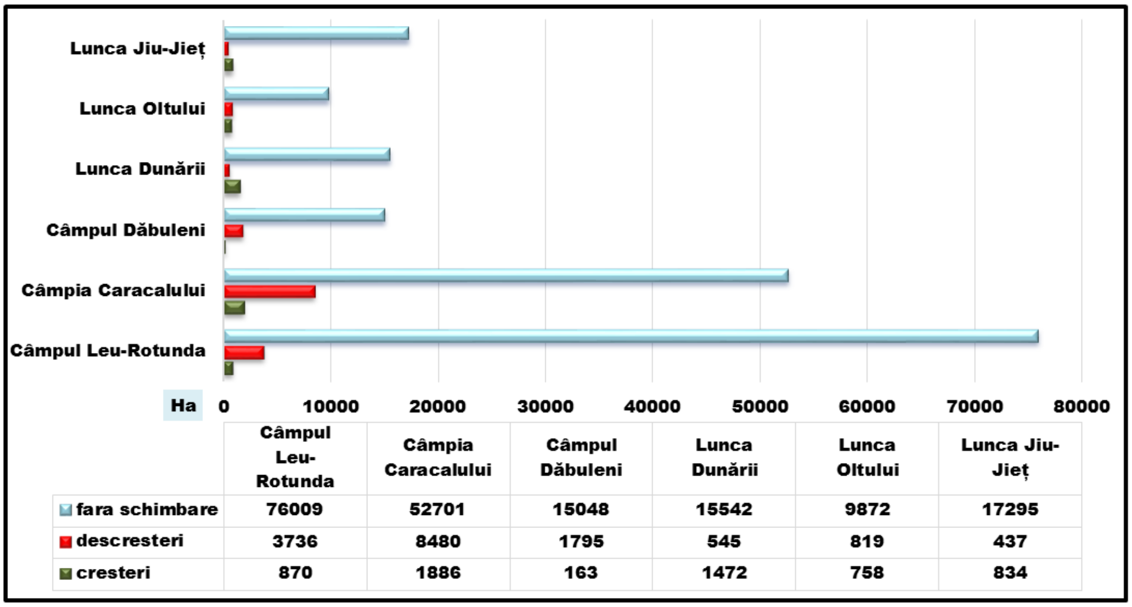


Fig. 12 Changes observed in land use change by relief units in Romanian Plain (Jiu-Olt Sector)

Table 11. Occupied surfaces (%) from changes in land use conformable with major vegetation classes (MSAVI2) by relief units in Romanian Plain (Jiu-Olt Sector)

Relief units	Surface area (%)	The percentage of change (%)		
		increases (0 in 2)	decreases (2 in 0)	without changes
Leu-Rotunda	38.2	0.6	2.5	50.9
Caracalului	30.4	1.6	7.1	44.4
Dabuleni	9.5	0.4	4.9	40.8
Danube meadow	7.3	5.2	1.9	54.5
Olt meadow	4.9	4.0	4.3	5.2
Jiu-Jieț meadow	8.1	2.6	1.4	54.5

On an area of 5.2% of the complex were recorded healthy increases in vegetation cover. Changing the structure of ownership land after leaving the communist system had a decisive role in creating facilities by anthropogenic intervention on the land and its use. The changes were caused by climatic factors, which certainly contributed the non-climatic factors, evidenced by the phenomenon of abandonment by deforestation, legislative changes, the uncertain situation on ownership land, poverty and irresponsibility of people.