MONITORING HYDRO-CLIMATIC HAZARD IN THE AREA OF ORAVITA: ASSESSING DROUGHT HAZARD

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***Abstract**. One of the most important hydro-climatic hazards is that of hydric deficits, i.e. drought or flood. Droughts can occur in any region on the Globe but the strongest effects are in arid, semi-arid and sub-humid areas where ecosystems are characterised by high fragility. Drought can also occur in areas where annual or periodical precipitations are "normal" or close to multi-annual means, but the water comes from rare precipitations (mm/min) with high intensities that do not allow accumulation of water in the soil. This type of drought is increasingly frequent in southern and eastern Romania and it tends to extend to central and western Romania. World Meteorological Organisation proposed to define drought as an atmospheric sequence characterised by amounts of precipitations 60% lower than those considered normal. The goal of this paper is to study drought hazard in the conditions of Oravita, Romania, during 2-11-2013. The three years were analysed through the prism of several indicators of drought characterisation in literature and compared to multi-annual mean values. We analysed the following hydro-climatic hazard monitoring parameters in the area of Oravita: the sum of monthly and annual precipitations, the monthly and annual mean of evapotranspiration, the monthly and annual hydric deficits and their graphic representation, monthly and annual mean temperatures and their evolution; we also calculated and analysed climate indicators of characterisation (Thornthwaite, Lang, characterisation depending on deficit of precipitations, etc.). From the point of view of the rainfall regime, an important indicator in defining drought and excess of humidity, the sum of monthly precipitations during summer or spring and their annual amount help draw a conclusion regarding the existence of hydro-climatic hazards during the studied period. Depending on the deficit of precipitations, compared to monthly, seasonal and annual multi-annual means, June, August and September are excessively droughty or droughty in all analysed years. The year 2013 was a very droughty year if we take into account the vegetation period; overall, 2013 was a little droughty year. Results show that there were droughty periods in the three years in Oravita, particularly during the hot season (April-September); 2013 proved the droughtiest year and it is labelled as semi-arid depending on all analysed indicators.*

***Keywords:** average monthly temperatures, sum of monthly precipitations, potential evapotranspiration, aridity coefficient, climate coefficient*

INTRODUCTION

In the last decade, in Romania, in Europe and worldwide there was an increase of mean temperatures, i.e. real warming. For Romania, meteorologists studies point to an increase of mean annual temperature of 0.5^0C in the last century, with some differentiations per regions.

Drought is a climate hazard with a long period of establishment and it is characterised by a decrease of precipitations below the mean level, by a decrease of the river level and of underground water supplies that determine a high deficit of humidity in the air and soil with direct effects on the environment and, above all, on agricultural crops.

Drought was defined as a period and state of hydric deficit caused by the negative difference between water inputs and outputs that generate reversible and irreversible unbalance and dysfunctions (SOROCOVSCHI V., 2009).

In areas with high drought hazard, climate is hot and dry, with mean annual temperatures above 10^0C, the sum of mean annual precipitations ranges between 350-550 mm, and that of vegetation periods (IV-IX) ranges between 200-350 mm (IENCIU, 2010).

A rather complete definition of drought mentions that it is an extreme phenomenon with a long period of establishment characterised by a decrease of the precipitations below the mean level because of a reduction of river flow and of underground water supplies and that determine a high deficit in humidity in the air and soil with direct effects on the environment and above all on agricultural crops (MOLDOVAN, 2003).

At global level, lands subjected to drought and desertification cover ¼ of the total area of land of the Earth and affect about one billion inhabitants in over 110 countries of the world among which Romania.

In Romania, there is a clear trend of intensifying and extending *drought* and *desertification* because of both natural and anthropic causes (deforestations, destruction of irrigation systems, etc.). Of the 14,700,000 ha of agricultural land, about 7,000,000 ha are affected by drought over long periods and in consecutive years (48% of the total) (National strategy regarding the reduction of drought effects, the prevention and control of land degradation and desertification short-, medium- and long-term, 2008).

Specialists estimate that drought and general phenomena caused by drought are caused by both changes in the general circulation of the atmosphere engendered by both greenhouse effect and certain anthropic causes engendered by irrational use, deforestation, or landscape changes with negative effects on water balance. Drought is caused by discontinuity in the normal functioning of the system of atmospheric currents.

MATERIAL AND METHOD

To characterise hydric deficit, we take into account size of precipitations during a certain period and deviations from normal values (multi-annual means) as well as other climate indicators.

In this paper, we analyse the following parameters:

- Annual and vegetation period precipitations during 2011-2013 recorded at the Meteorological Station in Oravita, their evolution and deviations from multi-annual means;
- Monthly and annual mean temperatures and their evolution during the period analysed;
- Monthly, annual and vegetation evapotranspiration during the period analysed and the evolution of consumptions compared to multi-annual means;
- Annual and vegetation hydro-climatic balance;
- Annual aridity indicators (de Martonne);
- Annual hydro-climatic indicators.

Potential evapotranspiration was calculated after the Thornthwaite method (1948) based on the mean air temperature, with the formula:

$$ETP = 16\left(\frac{10 \cdot tn}{I}\right)^a \cdot K$$

where:

ETP – monthly potential evapotranspiration (mm);

tn – monthly mean temperature for which we calculated ETP in ^{0}C;

I – thermal indicator of the area (sum of monthly thermal indicators);

$$I = \sum_{n=1}^{12} i_n$$

$$i_n = \left(\frac{t_n}{5}\right)^{1,514}$$

a = exponent depending on I;

a = 0.0000006751 I^3 - 0.00007711 I^2 + 0.0179211 I + 0.49239.

I_n = monthly thermal indicator.

Annual hydro-climatic balance was established after the “Methodology of soil studies – Part III – Ecopedologic indicators” using the following relations:

Hydro-climatic balance = Precipitations – Potential evapotranspiration.

Hydro-climatic indicator = (Precipitations/ Potential evapotranspiration) x 100

Aridity indicator (de Martonne) = Precipitations/Temperature + 10;

Interpretation of de Martonne aridity indicator:

$0 < A < 5$ Arid climate

$5 < A < 20$ Semi-arid climate

$20 < A < 30$ Semi-humid climate

$30 < A < 55$ Humid climate

Results were interpreted after the table suggested by Donciu (1986) where he presents limit values of the main humid climate types in Romania (Table 1).

Table 1.

Limit values of the main humid climate types in Romania

Climate type	P – ETP (mm)	Donciu indicator	Thornthwaite indicator	De Martonne indicator
Excessively humid	600 to 1200	200 to 570	100 to 470	60 to 187
Very humid	300 to 600	160 to 200	60 to 100	50 to 60
Humid	100 to 300	120 to 160	20 to 60	40 to 50
Moderately humid I	0 to 100	100 to 120	10 to 20	35 to 40
Moderately humid II	-100 to 0	90 to 100	0 to 10	30 to 35
Moderately dry	-200 to -100	70 to 90	-20 to 0	24 to 30
Semi-arid	-350 to -200	50 to 70	-30 to -20	15 to 24

Characterising climate conditions depending on the deficit of precipitations was done calculating the percentage of precipitations of mean values as shown in Table 2.

Table 2.

Characterisation of weather conditions depending on the deficit of precipitations (after Barbu I. and Popa I., 2001)

% of monthly mean precipitations	% of seasonal and annual mean precipitations	Characterisation
91-110	96-105	Normal
81-90	90-95	Little droughty
71-80	85-90	Droughty
51-70	75-85	Very droughty
< 50	< 75	Excessively droughty

Hydrothermal indicators

Characterisation after Thornthwaite

It is based on the differences between precipitations and evapotranspiration. We compare on a monthly basis the water supply from precipitations with losses through evapotranspiration.

By noting with d = ETP-P – annual water deficit (sum of monthly water deficits) and with s = P-ETP – annual water excess (sum of monthly excesses over a year) we calculate:

- Humidity indicator **Iu = (s/ETP)*100**
- Aridity indicator **Ia = (d/ETP)*100**

where ETP is the annual value of potential evapotranspiration.

The global indicator of humidity Im confers an annual precipitation characterisation:

Im = Iu – 0.6*Ia or **Im = [(s – 0.6*d)/ETP]*100**

Table 3.

Climate characterisation after Thornthwaite (after Neacşa and Berbecel)

Global humidity indicator (Im)	Annual characterisation
Im > 100	Super-humid
100 > Im > 80	Humid
80 > Im > 20	Semi-humid
20 > Im > 0	Sub-humid
0 > Im > -20	Sub-dry
-20 > Im > -40	Semi-arid
-40 > Im	Arid

Climate indicators

Lang indicator allows a delimitation of the climates per plane areas (agricultural ones). It is not applicable to monthly values.

$$L = \frac{P}{T} \text{ annual}$$

P = annual precipitations (mm)

T = annual mean temperatures (^{0}C)

Interpretation:

0 < L < 20 Arid climate

20 < L < 40 Mediterranean climate

40 < L < 70 Semi-arid climate

70 < L < 1000 Humid climate

RESULTS AND DISCUSSION

Following the analysis of the evolution of monthly temperatures in Oravita and of the deviations compared to multi-annual mean values, we show in Figure 1 that 2013 was the hottest year of the three years when temperatures were higher than multi-annual means except for March.

In all three studied years, annual mean temperatures were higher than multi-annual means, and the mean of the hot period was above the multi-annual mean with values ranging between 1.2 and 2.6°C.

We see in Figure 2 that 2013 was a precipitation-deficit year including during the hot period.

The poorest months in precipitations were July, with only 27.6 mm, June with only 42.0 mm (46.7 mm less than the multi-annual mean), September and October. In 2011, the amount of annual precipitations was 720.5 mm (65.3 mm less than the multi-annual mean in Oravita). The months with the highest deficit of precipitations were August (-67.0 mm), September (-46.2 mm), June (-19.0 mm), and 2012 had a slight deficit of precipitations (June-September had much lower precipitations than normal ones for the area).

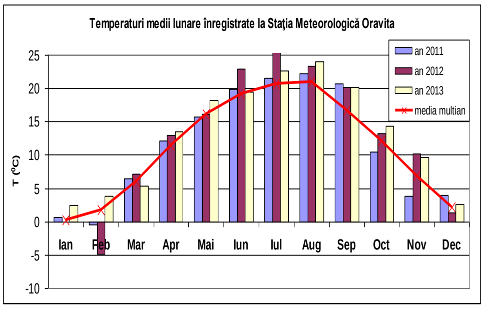

Figure 1. Annual mean temperatures (2011-2013)

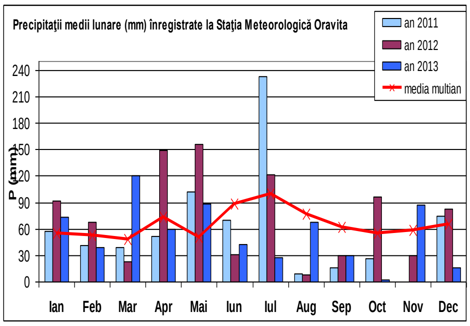

Figure 2. Annual mean precipitations (2011-2013)

In 2011, the annual mean of air relative humidity was 70%, equal to the normal one for the area; during vegetation, this mean was 64%, 3% lower than the normal one for the area. In 2012 and 2013, the annual mean was 67%, 3% lower than the multi-annual mean; during vegetation, it was 7-8% lower than the multi-annual mean (Figure 3).

Figure 4 shows the evolution of monthly evapotranspiration values in the three studied years in Oravita. It also shows that the highest values were in 2012 followed by 2013, above multi-annual means. In 2011, annual mean evapotranspiration was 708.6 mm (+30.4 mm more than the multi-annual mean); it was higher than the normal value for the area also during the hot period of the year.

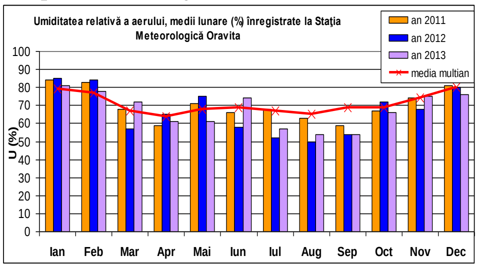

Figure 3. Relative air humidity (monthly means)

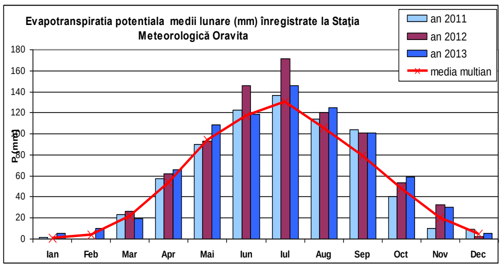

Figure 4. Potential evapotranspiration (monthly means)

Hydro-climatic balance supplies a clear image of the hydric stress periods, which allowed the monitoring of dry periods and of dry years.

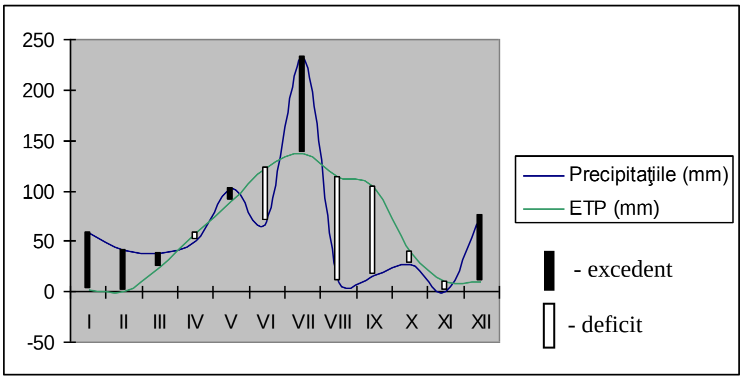

Figure 5. Evolution of hydro-climatic balance curves (2011)

The graphic representation of the hydro-climatic balance curves (Figures 5-7) shows the distribution of hydric deficit periods and their intensity during the three years. The year 2013 had the highest hydric deficits followed by 2012 when hydric deficit periods lasted from June to September.

In 2011, there was the lowest hydric deficit of the analysed period (275.0 mm, i.e. the sum of monthly hydric deficits) that lasted from April to November (except for May and July).

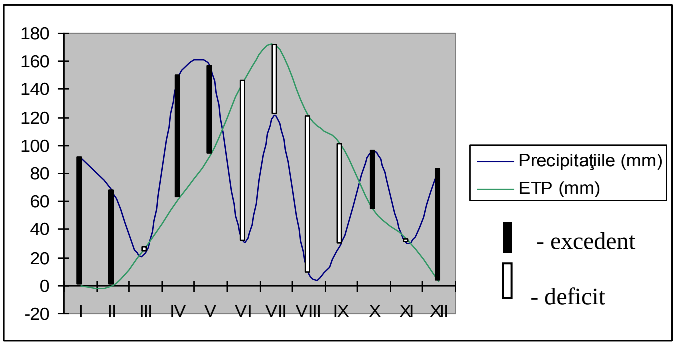

Figure 6. Evolution of hydro-climatic balance curves (2012)

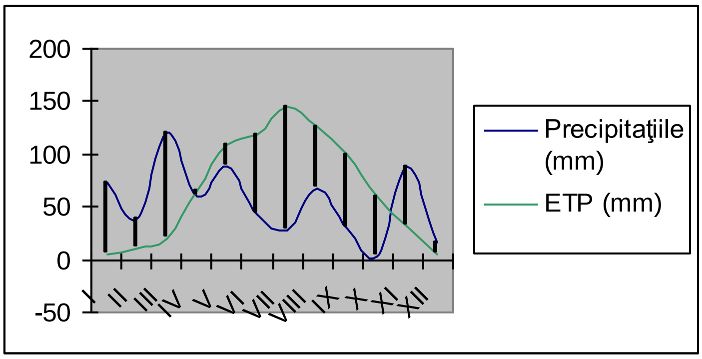

Figure 7. Evolution of hydro-climatic balance curves

Table 4.

Characterisation of the years 2011, 2012 and 2013 in Oraviţa depending on the main climate indicators

Climate type depending on indicators	**P – ETP (mm)**	**Donciu indicator**	**Thornthwaite indicator**	**De Martonne indicator**	**Global humidity indicator Thornthwaite**	**Lang indicator**
2011	11.9	101.67	1.67	33.66	17.2	63.20
Interpretation	Moderately humid I	Moderately humid I	Moderately humid II	Humid climate	Sub-humid climate	Semi-arid climate
2012	78.8	109.74	9.74	39.26	27.23	70.42
Interpretation	Moderately humid I	Moderately humid I	Moderately humid II	Humid climate	Sub-humid climate	Semi-arid climate
2013	10.9	98.35	-1.64	28.42	2.76	50.28
Interpretation	Moderately humid II	Moderately humid II	Moderately dry	Semi-humid climate	Sub-humid climate	Semi-arid climate

Table 4 presents the main climate indicators for the three studied years.

We can see that the hydro-climatic balance points to a higher deficit of humidity in 2012 (78.8 mm) that characterises this year as moderately humid I. The Thornthwaite global humidity indicator also shows that 2011 and 2012 were semi-humid, and 2013 was sub-humid. The Lang indicator shows that all three studied years were semi-arid.

Table 5 shows the characterisation of the hot period (IV-IX) during 2011-2013 depending on the deficit of precipitations compared to monthly, seasonal and annual means. June, August and September were excessively dry or dry during this period. In 2011, April also was very dry, while in 2012 April was rainy, and in 2013 it was dry. The year 2013 was very dry including during the vegetation period and 2013 was, overall, a little dry year.

Table 5.

Characterisation of weather conditions in Oravita depending on the deficit of precipitations during the hot period for 2011, 2012 and 2013
(% of monthly, seasonal and annual mean precipitations)

Year	Month							
	IV	**V**	**VI**	**VII**	**VIII**	**IX**	**IV-IX**	**Annual**
2011	69.3	203.9	78.5	232.1	12.5	25.2	106.6	91.7
Interpre-tation	Very dry	Rainy	Dry	Rainy	Excessi-vely dry	Excessi-vely dry	Normal	Normal
2012	202.6	311.5	35.06	121.2	10.7	47.5	109.9	112.9
Interpre-tation	Rainy	Rainy	Excessi-vely dry	Rainy	Excessi-vely dry	Excessi-vely dry	Normal	Normal
2013	80.21	176.5	47.5	27.5	89.03	47.5	69.8	83.2
Interpre-tation	Dry	Rainy	Excessi-vely dry	Excessi-vely dry	Little dry	Excessi-vely dry	Very dry	Little dry

CONCLUSIONS

- Analysis of the period 2011-2013 in Oravița shows that 2013 was the hottest year with an annual mean temperature of 13°C, while in 2012, annual mean temperature was 12.6°C, and in 2011 it was 11.4°C with a multi-annual mean of 11.3°C. The same situation occurred during vegetation when the multi-annual mean of the season was 2.6°C higher in 2012, and 2°C higher in 2013.
- The year with the highest deficit of precipitations in Oravita was 2013, when the sum of precipitations was only 653.7 mm (compared to the multi-annual mean of 785.8 mm), while in 2011, the total amount of precipitations was 720.5 mm, i.e. 65.3 mm lower than the normal. The year 2012 had an excess of annual precipitations compared to the multi-annual sum (+101.6 mm).
- The highest values of potential evapotranspiration were in 2012: starting with June, the value of annual ETP was 808.6 mm, i.e. 130.4 mm more than the normal, and in 2013 total water consumption was 116.1 mm above the multi-annual mean. The lowest values of evapotranspiration in the three studied years in Oravita was in 2011, when it reached 708.6 mm.
- The highest hydric deficits were in 2013 (406.2 mm) from April to October, while in 2012 the monthly hydric deficit was lower (353.4 mm), between June to September. The lowest annual hydric deficit was in 2011 (275 mm), more during the hot period.
- Depending on the annual hydric deficit (P-ETP) in the three studied years, on the

Donciu indicator, the years 2011 and 2012 were moderately humid I, and 2013 was moderately humid II. According to the Thornthwaite indicator, the years 2011 and 2012 were moderately humid II, and 2013, was moderately dry. According to the Lang indicator, the three studied years were semi-arid.

- Weather conditions in Oravita depending on the deficit of precipitations in 2011 and 2012 made them normal, while 2013 was little dry. Hot seasons were normal in 2011 and 2012 and 2013 was very dry.
- It is clear that during the analysed period there were periods of hot temperatures with no precipitations and periods with deficit of precipitations during hot periods followed by considerable rainfall, which shows the aggressiveness of weather phenomena because of global warming.

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