MONITORING HYDRO-CLIMATE RISKS IN THE LUGOJ AREA, ROMANIA

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Abstract: *The most important hydro-climate risks in the Lugoj area, Romania, are hydric deficits, i.e. drought and flood periods. Drought, together with other destructive phenomena such as floods and pollution, is seen as the temporary incapacity of water resources of meeting consumption needs; it is, thus, one of the main global issues of our days. There have been, because of climate change, droughty periods in areas where the sum of annual or season precipitations is close to multiannual means: the problem is that the water came from high intensity (mm/min) precipitations, which prevented water from accumulating in the soil. The study aimed at presenting the hydric deficits (the existence of droughty periods and of hydric excess) in the Lugoj area over five years (2010-2014). The five years have been analysed from the perspective of several indicators of drought in literature. The following parameters of monitoring hydro-climate risks in the Lugoj area have been studied: sum of monthly and annual precipitations, mean monthly and annual evapotranspiration, monthly and annual hydric deficits and their graphic representation, mean monthly temperatures and their evolution; we have calculated and analysed climate and hydro-thermal indicators of drought (Topor, Lang), we have characterised depending on the precipitation deficit, the Thornthwaite indicator of precipitation efficiency, and the hydro-thermal indicator Seleaninov. From the point of view of the rainfall regime, an important indicator in acknowledging drought and humidity excess depending on the sum of monthly precipitations in summer and even in spring (annual sum of precipitations), we can draw the conclusion that, during the period studied (2010-2014), the years 2010 and 2014 were humid, rainy. Depending on the precipitation deficit, compared to monthly, seasonal and annual multiannual means, we can say that June, August and September were excessively droughty and droughty months in all analysed years. The years 2011, 2012 and 2013 were demi-arid according to most indicators analysed, i.e. years with monthly and annual mean temperatures higher than multi-annual ones, with significant hydric deficits during the hot season. Results show that there were periods with hydric deficits, droughty periods in three years (2011-2013) of the five years we analysed in Lugoj, mainly during the hot season (April-September); these years were also defined as demi-arid in most indicators analysed.*

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

INTRODUCTION

The hazard represents "a threatening event or the appearance probability in a region, and in a given period of a natural phenomenon with destructive potential (material damages, prejudices brought to the environment, human victims)"[11].

Risk definition is "the possible number of human losses, injured persons, material damages of any kind made during a reference time and in a given region, in case of the existence of a particular natural phenomenon".[MAC, I. PETREA, D]

Drought and floods are natural hazards induced by climate phenomena and processes that generate losses of human lives, great material damage and important ecological unbalance in the normal evolution of the environment.

If floods are caused by exceeding atmospheric precipitations during certain periods, droughts are the result of low precipitations in a certain region (below multi-annual mean) on the background of high temperatures over a certain period and whose size differs from area to area [SABAU, N.C. MAN, T.E., ARMAS, A. BALAJ, C., GIRU, M.,].

PEREIRA ET AL. (2002) defined drought as a temporary natural unbalance of available water resources as a result of a period with persisting volumes of precipitations lower than the mean values recorded with uncertain frequency, duration, and severity that are difficult to predict and that cause a diminution of available water resources [HĂLBAC-COTOARĂ-ZAMFIR R, PEREIRA S.L., CORDERY I, IACOVIDES I.,].

In 2013, the European Commission issued the Communique “A EU strategy regarding the adaptation to climate changes” (COM (2013) 216 final) accompanied by the Guide regarding the development of adaptation strategies (SWD (2013) 134 final). The Guide was designed to help Member States in developing the national adaptation strategies (Guide for the preparation of Drought Management Plans, their Development and Implementation within the context of the EU Water Frame Directive as part of the Hydrographic Basin Management Plans) [12].

MATERIAL AND METHOD

In this paper, we analyse the following factors:

Mean monthly and annual temperatures and their evolution during the period analysed, with the differences compared to multi-annual means;

Annual precipitations and precipitations during vegetation recorded at the Meteorological Station in Lugoj, and their evolution and deviations compared to multi-annual means;

Evapotranspiration monthly, annual and vegetation values calculated with the Thornthwaite formula;

Annual hydric indices Topor index, annual index of wetness after Majercakova, hydrothermal index after Seleaninov.

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

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

where:

ETP – monthly potential evapotranspiration (mm);

tn – mean monthly temperature for which we calculate ETP in °C;

I – area thermal index (sum of monthly thermal indices);

a = an exponent depending on I;

a = $0.0000006751\ I^3 - 0.00007711\ I^2 + 0.0179211\ I + 0.49239$;

In = monthly thermal index.

To characterise synthetically the climate, we used the following climate indices:

Hydro climate balance = Precipitations – Potential evapotranspiration; annual indices of aridity (de Martonne), Thorthwaite indice

Results were interpreted according to the table suggested by Donciu (1986) that presents limitative values of the main climate types of wetness in Romania, table 1[2].

Table 1

Limitative values of main climatic types of humidity in Romania (DONCIU, 1986)

Climatic Type	P –ETP (mm)	Donciu index	Thornthwaite index	De Martonne index
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
Wet	100 to 300	120 to 160	20 to 60	40 to 50
Moderately wet I	0 to 100	100 to 200	10 to 20	35 to 40
Moderately wet II	-100 to 10	90 to 100	0 to 10	30 to 35
Moderately dry	-200 to -100	70 to 90	-20 to 0	24 to 30
Semiarid	-35- to -200	50 to 70	-30 to -20	15 to 24

The global index of wetness lm supplies an annual pluviometric characterisation [3]:

Im = Iu – 0.6*Ia or Im = [(s – 0,6*d)/ETP]*100

Table 2.

Climate characterisation after Thornthwaite

Global index of wetness (Im)	Annual characterisation
Im>100	Over wet
100>Im>80	Wet
80>Im>20	Semi wet
20>Im>0	Sub wet
0>Im>-20	Sub dry
-20>Im>-40	Semiarid
-40>Im	Arid

Characterisation of climate conditions depending on the deficit of precipitations (table 3) [1]

Tabelul 3

Characterisation of climate conditions depending on the deficit of precipitations (after BARBU & POPA, 2001)

% of mean monthly precipitations	% of mean seasonal, annual 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

The N. Topor Index is a hidrotermic index [6]

Table 4.

Characterisation after the N. Topor index

Pluviometric index (Ia)	Characterisation
Ia<0,33	Exceptionally droughty
0,33<Ia<0,40	Excessively droughty
0,41<Ia<0,70	Very droughty
0,71<Ia<0,84	Droughty
0,85<Ia<1,00	Less droughty
1,01<Ia<1,17	Normal
Ia>1,18	More rainy

Table 5.

Annual index of wetness after Majercakova (2007) [3]

Year defined in relation to wetness conditions	Relationship between current annual precipitations and multi-annual mean
ED – Extremely dry	P<70%
VD – Very dry	70%<P<80%
D – Dry	80%<P<90%
N – Normal	90%<P<110%
W – Wet	110%<P<120%
VW – Very Wet	120%<P<130%
EW – Extremely wet	130%>P

Years are classified by comparing annual precipitations as a percentage of the multi-annual mean.

Hydrothermal index after Seleaninov [6]

It is determined with the formula:

K = P/(t’/10)

where:

P – total precipitations of the month being considered;

t’ – monthly mean temperature multiplied by the number of days of the month.

Drought intensity is evaluated as follows:

K<1 – aridity conditions ;

1<k<1.7 – normal conditions (equilibrium of hydric balance);

k>1.7 – hydric excess conditions.

RESULTS AND DISSCUSIONS

Analysing the evolution of monthly mean temperatures in Lugoj and their deviations compared to the multi-annual means, we see in Figure 1 that 20014 was the hottest year, followed by 2013 and 2012. In all five years we analysed, annual mean temperatures were higher than the normal one, with values ranging between 1.0-2.1°C; in the hot season, the highest mean of temperature was in 2012, i.e. 2.9 2.9°C more, followed by 2013 (+1.14°C).

Figure 2 shows that 2011 was the year with the highest deficit of precipitations, including during the hot season, when the total amount of precipitations was 389.8 mm, compared to the multi-annual mean of 672.3 mm. Of the five years we analysed (2010-2014), the annual sum of precipitations was much higher than the normal one for the area, with values ranging between 118 mm and 65 mm. There was the same trend during the hot period.

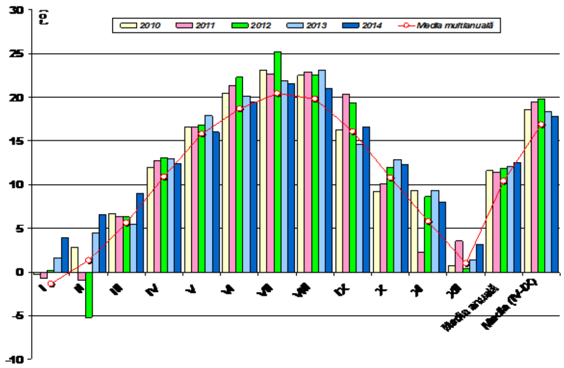

Figure 1. Monthly mean temperatures in the years 2010-2014

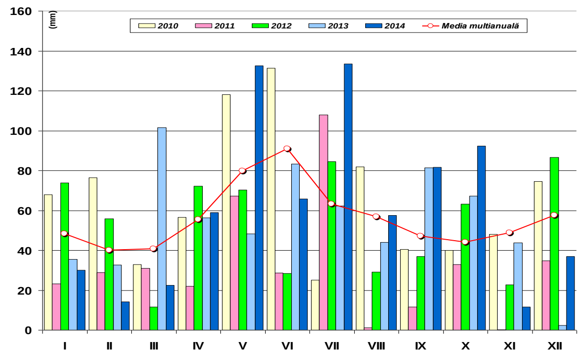

Figure 2.Monthly mean precipitations 2010-2014

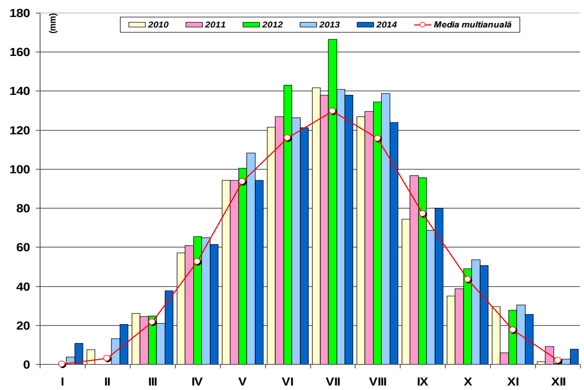

Figure 3. Monthly means of potential evapotranspiration

Figure 3 shows the evolution of monthly evapotranspiration values during the five studied years in Lugoj. In 2012, annual evapotranspiration had the highest value, 808.08 mm (+136.54 mm more than the multiannual mean), followed by 2013, with an annual potential evapotranspiration of 772.88 mm (+101.34 mm higher than the multiannual mean).

Table 6.

Characterisation of weather conditions in Lugoj depending on the deficit of precipitations during the hot season for the years 2010-2014 (% of monthly, seasonal and annual means)

An	IV	V	VI	VII	VIII	IX	IV-IX	Anual
2010	102,16	147,8	144,6	39,55	144,2	85,98	115,30	117,51
Interpretation	normal	Excessively rainy	Excessively rainy	Excessively droughty	Excessively rainy	litle droughty	litle rainy	litle rainy
2011	39,53	84,33	31,60	170,7	2,29	24,5	60,76	57,98
Interpretare	Excessively droughty	litle droughty	Excessively droughty	Excessively rainy	Excessively droughty	Excessively droughty	Excessively droughty	Excessively droughty
2012	130,32	88,09	31,38	133,8	51,15	78,55	81,83	94,57
Interpretare	rainy	litle droughty	Excessively droughty	rainy	very droughty	droughty	very droughty	litle droughty
2013	101,6	60,52	91,74	98,6	77,7	172,8	95,6	97,8
Interpretare	normal	very droughty	normal	normal	droughty	rainy	litle droughty	normal
2014	106,5	166,2	72,4	211	101,2	173,5	134,5	109,7
Interpretare	normal	rainy	droughty	rainy	normal	rainy	rainy	little rainy

Table 6 presents the characterisation of the hot period (IV-IX) of the years 2010-2014 depending on deficit of precipitations compared to monthly, seasonal and annual means. We can see that 2011 was excessively droughty both during the hot period and the entire year, followed by 2012 that was little droughty and very droughty during vegetation. The years 2010 and 2014 were little rainy and 2013 was normal and little droughty during the hot season. Table 7 presents the main climate indices calculated for the five studied years (2010-2014) in Lugoj. We can see that most climate indices range 2011 in the category semiarid and 2014 in the category moderate wet II and moderate dry, respectively.

Table 7.

Characterisation of the years 2010-2014 in Lugoj depending on the main climate indices

Climatic type depending on indices	P – ETP (mm)	Donciu Index	Thornthwaite Index	De Martonne Index	Thornthwaite global index of Wetness	Lang Index
2010	74,63	110,4	10,42	36,58	21,4	68,1
Interpretare	Moderat wet I	Moderat wet I	Moderat wet I	Wet climat	Semi wet climat	Semiarid climat
2011	-335,07	53,77	-46,22	18,21	-23,09	34,2
Interpretare	Semiarid	Semiarid	Semiarid	Semiarid climat	Semiarid	Mediteranean climat
2012	-172,3	78,68	-21,32	29,16	4,82	53,8
Interpretare	Moderat dry	Moderat dry	Semiarid	Semi wet climat	Sub wet climat	Semiarid Climat
2013	-114,2	85,22	-14,77	29,8	0,06	54,4
Interpretare	Moderat dry	Moderat dry	Moderat dry	Semi wet climat	Sub wet climat	Semiarid climat
2014	-34,16	95,57	-4,45	33,6	4,0	58,6
Interpretare	Moderat wet II	Moderat wet II	Moderat dry	Wet climat	Sub wet climat	Semiarid climat

Figure 4 shows that during 2010-2015 in Lugoj, depending on the Topor Index, there were two droughty years (2013, 2014), an exceptionally droughty year (2011), a rainy year (2010) and a normal year (2012).

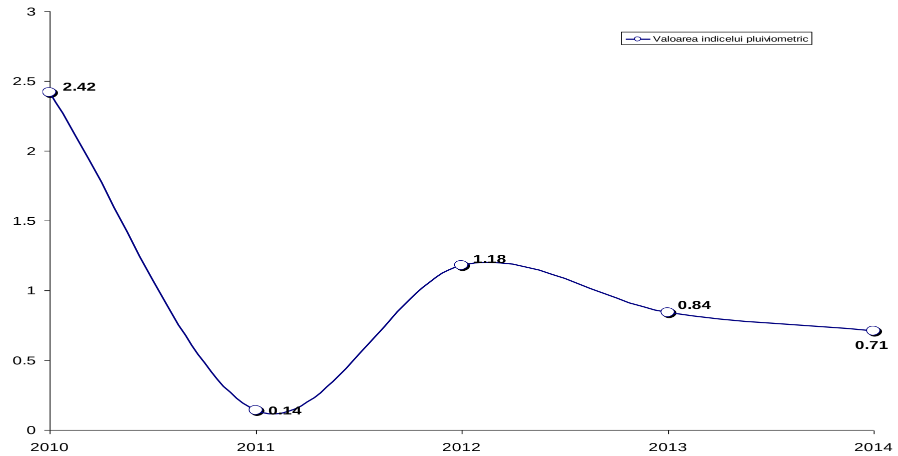

Figure 4. Pluviometric characterisation after the N. Topor Index (2010-2014) in Lugoj

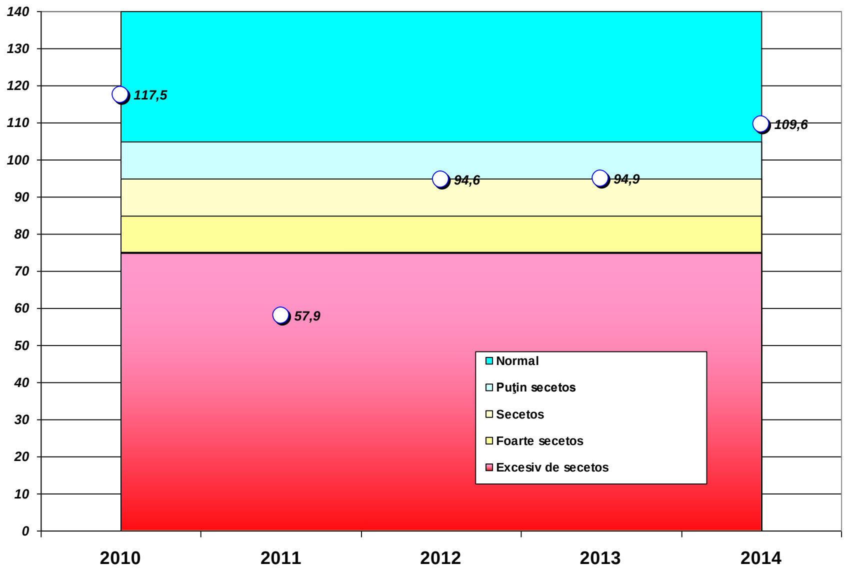

Figure 5. Annual index of wetness after Majercakova in Lugoj (2010-2014)

Figure 5 shows that, depending on the wetness index Majercakova, of the five studied years in Lugoj during 2010-2014, one year was extremely dry (2011), one was very wet (2010), one was wet (2014), and two were normal (2012, 2013).

Figure 6 presents the evolution of the Seleaninov hydrothermal indices in Lugoj during the period analysed in both the hot season and as annual value. We see that 2011 was characterised as arid both overall and during the hot season. The year 2012 was arid during the hot season and normal overall, with three arid months during the hot season. The years 2013 and 2014 were normal years both during the hot season and overall, while 2013 also had three arid months.

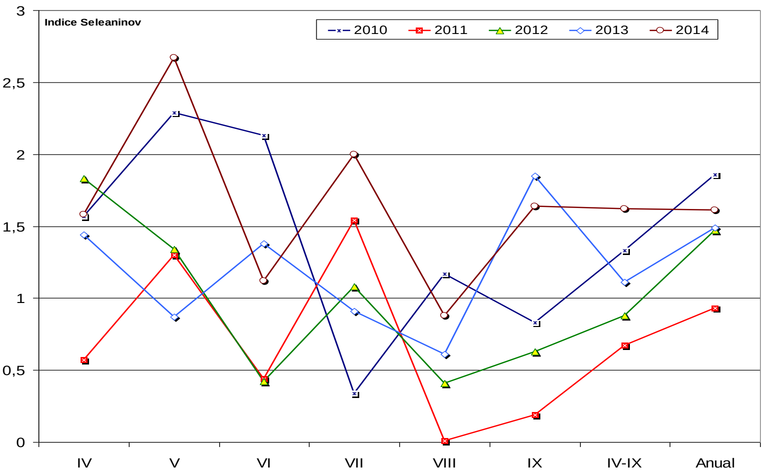

Figure 6. The Seleaninov hydrothermal index in Lugoj (2010-2014)

CONCLUSIONS

Analysis of the years 2010-2014 in Lugoj shows that 2014 was the hottest year, with a mean annual temperature of 12.5°C, followed by 2013 with a mean annual temperature of 12.1°C compared to the normal mean of the area of 10.4°C;

The year with most deficit of precipitations was 2011, when the sum of annual precipitations was only 389.8 mm (compared to the multiannual mean of 672.3 mm), while 2010 and 2014 exceeded in precipitations;

The highest hydric deficits were in 2011 (419.36 mm) from April to November, while in 2012 the sum of hydric deficits was 410.58 mm. In 2014 and 2010, total hydric deficits were much lower;

Depending on the percentage of precipitations of seasonal and annual precipitations, 2011 was excessively droughty, and 2012 was very droughty, while 2014 and 2010 were little rainy, and 2013 was dry both during the hot season and overall;

Depending on the main climate indices, on the Donciu Index, on the Thornthwaite Index, on the de Martonne Index, on the Thornthwaite global index of wetness, and on the Lang Index, the years 2011 and 2012 were semiarid and moderate dry in most indices and 2014 and 2010 were moderate wet II and I and moderate dry, respectively, and semiarid according to the Lang Index;

The Topor Index shows that there were two droughty years (2013, 2014), an exceptionally droughty year (2011), a rainy year (2010) and a normal year (2012);

The Seleaninov hydrothermal Index shows that of the five studied years, one was arid during both the hot season and overall, and three years were normal, of which one arid during the hot season and one excessively wet;

Analysis of the period 2010-2014 shows that there were excessively droughty and droughty years and arid periods with hydric deficits particularly in the hot season in Lugoj, a risk factor increasingly common in Western Romania, as well as an excessively wet year.

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