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THE AGRO-CLIMATIC RESOURCES OF THE YEAR 2015 AND THEIR IMPACT ON THE AGRICULTURAL CROPS IN THE SOUTH – WEST OF ROMANIA

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Abstract

Knowing the agro-climatic resources is a compulsory condition in order to implement a sustainable agricultural management. The main purpose of this study is to analyze and evaluate the agro-climatic resources in relation with the bio-climatic requirements of the main summer cultures, such as maize and sunflower. The analysis will be done for the South-West of Romania, for the year 2015. The year 2015 is considered the warmest year in Romania. The analysis of temperature and precipitation resources will be based on the climatic data from 15 weather stations. The impact of the agro-climatic resourses on the maize and sunflower crops will be analyzed both on the surface and production data provided by the National Institute of Statistics and on the satellite images for the NDVI index. From the analysis, one could that the monthly interval of April-August 2015 was characterized by high temperatures and a scarce precipitation regime. This reflected in the agricultural yields of maize and sunflower, because this range corresponds to the development of the phenological phases of these crop plants.

Key words**:** *agricultural crops, agricultural management, temperature, precipitation, the South-West of Romania*

INTRODUCTION

The global climate warming phenomenon has already been highlighted by the analysis of the climatic data over long periods of time. The same trend of climate warming has also been highlighted in Romania by the calculation of the linear trends and their statistical significance for the annual and seasonal average temperatures [3]. According to the World Meteorological Organization (WMO), the last four years (2015, 2016, 2017 and 2018) are the warmest years, comparing to the pre-industrial period (1850-1900) [13]. In Romania, according to the National Meteorological Administration (NMA), 2015 is the warmest year, with a positive anomaly of 1.7°C, comparing to the multiannual average over the period 1900-2018 [12]. Between 1900-2018, the heating rate was 1.05°C [12].

The aim of the study is to analyze the temperature and precipitation resources of the year 2015 in relation to the main summer plant cultures, such as maize and sunflower, for the South-Western Romania. The South-West of Romania or the South-West Oltenia Development Region represents 12.2% of the country's area and is characterized by varied landforms, with altitudes increasing from South to North, from 25-36 m to over 2,000 m [5], being an important agricultural region of

the country (Fig. 1). The geographical area is characterized by a mid-latitude continental climate, influenced by a multitude of air masses: polar, maritime, tropical and arctic [7]. Comparing to the multiannual average of the period 1901-1990, the year 2015 was warm, with the annual average temperature for the entire region of 12°C and with a positive anomaly of 1.9°C for the South-West of Romania. In terms of annual precipitations, for the entire region, the year 2015 was normal. The climatic factors such as air temperature, soil surface temperature and atmospheric precipitation influence the physiological processes of the agricultural plants, with inferior and superior thresholds for each stage of development, beyond which the thermal or hydric stress occurs [4].

MATERIALS AND METHODS

In the agro-climatic analysis of the year 2015, the weather data from 15 weather stations (w.s.) in the administration of the National Meteorological Administration (NMA) of the Regional Meteorological Center of Oltenia referring tothe monthly average, minimum and maximum air and surface soil temperatures and monthly precipitation amounts have been used (Fig. 1).

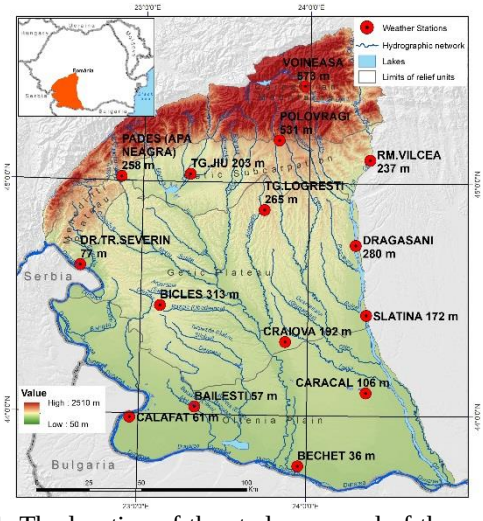

Fig. 1. The location of the study area and of the weather stations. Source: own processing from GIS open sources

The monthly and annual values of the year 2015 are compared to the monthly and annual averages from 1901 to 1990.

The agro-climatic information produced by NMA is also added. There were also calculated the Spring Arrival Index as the sum of the positive daily average air temperature values for the period between February 1 to April 10, 2015, thus expressing the thermic potential of winter to spring transition period [1, 2].
The Hellmann Criterion has been used in order to determine the weather types (Table 1).

Table 1. The matrix of the weather types according to the Hellman Criterion.

Types of temperature time	Anomaly from the multiannual average (°C)	Types of precipitation time	Anomaly from the multiannual average (%)
excessively cold (EC)	≤ -5.0	excessively droughty (ED)	> -50.0
very cold (VC)	- 4.9...-2.6	very droughty (VD)	- 50...-30.1
cold (CL)	-2.5...-1.1	droughty (D)	-30...-20.1
cool (CO)	- 1.0...-0.6	slightly dry (SD)	- 20...-10.1
normal (N)	± 0.5	normal (N)	± 10
slightly warm (SW)	0.6 – 1.0	slightly rainy (SR)	10.1 – 20
warm (W)	1.1 – 2.5	rainy (R)	20.1 – 30
very warm (VW)	2.6 – 4.9	very rainy (VR)	30.1 – 50
excessively warm (EW)	≥ 5.0	excessively rainy (ER)	> 50.0
Types of spring		**Anomaly from the multiannual average (%)**	
excessively late (EL)		≤-70	
very late (VL)		-69.9...-50	
late (L)		-49.9...-30	
slightly late (SL)		-29.9...-10	
normal (N)		-9.9...+10	
slightly early (SE)		10.1...30	
early (E)		30.1...50	
very early (VE)		50.1...69.9	
excessively early (EE)		≥70	

Source: adapted after Marinică and Marinică, 2016.

The health status of the agricultural crops for the year 2015 is highlighted by the Normalized Difference Vegetation Index (NDVI) extracted from the MOD13Q1 satellite products with a resolution of 250 m.
Also, crop production and surface data from the National Statistics Institute (NSI) have been used for maize and sunflower in order to highlight the role of the climatic conditions on the agricultural yields.
The land coverage information was based on the European Reference Data Set - Corine Land Cover 2015.

RESULTS AND DISCUSSIONS

The characteristics of the agro-climatic resources of the year 2015

In January 2015, the air temperature has recorded monthly average values between 2.1°C at Dr. Tr. Severin and -0.4°C at Voineasa, being the only negative monthly average in the whole region. These monthly averages, compared to the averages of the period 1901-1990, have recorded deviations between 4.3°C at Voineasa and 2.6°C at Padeş. At the level of the South-West Oltenia Development Region, the monthly average air temperature for January was 0.6°C, recording a deviation from the period 1901-1990 of 3.4°C, which confirms that the month was warm for this region.

The minimum monthly air temperature values were recorded on January 1st and were between -29.8°C at Padeş and -13.9°C at Dr. Tr. Severin and Drăgăşani, and their average value for the whole region was -19.6°C. Since January 3rd, the weather has warmed up and has been warmer than normal throughout the month. A moderate heat wave occurred between January 9 and January 16 and a mild one between January 29 and January 31. As a result, the maximum monthly temperatures reached maximum values on January 11 and recording a 7.5°C point difference between 19.5°C in the South and 12.0°C in the North of the region. The monthly average air temperature maxima for January in the South-Western Romania was 15.5°C. The soil surface temperature recorded values between -31.0°C at Padeş and -9.9°C at Calafat for the meteorological parameter – the minimum monthly temperature. The monthly average minimum soil surface temperature was -22.1°C for the entire study area. The maximum monthly soil surface temperatures reached maximum values which ranged from 10.3°C at Slatina to 20.0°C at Drăgăşani. The maximum monthly average soil surface temperature was 13.4°C for the entire region. In terms of precipitations, January was characterized by monthly volumes, ranging from 88.8 l/m2 at Padeş and 15.1 l m2 at Bâcleş. At the level of the South-West Oltenia Development Region, the monthly average amount of precipitation was 43.0 l/m2. This monthly average precipitation amount compared to the monthly average amount for the period 1901-1990 had a deviation of -2.1%, indicating that January was normally rainy. The precipitation deficit was recorded in large areas in the South of the region and in restricted areas in the West and North-East of the region.

The monthly average air temperatures for February ranged between -0.7°C at Voineasa (the only negative value) to 2.3°C at Dr. Tr. Severin and Rm. Vâlcea, and their anomalies from the monthly average of the interval 1901-1990 ranged between 2.3°C at Rm Valcea and 0.7 °C at Calafat and Băileşti. Therefore, according to the Hellmann Criterion, February, was a warm month (W) for the most part of the region. February was warm (W) for the meteorological stations Rm. Vâlcea, Tg. Jiu, Drăgăşani and Caracal. At the level of the region, February 2015 was a warm month (W), recording a monthly average of 0.9°C and a deviation of 1.7°C over the period 1901-1990. The monthly air temperature minima ranged from -18.2°C at Băileşti and 7.6°C at Dr. Tr. Severin and with an average of -12.0°C for the entire study area. The monthly air temperature maxima varied between 16.4°C at Rm. Vâlcea and 11.6°C at Calafat, with an average for the entire study area of 13.7°C. At the soil surface, the minimum temperatures ranged between -21.0°C at Băileşti to -9.0°C at Rm. Vâlcea, and their average for the whole region was -14.0°C. The maximum soil surface temperatures ranged between 16.1°C at Slatina and 23.0°C at Padeş, and their average for the whole region was 20.3°C.

The monthly precipitation amounts ranged between 28.2 l/m^2 at Bechet to 89.7 l/m^2 at Padeş, and their percentage anomalies from the multiannual averages 1901-1990 ranged between -28.7% at Polovragi to 78.8% at Băileşti. By applying the Hellmann Criterion, there appears that February was characterised by droughty (D) on restricted areas at Polovragi and Tg. Logreşti, slightly dry conditions (SD) at Bechet, normal conditions at Caracal, Slatina and Rm. Vâlcea, slightly rainy regime (SR) at Rm. Vâlcea, rainy regime (R) at Dr. Tr. Severin and Tg. Jiu, very rainy regime (VR) at Calafat, Craiova and Padeş and excessivelty rainy regime (ER) at Băileşti. The monthly average quantity for the whole region was 47.1 l/m^2, and

its percentage anomaly from the period 1901-1990 was 11.8%, indicating that February was a slighty rainy month for the whole region.

Table 2. The temperature and precipitation regime of the spring of 2015

the weather station	H (m)	SAI (°C)	Type	The temperature regime (°C)			
				N	T	Δ =T-N	HCr
Dr. Tr. Severin	77	385.1	N	11.6	12.8	1.2	W
Calafat	66	358.6	N	11.6	12.9	1.3	W
Bechet	65	350.2	N	11.6	12.5	0.9	SW
Băileşti	56	351.9	SE	11.6	12.5	0.9	SW
Caracal	112	348.8	SE	11.2	12.4	1.2	W
Craiova	190	325.7	SE	11.2	12.0	0.8	SW
Slatina	165	332.4	SE	11.1	12.0	0.9	SW
Bâcleş	309	286.1	SE	10.1	11.1	1.0	W
Tg. Logreşti	262	291.0	SE	9.7	10.6	0.9	SW
Drăgăşani	280	346.6	E	10.5	12.0	1.5	W
Padeş	250	293.8	SE	9.8	11.1	1.3	W
Tg. Jiu	210	342.0	SE	10.5	11.9	1.4	W
Polovragi	546	256.7	SE	9.2	10.2	1.0	W
Rm. Vâlcea	243	360.7	SE	10.4	12.0	1.6	W
Voineasa	587	193.7	SE	7.4	8.5	1.1	W
Oltenia average	-	321.6	SE	10.5	11.6	1.1	W

the weather station	H (m)	The precipitation regime (l/m²)				
		P	NP	Δ=P-NP	Δ%	HCr
Dr. Tr. Severin	77	141.6	186.5	-44.9	-24.1	D
Calafat	66	118.3	146.2	-27.9	-19.1	D
Bechet	65	164.9	143.5	21.4	14.9	SD
Băileşti	56	121.5	157.8	-36.3	-23.0	D
Caracal	112	120.5	142.2	-21.7	-15.3	SD
Craiova	190	219.5	135.2	84.3	62.4	ER
Slatina	165	141.7	149.7	-8.0	-5.3	N
Bâcleş	309	107.6	172.5	-64.9	-37.6	VD
Tg. Logreşti	262	150.3	161.2	-10.9	-6.8	N
Drăgăşani	280	158.7	147.2	11.5	7.8	N
Padeş	250	176.6	248.8	-72.2	-29.0	VD
Tg. Jiu	210	113.5	193.1	-79.6	-41.2	VD
Polovragi	546	166.7	225.2	-58.5	-26.0	D
Rm. Vâlcea	243	139.6	192.6	-53.0	-27.5	VD
Voineasa	587	91.8	200.6	-108.8	-54.2	ED
Oltenia average	-	142.2	173.5	-31.3	-18.0	SD

H – altitude of the weather stations; SAI – Spring Arrival Index; Type – type of spring warming; N – the multiannual average temperature (1901-1990); T –the annual average temperature; Δ=T-N – the annual average temperature anomaly from the multi-annual average; P – the precipitation amount; NP – the multiannual precipitations (1901-1990); Δ=P-NP – the deviation of the annual precipitation amount from the multiannual amount; Δ% – the percentage anomalies of the annual precipitation amount from the multiannual amount; HCr = Hellmann Criterion.
Source: temperature and precipitation data from NMA.

The gradual increase of air temperature, which occurs during the last month of the winter - February and continues throughout spring, determines the climatic process of spring warming. For the year 2015, the sping arrival indices had values between 385.1°C at Dr. Tr. Severin and 193.7°C at Voineasa. For the South-West Oltenia Development Region, the average spring arrival index was 302.9°C with percentage deviations of 34.4% in Drăgăşani and 4.3% in Calafat compared to the period 1901-1990 (Table 2).

According to the Hellmann Criterion, it appears that the spring warming of 2015 was normal (N) in the extreme West and South-West (at Dr. Tr. Severin, Calafat and Bechet) and slightly early (SE) in most of the region and only early (E) in the Drăgăşani area. The anomaly of the average sputtering Index for the whole region was 2.6%, indicating that spring warming in 2015 was slightly early (SE). The slightly early spring warming has determined the beginning of the crop vegetation since the last decade of February. In spring, the average air temperature for the South-West region of Romania was 11.6°C, oscillating between 12.9°C at Calafat and 8.5°C at Voineasa (Table 2). Compared to the period 1901-1990, the annual average deviations were between 1.6°C at Rm. Vâlcea and 0.8°C at Craiova, with a deviation for the whole region of 1.1°C (Table 2).

As a result, the spring of 2015, in the South-West Oltenia Development Region was warm (W). The increase of the monthly average temperatures across the region from February to March was 4.4°C, from March to April was 5.0°C, and from April to May was 6.7°C, the latter being the highest of all the spring and even throughout the year, which caused an explosive development of all the plant species, as well as the increased water requirements for the agricultural crops. The average temperature increase throughout the spring months was 16.1°C.

The maximum monthly air temperatures varied from 23.3°C in April at Polovragi to 28.7°C at Bechet. The average air temperature maxima for the South-West of Romania was 26.1°C in 2015. The maximum monthly temperatures in May varied between 31.8°C at Bechet and 26.3°C at Polovragi. At the region level, the average air temperature maxima for May was

29.4°C. In April, the soil surface temperature reached maximum values of 53.2°C at Dr. Tr. Severin and 27.7°C at Caracal, with an average for Romania of 41.2°C. The maximum soil surface temperature values in May were 58.0°C at Băileşti and 37.7°C at Caracal, with an average for Romania of 45.0°C. These high thermic values have produced important stationary pressures in the agricultural crops and the lack of atmospheric precipitation has led to a drastic reduction of the water reserve in the soil and the intensification of the soil drought.

The annual precipitation amounts ranged between 91.8 l/m^2 at Voineasa to 219.5 l/m^2 at Craiova, and their percentage abatement from the 1901-1990 multiannual values ranged from -79.6% to Tg. Jiu and 84.3% at Craiova, which according to the Hellmann Criterion, determined the classification of the precipitation time types from excessively droughty (ED) at Voineasa, to excessively rainy (ER) at Craiova (Table 2). The singular situation at Craiova weather station is due to the high precipitation amounts from March (100.3 l/m^2) and May (85.2 l/m^2). Most of Oltenia's precipitations were low, and the atmospheric drought had different degrees of intensity, ranging from slightly dry (SD) to excessively droughty conditions (ED) (Table 2). The rainiest month of spring was March, with precipitations ranging from 47.0 l/m^2 to 100.3 l/m^2 at Craiova, with an average of 67.0 l/m^2 for the entire region. April and May were, on average, very droughty over the entire South-Western region of Romania. As a result of the atmospheric drought, correlated with the high air temperatures at the end of spring, the moisture reserve on the soil profile 0-100 cm has registered water deficiencies, locally in the East of the study area. In Oltenia, on extended surfaces, the water supply of the soil was pretty satisfactory and close to optimal limits, which demonstrates the importance of precipitations during winter and the first month of spring [9].During the summer of the year 2015, the average air temperatures varied between 18.1°C at Voineasa and 24.7°C at Dr. Tr. Severin and their deviation from the 1901-1990 multiannual averages were between 0.8°C at Bechet and 3.1°C at Padeş (Table 3).

Table 3. The temperature and precipitation regime of the summer of 2015

the weather station	H (m)	The air temperature regime (°C)					
		N	T	Δ = T-N	HCr	T_{max} VII	T_{max} VIII
Dr. Tr. Severin	77	22.0	24.7	2.7	VW	38.5 /20	38.9 /12
Calafat	66	22.3	24.2	1.9	W	39.4 /20	40.9 /12
Bechet	65	22.2	23.0	0.8	SW	38.5 /20	38.3 /16
Băileşti	56	22.1	23.6	1.5	W	37.3 /30	38.1 /12
Caracal	112	22.0	23.8	1.8	W	38.3 /30	37.0 /16
Craiova	190	21.7	23.2	1.5	W	37.3 /20	36.8 /12
Slatina	165	21.6	23.2	1.6	W	37.3 /30	36.8 /16
Bâcleş	309	20.4	22.6	2.2	VW	35.9 /20	36.7 /11
Tg. Logreşti	262	19.9	21.1	1.2	W	35.7 /30	35.7 /16
Drăgăşani	280	20.9	23.0	2.1	VW	36.6 /30	35.5 /12;16
Padeş	250	19.1	22.2	3.1	VW	36.5 /20	38.8 /12
Tg. Jiu	210	20.5	23.2	2.7	VW	38.0 /7	38.9 /12
Polovragi	546	18.9	21.1	2.2	VW	33.7 /20	34.9 /12
Rm. Vâlcea	243	20.2	22.8	2.6	VW	38.1 /18	39 /12
Voineasa	587	16.2	18.1	1.9	W	33.3 /7;8	33.0 /12;13
Oltenia average	-	20.7	22.1	1.4	W	37.0	37.2

the weather station	H (m)	The precipitation regime (l/m^2)				
		P	NP	Δ = P-NP	Δ%	HCr
Dr. Tr. Severin	77	87.4	160.0	-72.6	-45.4	ED
Calafat	66	125.6	146.8	-21.2	-14.4	SD
Bechet	65	193.2	146.8	46.4	31.6	VR
Băileşti	56	126.6	150.5	-23.9	-15.9	SD
Caracal	112	155.0	167.4	-12.4	-7.4	N
Craiova	190	190.2	164.7	25.5	15.5	SR
Slatina	165	302.6	184.9	117.7	63.7	ER
Bâcleş	309	198.3	152.5	45.8	30.0	VR
Tg. Logreşti	262	158.8	165.4	-6.6	-4.0	N
Drăgăşani	280	163.1	185.6	-22.5	-12.1	SD
Padeş	250	164.8	232.0	-67.2	-29.0	VD
Tg. Jiu	210	115.8	219.2	-103.4	-47.2	ED
Polovragi	546	261.2	277.7	-16.5	-5.9	N
Rm. Vâlcea	243	128.5	254.3	-125.8	-49.5	ED
Voineasa	587	235.5	268.1	-32.6	-12.2	SD
Oltenia average	-	173.5	191.7	-17.9	-9.4	N

H – altitude of the meteorological station; N – the multiannual average temperature (1901-1990); T – the annual average temperature; Δ=T-N – the anomaly of the average temperature from the multiannual average; T_{max}VII – the maximum monthly temperature in July/date of recording; T_{max}VII – the maximum monthly temperature in August/date of recording; P – the annual precipitation amount; NP – the multiannual precipitation amount (1901-1990); Δ=P-NP – the deviation of the annual precipitation amount from the multiannual amount; Δ% – the percentage anomalies of the annual precipitation amount from the multiannual amount; HCr – the Hellmann Criterion.
Source: the temperature and precipitation data from NMA.

According to the Hellmann Criterion, the summer of 2015 was warm (W) on a restricted area in the extreme South of the Bechet region and warm (W) and very warm (VW) in the rest of the region (Table 3).

The annual average air temperature calculated for the whole region was 22.1°C and its anomaly from the 1901-1990 period was 1.4°C, indicating that the summer of the year 2015 was warm (W) (Table 3).

June 2015 was sligtly warm (SW), with maximum air temperatures between 29.4°C at Voineasa and 35.6°C at Dr. Tr. Severin. The warmest summer months were July and August. July was warm (W) throughout the region, with the average monthly average for Oltenia of 24.2°C being the highest monthly average throughout the year. The maximum monthly air temperatures in July were recorded mostly on July 20th and July 30th, and ranged between 33.3°C at Voineasa to 39.4°C at Calafat (Table 3). According to the monthly report of the National Oceanic and Atmospheric Administration (NOAA), July 2015 has recorded the highest monthly average temperature of 16.61°C from 1880 to nowadays, at global level [6]. August was a sligtly warm month (SW) for the entire region, with a monthly average of 22.4°C. The increase in the monthly average air temperature from May to June was of 2.5°C, from June to July of 4.5°C, and from July to August of -2.2°C, being the first decrease in the monthly average during the year. The increase from spring to summer in the average season for the whole region was 10.5°C, the summer average being almost twice as high as in spring. The maximum air temperatures in August were recorded on August 12 and August 16 and varied between 33.0°C at Voineasa and 40.9°C at Calafat (Table 3).

At the ground level, in June, the maximum monthly temperatures varied between 33.5°C at Caracal and 66.0°C at Băileşti and their average value for the whole region was 51.2°C. In July, the maximum monthly soil temperature oscillated between 40.0°C at Caracal to 69.5°C at Padeş while their average correspondent value for the whole region was 54.3°C. August was characterized by the highest soil surface temperature of 39.2°C at Slatina and 69.8°C at Padeş while their average value for the whole region was 54.6°C. During the summer and the first autumn month, five heatwaves lasting for 37 days, accounting 40.2% of the total summer days were recorded. As a result, the air and the prolonged soil thermal stress associated with the atmospheric and soil drought forced growth of plants, maturing and early baking, leading to major crop losses in all types of the agricultural crops [9].

The annual precipitation amounts ranged from 87.4 l/m^2 at Dr. Tr. Severin to 302.6 l/m^2 at Slatina, and their percentage deviation from the 1901-1990 multiannual quantity ranged from -49.5% at Rm. Vâlcea to +63.7% at Slatina, leading to the classification of the seasonal precipitation time types from excessively rainy (ER) at Slatina to excessively droughty (ED) on the lineage of the weather stations Rm. Vâlcea, Tg. Jiu and Dr. Tr. Severin (Table 3). The summer of 2015 was characterized by an average amount of 183.1 l/m^2 for the whole study area, and a percentage deviation of -9.4% compared to 1901-1990, which means it was a normal rainfall summer (Table 3). Only at Bechet, in the extreme South of the region, the weather was very rainy (VR). In most of the study region, there was a dry weather. Precipitations were recorded on small areas at Craiova, Slatina and Bâcleş. The monthly precipitation amount in June ranged between 25.2 l/m^2 at Dr. Tr. Severin and 137.0 l/m^2 at Bechet, and their average value for the entire region was 79.6 l/m^2, the percentage anomaly from 1901-1990 was -5.4%, which means a normal precipitation month, on average. There were 27 rainy days, but most of the daily precipitations were insignificant. In June, important precipitation deficits that generated atmospheric and soil drought, associated with the progressive increase in air and soil temperature, were recorded in the Northern Oltenia and in the extreme West, at Dr. Tr. Severin. The monthly precipitation amount in July ranged between 1.6 l/m^2 at Bechet and 65.8 l/m^2 at Voineasa. For the South-West Romania Development Region, the monthly average precipitation amount for July was 26.2 l/m2, with deviations between -96.4% at

Băileşti and -25.7% at Voineasa, compared to the period 1901-1990. Consequently, at the region level, July was an excessively droughty month (ED), excepting the restricted Voineasa area where it was droughty (D) according to the Hellmann Criterion. In Oltenia, the drought manifested itself strongly during the period July 1st-August 8th, for 46 days, representing 50.0% of the total summer days.

The monthly precipitations in August ranged from 39.2 l/m^2 at Calafat to 149.6 l/m^2 at Slatina and the percentage anomalies from the average 1901-1990 monthly amount varied between -33.1% at Tg. Jiu and 219.7% at Slatina which, according to the Hellmann Criterion, shows that August was very droughty (VD) on a restricted area at Tg. Jiu (the only area with a monthly drought) and excessively rainy (ER) over an extended area (Craiova, Slatina, Bâcleş, Tg.Logreşti and Polovragi) in the rest of the region, the precipitation excess having intensities which ranged from slighty rainy (SR) to very rainy conditions (VR). Between August 16 and August 22, heavy precipitations occured in much of the region, thus interrupting the drought period but the atmospheric drought returned and lasted from August 23 to September 8.

The autumn of 2015 was characterized by average air temperature values between 9.3°C at Voineasa and 13.5°C at Dr. Tr. Severin, and their deviation from the 1901-1990 multiannual average varied between 0.9°C at Tg. Logreşti and Padeş and 2.1°C at Voineasa and Parâng. Based on the Hellmann Criterion, these anomalies show that the autumn of 2015 was warm (W) in most of the region (Table 4). The annual air-temperature average for the whole region was 12.2°C, and its deviation from the 1901-1990 multiannual average was 1.2°C, which confirms that the autumn of 2015 was warm (W) (Table 4). The month of September was warm in general, with monthly maximum temperatures in the first days of the month ranging from 31.4°C at Voineasa (September 1st) to 37.7°C at Calafat (September 1st). At the level of the South-West region of Romania, the monthly average air temperature maxima for September was 35.4°C. The maximum monthly soil surface temperature, in September, oscillated between 61.0°C and 35.8°C, with an average of 49.3°C for the entire region.

Table 4. The temperature regime and the precipitation regime of the autumn of 2015

the weather station	H (m)	The air temperature regime (°C)					
		N	T	Δ = T-N	HCr	T_{max} IX	T_{max} X
Dr. Tr. Severin	77	12.3	13.5	1.2	W	37.1/3	23.2/6
Calafat	66	12.1	13.3	1.2	W	37.7/1	24.7/5
Bechet	65	11.5	12.5	1.0	SW	37.5/3	23.8/4
Băileşti	56	11.5	12.8	1.3	W	37.4/5	24.5/5
Caracal	112	11.6	13.0	1.4	W	36.6/5	22.8/6
Craiova	190	11.5	12.6	1.1	W	35.2/2	22.8/6
Slatina	165	11.6	12.6	1.0	SW	35.9/2	23.1/6
Bâcleş	309	10.8	12.3	1.5	W	34.4/2;3	21.9/5
Tg. Logreşti	262	10.3	11.2	0.9	SW	34.1/2	22.4/6
Drăgăşani	280	11.6	13.0	1.4	W	35.1/2	22.7/6
Padeş	250	10.3	11.2	0.9	SW	35.0/2	22.5/6
Tg. Jiu	210	10.8	11.9	1.1	W	35.8/3	23.3/6
Polovragi	546	10.2	11.5	1.3	W	32.3/18	19.8/6
Rm. Vâlcea	243	10.7	12.5	1.8	W	36.0/2	23.6/6
Voineasa	587	7.2	9.3	2.1	W	31.4/1	20.5/3
Oltenia average	-	11.0	12.2	1.2	W	35.4	23.5

the weather station	H (m)	The precipitation regime (l/m^2)				
		P	NP	Δ = P-NP	Δ%	HCr
Dr. Tr. Severin	77	331.7	186.3	145.4	78.0	ER
Calafat	66	225.6	141.8	83.8	59.1	ER
Bechet	65	205.5	134.7	70.8	52.6	ER
Băileşti	56	217.3	137.9	79.4	57.6	ER
Caracal	112	299.7	123.4	176.3	142.9	ER
Craiova	190	317.4	122.1	195.3	160.0	ER
Slatina	165	313.3	132.2	181.1	137.0	ER
Bâcleş	309	182.3	144.2	38.1	26.4	ER
Tg. Logreşti	262	261.3	135.7	125.6	92.6	ER
Drăgăşani	280	302.8	153.2	149.6	97.7	ER
Padeş	250	464.8	214.3	250.5	116.9	ER
Tg. Jiu	210	294.6	180.1	114.5	63.6	ER
Polovragi	546	338.8	209.0	129.8	62.1	ER
Rm. Vâlcea	243	350.8	156.8	194.0	123.7	ER
Voineasa	587	188.1	164.5	23.6	14.3	SR
Oltenia average	-	286.3	155.7	130.6	83.8	ER

H – altitude of the meteorological station; N – the multiannual average temperature (1901-1990); T – the annual average temperature; Δ=T-N – the annual average temperature devation from the multiannual average temperature; T_{max}IX – the maximum monthly temperature in September/date of registration; T_{max}X – the maximum monthly temperature in October/date of registration; P – the annual precipitations; NP – the multiannual precipitation amount (1901-1990); Δ=P-NP – the deviation of annual precipitation amount anomalies from the multiannual precipitation amount; Δ% – the percentage anomalies of the annual precipitation amount from the multiannual amount; HCr – Hellmann Criterion.
Source: temperature and precipitation data from NMA

The monthly average air temperature in October ranged from 11.3°C at Dr. Tr. Severin and 7.8°C at Voineasa, and their deviations from the 1901-1990 period ranged between -1.1°C at Calafat and +0.2°C at Rm.Vâlcea, making it a thermally normal month in most of Oltenia.

The monthly air temperature average calculated for the whole region was 9.8°C, and its anomaly from the 1901-1990 period was -0.6°C, which confirms that October was, on average, a thermally normal month for the entire region.

The maximum monthly air temperatures were recorded on October 5 and October 6 and ranged between 19.8°C at Voineasa and 24.7°C at Calafat. The optimum air and soil surface temperatures allowed the establishment of the autumn crops until November 23, creating favorable conditions for the onset of the upcoming agricultural year 2015-2016. On the ground, the maximum temperatures ranged from 24.3°C at Slatina to 36.4°C at Băileşti, in October.

November was characterized by mean air temperature values ranging between 4.9°C at Voineasa and 9.4°C at Calafat and their anomalies from the average value of the 1901-1990 period ranged between 1.3°C at Padeş and 3.4°C at Calafat, indicating that this month was warm (W) in most of Oltenia. The monthly average air temperature calculated for the whole region was 7.5°C with a positive anomaly of 2.6°C over the period 1901-1990. The air temperature recorded most of the monthly maxima in the second decade of November, ranging from 24.9°C at Calafat and 19.0°C at Voineasa. For the study area, the monthly average maxima was 21.9°C. Regarding the soil surface temperature, the maximum monthly values varied between 32.3°C at Rm. Vâlcea and 18.2°C at Slatina, and the average of the monthly maxima was 21.9°C for the whole study area. All these indicate a high thermic potential in November 2015 and a high degree of the favorability for the autumn crops.

The decrease in the monthly average air temperature for the whole region was -4.1°C from August to September, -6.5°C from September to October (the largest decrease in the year 2015), and 2.3°C from October to November.

The annual precipitations ranged between 182.3 l/m^2 at Bâcleş and 464.8 l/m^2 at Craiova and their percentage anomalies from 1901-1990 ranged between 14.3% at Voineasa and 160.0% at Craiova, which shows that the autumn of 2015 was excessively rainy (ER) in most of Oltenia (Table 4). In 2015, the autumn recorded an average seasonal quantity, for the study area, of 286.3 l/m^2 and a percentage deviation of 83.8% compared to the interval 1901-1990, meaning that, in general, the autumn was excessively rainy (ER) on the whole region, according to the Hellmann Criterion (Table 4).

In September, the monthly precipitations ranged from 56.0 l/m^2 at Calafat to 165.4 l/m^2 at Padeş, and the percentage anomalies were 281.7% at Craiova and 44.7% at Calafat, compared to 1901-1990. As a result, September 2015 was, for most of the South-West Oltenia Development Region, an excessively rainy month (ER), according to the Helmann Criterion. The monthly average precipitation amount for the South-West of Romania was 63.2 l/m^2, recording a percentage deviation of 133.8% compared to 1901-1990, thus, this month is characterized by an excessively rainy time (ER).

In October, the monthly precipitations ranged between 31.1 l/m^2 at Voineasa and 192.6 l/m^2 at Padeş. According to the Hellmann Criterion, October was very droughty ,only at Voineasa (a percentage deviation of -44.6%, compared to 1901-1990), and for the rest of the region it was excessively rainy. For October, for all the study area, the monthly average amount was 83.8 l/m2, with a percentage deviation of 55.6% compared to the period 1901-1990, which confirms that October was excessively rainy, on average, in the entire region.

November was characterized by monthly precipitations which ranged between 27.2 l/m^2 at Bâcleş and 125.5 l/m^2 at Rm. Vâlcea, and their percentage anomalies from 1901-1990 ranged from -43.2% at Bâcleş to 145.6% at Caracal. The monthly average precipitations for the study area recorded the value of 90.9 l/m^2. November for the South-West region of Romania was excessively rainy (ER), with a percentage deviation of 58.9% compared to the period 1901-1990. The soil water reserve was optimal or near an optimum state în toamna

2015, in the South-West Romania Development Region [9]. Under warm (W) or slightly warm (SW) temperature conditions and with optimal or nearly optimal water reserves, the agricultural crops set up in the autumn of 2015 had good growing conditions.

December 2015 was characterized by a monthly average thermal regime with values ranging from 1.5°C (Voineasa) to 7.1°C (Calafat). This month, according to the Hellmann Criterion, was very warm (VW), with deviations between 3.4°C (Voineasa) and 6.3°C (Bâcleş) compared to the period 1901-1990. At the level of the South-West Oltenia Development Region, December 2015 had a monthly average value of 4.9°C, and its anomaly from the period 1901-1990 was 5.0°C, being one of the biggest anomalies in the history of the meteorological observations for December (at the country level being the third in descending order), which confirms that it was a very warm month (VW), on average, in the whole region. The maximum monthly air temperatures were recorded between December 22nd-28th and were totally atypical, ranging from 14.3°C at Voineasa to 19.3°C at Polovragi, while their average value for the entire region was 16.9°C. On the ground surface, the maximum monthly temperatures ranged between 9.9°C at Slatina to 25.3°C at Drăgăşani, and their average value for the whole region was 17.6°C. December was an excessively droughty month (ED) at all weather stations, the drought being mainly of atmospheric nature, but the water reserve in the soil remained optimal and the vegetation phases continued unabated throughout the month.

The impact of the agro-climatic resources on maize and sunflower crops

During the vegetative season, the agricultural crops have different demands on the climatic conditions.

The agro-meteorological parameters that evolve beyond the optimum necessary for the growth and development of the agricultural plants are considered stressors with unfavorable effects on the status of the vegetation and agricultural production [10].

The critical period regarding the temperature and maximum water consumption for the main summer crops, such as maize and sunflower, is the July-August interval [9, 10].

The impacts of temperature and precipitation resources on the status of vegetation and agricultural production were also analyzed by using the NDVI satellite index and the agricultural data for yields of the maize and sunflower.

For the year 2015, the spatial distribution of the arable land in the South-Western Romania or the South-West Oltenia Development Region is shown in Figure 2.

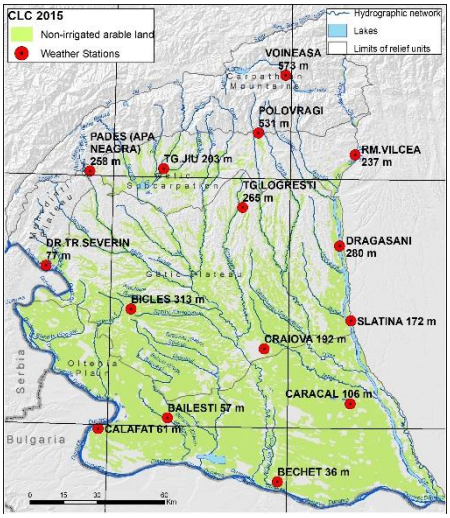

Fig. 2. The spatial distribution of the arable land in the South-West of Romania.
Source: own processing from CLC 2015.

By using the MODIS satellite imagery, the NDVI index has been calculated, indicating the biomass quality for June, July and August as a 16-day synthesis. NDVI is an index that varies between -1 and +1.

Positive NDVI values greater than +0.2 indicate good health for the vegetation, and values greater than 0.6 indicate dense vegetation that characterizes the forest areas in the temperate areas [8]. Figure 3 shows the space-time analysis of the NDVI index for the study area.

Based on Figure 3, there can be noticed that the NDVI index values decreased from June to August, indicating a deteriorating health status of vegetation, due to the low precipitation regime and the heat, which characterized this monthly interval corresponding to the development of the phenological phases of the maize and sunflower.

According to the National Institute of Statistics, the crop yields of maize and sunflower were lower as compared to 2014 and 2016, reflecting

the climatic context of the year 2015 (Table 5) [11].

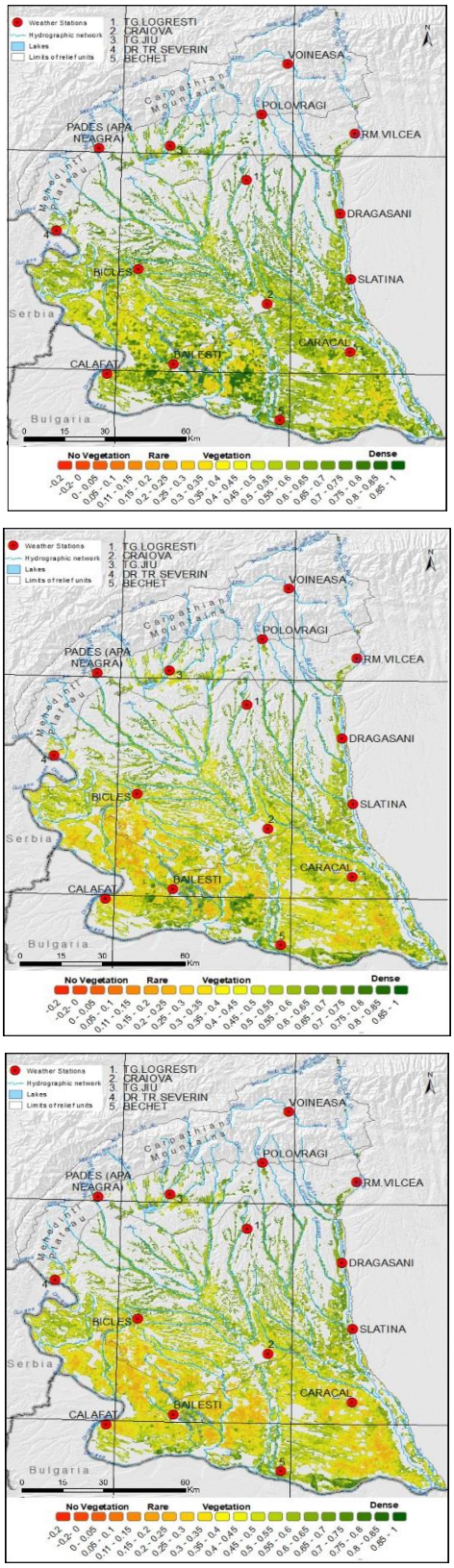

Fig. 3. The space-time distribution of the NDVI index values in June (above), July (middle) and August (down) 2015, in the South-Western Romania.
Source: own processing from MODIS satellite imagery

Table 5. The cultivated surface and the agricultural production of maize and sunflower in the South-West Oltenia Development Region.

Culture	Year	Surface (ha)	Production (tone)	Average of production (kg/ha)
Maize	2014	349,284	1,444,982	4,137
	2015	360,465	1,066,284	**2,958**
	2016	362,148	1,243,414	3,433
Sunflower	2014	123,446	268,521	2,175
	2015	128,564	209,666	**1,631**
	2016	185,838	300,572	1,617

Source: NIS processed data, 2019.

CONCLUSIONS

Overall, the year 2015 was warm (W), with the annual average anomaly from the previous century of 1.9°C, but a normal year from the precipitation point of view. The spring warming occured earlier. The spring was warm and, on average, sliaghtly dry, and the atmospheric and soil drought was dominant especially during the months of April and May. The summer was warm, with long periods of atmospheric and soil drought, but normal from precipitation point of view.
The autumn was warm and excessively rainy, which led to favorable conditions for the onset of the agricultural year 2015-2016.
The largest negative anomalies of the monthly precipitations were recorded in July and December. In September, the highest positive anomaly of the monthly precipitations has been registered. As a result, the atmospheric and soil drought during the spring and summer months deteriorated the health status of the vegetation and there were significant decreases in the agricultural crops for maize and sunflower, in the South-Western Region of Romania.

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