MONITORING PRIMARY HYDRO-CLIMATE INDICES IN THE TIMISOARA AREA, ROMANIA

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Abstract. The most important hydro-climate risks in the Timisoara area, Romania, are hydric deficits and humidity excess periods. 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 Timisoara area over two years (2013-2014). The years have been analysed from the perspective of several hydroclimate indicators in literature. The following parameters of monitoring hydro-climate risks in the Timisoara area have been studied: average monthly temperatures, 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 (Hellman, Topor, Lang), we have characterised depending on the precipitation deficit, the Thornthwaite indicator of precipitation efficiency. 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 (2013-2014), and the year 2014 was humid, rainy. Depending on the precipitation deficit, compared to monthly, seasonal and annual multiannual means, we can say that June, August and September were droughty periods and months in the analysed years. The year 2013 was semi-arid according to most indicators analysed, 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 the year (2013) (April-August); this year was also defined as semi-arid in most indicators analysed and the year 2014 was humid and rainy.

Keywords: potential evapotranspiration, climate coefficient, annual hydric deficits, precipitation deficit

INTRODUCTION

Drought and phenomena associated with it, i.e. hydric deficits and desertification, are huge issue humankind has had to deal with in the last fifty years.[7],[8] Droughts are the result of decreasing precipitation levels in a certain area (below multiannual mean) on the background of high temperatures over a certain period, and whose size differs from one area to another.[3],[6] The expansion of these unwanted phenomena at global level is emphasised by climate data that point to a progressive warming of the atmosphere and a diminution of the amount of precipitations, i.e. an uneven distribution that causes drought.[4],[5] Observations and measurements all over the Globe and in Romania on certain climate parameters and on the effects of climate on water resources point to the hypothesis of climate change.[6],[7]
MATERIAL AND METHODS
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 Timisoara 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, Hellman index
Potential evapotranspiration was calculated with the Thornthwaite formula (1948) based on the mean air temperature [6]:

\[ ETP = 16 \left( \frac{10 \cdot \ln I}{I} \right)^a \cdot K \]

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 P - 0.00007711 P + 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), Thornthwaite index

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. [1]

<table>
<thead>
<tr>
<th>Climatic Type</th>
<th>P–ETP (mm)</th>
<th>Donciu index</th>
<th>Thornthwaite index</th>
<th>De Martonne index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excessively humid</td>
<td>600 to 1200</td>
<td>200 to 570</td>
<td>100 to 470</td>
<td>60 to 187</td>
</tr>
<tr>
<td>Very humid</td>
<td>300 to 600</td>
<td>160 to 200</td>
<td>60 to 100</td>
<td>50 to 60</td>
</tr>
<tr>
<td>Wet</td>
<td>100 to 300</td>
<td>120 to 160</td>
<td>20 to 60</td>
<td>40 to 50</td>
</tr>
<tr>
<td>Moderately wet I</td>
<td>0 to 100</td>
<td>100 to 200</td>
<td>10 to 20</td>
<td>35 to 40</td>
</tr>
<tr>
<td>Moderately wet II</td>
<td>-100 to 10</td>
<td>90 to 100</td>
<td>0 to 10</td>
<td>30 to 35</td>
</tr>
<tr>
<td>Moderately dry</td>
<td>-200 to -100</td>
<td>70 to 90</td>
<td>-20 to 0</td>
<td>24 to 30</td>
</tr>
<tr>
<td>Semi-arid</td>
<td>-35 to -200</td>
<td>50 to 70</td>
<td>-30 to -20</td>
<td>15 to 24</td>
</tr>
</tbody>
</table>

Table 1

Limitative values of main climatic types of humidity in Romania (Donciu, 1986) [1]
The global index of wetness Im supplies an annual pluviometric characterisation [2]:

\[ Im = I_u - 0.6*I_a \] or \[ Im = \left[ \frac{(s - 0.6*d)}{ETP} \right] * 100 \]

<table>
<thead>
<tr>
<th>Global index of wetness (Im)</th>
<th>Annual characterisation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Im&gt;100</td>
<td>Over wet</td>
</tr>
<tr>
<td>100&gt;Im&gt;80</td>
<td>Wet</td>
</tr>
<tr>
<td>80&gt;Im&gt;20</td>
<td>Semi wet</td>
</tr>
<tr>
<td>20&gt;Im&gt;0</td>
<td>Sub wet</td>
</tr>
<tr>
<td>0&gt;Im&gt;-20</td>
<td>Sub dry</td>
</tr>
<tr>
<td>-20&gt;Im&gt;-40</td>
<td>Semi-arid</td>
</tr>
<tr>
<td>-40&gt;Im</td>
<td>Arid</td>
</tr>
</tbody>
</table>

- **The de Martonne aridity index** allows the delimitation of arid, semi-humid climates, while the monthly one differentiates the areas affected by drought. [1], [2]

\[ A = \frac{P}{T + 10} \text{ annual} \]

\[ A_i = \frac{12 \cdot P_i}{T_i} \text{ monthly} \]

P = annual or monthly precipitations (mm)
T = mean annual or monthly temperatures (°C)

**Interpretation of the de Martonne aridity index:**

0 < A < 5 Arid climate

5 < A < 20 Semi-arid climate

20 < A < 30 Semi-humid climate

30 < A < 55 Humid climate

- **The Donciu humidity index** is calculated with the formula:

\[ I_D = 100 \cdot \frac{P}{ETP} \%

where:

P – sum of annual precipitations (mm);

ETP – potential evapotranspiration (mm).

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- precipitation efficacy (P - ETP), where P is the sum of annual precipitations (mm) and ETP is potential evapotranspiration (mm); [1]

- The Lang index allows delimiting climate in plane areas (agricultural areas). It cannot be applied to monthly values. It can be calculated with the formula:

\[
L = \frac{P}{T}^{\text{annual}}
\]

where:

\(P\) = annual precipitations (mm)

\(T\) = mean annual temperatures (°C)

Interpretation:

\(0 < L < 20\) Arid climate

\(20 < L < 40\) Mediterranean climate

\(40 < L < 70\) Semi-arid climate

\(70 < L < 1000\) Humid climate [2]

- The Hellman Index

Pluviometric characterisation of a month is done by comparing the amounts of precipitations of the month with the multiannual mean. It is grouped into 9 categories. [2],[3]

The N. Topor Index is a hydrothermal index [2]

<table>
<thead>
<tr>
<th>Pluviometric index (Ia)</th>
<th>Characterisation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ia&lt;0.33</td>
<td>Exceptionally droughty</td>
</tr>
<tr>
<td>0.33&lt;Ia&lt;0.40</td>
<td>Excessively droughty</td>
</tr>
<tr>
<td>0.41&lt;Ia&lt;0.70</td>
<td>Very droughty</td>
</tr>
<tr>
<td>0.71&lt;Ia&lt;0.84</td>
<td>Droughty</td>
</tr>
<tr>
<td>0.85&lt;Ia&lt;1.00</td>
<td>Less droughty</td>
</tr>
<tr>
<td>1.01&lt;Ia&lt;1.17</td>
<td>Normal</td>
</tr>
<tr>
<td>Ia&gt;1.18</td>
<td>More rainy</td>
</tr>
</tbody>
</table>

Table 3
RESULTS AND DISCUSSIONS

Analysis of the evolution of mean monthly temperatures in Timisoara and of their differences compared to the multiannual means as shown in Figure 1 points to 2014 as the hottest year followed by 2013.

In the two studied years, mean annual temperatures were higher than the normal, with values ranging between 1.2 and 1.6°C, while in the hot season, the highest value of temperature was in 2013, i.e. 0.8°C more than the normal one, followed by 2014, when the mean during the hot period was sensibly equal to the normal one. The hottest months of 2014 were during the cold season: February and January with 3°C (4.2°C more than the normal one), as well as March and November.

Figure 1. Monthly mean temperatures in the years 2013-2014

Figure 2. Monthly mean precipitations 2013-2014
The year 2013 was special from the point of view of the amount of precipitations: the total sum of annual precipitations was 902 mm, much higher than the annual mean (618.8 mm); in the hot season also the amount of precipitations was much higher than normal values in Timişoara (214.8 mm more than the normal). There were also months with precipitation deficits during the hot season: June with 23 mm (60 mm less than the normal), July (46.5 mm less than the multiannual mean), February (24.6 mm less) as well as April and May (Figure 3).

Figure 3 shows that in 2013 the total hydric deficit was higher but shorter from April to July only.

The year 2014 had a lower hydric deficit (Figure 4) as both value and duration (July-September) – only 153.4 mm. The sum of hydric extra amounts was much lower than in 2013 – 285 mm.

Figure 4. Hydroclimate balance in Timişoara (2014)
Table 4 shows that the two studied years in Timisoara were humid, moderately humid or semi-humid according to the Donciu, Thornthwaite, de Martonne, or Lang indices.

Depending on the Hellman criterion, Table 5 shows that the year 2013 had six droughty months (April-October and December and February), while in 2014, most months were rainy, except for August, when it was droughty.

Table 6 Pluviometric characterisation after the Topor index during 2013-2014 in Timisoara

CONCLUSIONS

- The analysis of the years 2013-2014 in Timisoara shows that the year 2014 was the hottest one, that the mean annual temperature was 12.5°C, followed by the year 2013 with a mean annual temperature of 12.1°C, compared to the normal area temperature of 10.9°C;
- Pluviometrically, the year 2014 exceeded in precipitations, as did the year 2013: in both years, the annual sum of the precipitations was considerably higher than the normal one;
- The highest hydric deficits were in the year 2013, from April to July (313.3 mm), while in 2014 the hydric deficit was very low (153.4 mm) with a short period in July-September;
- Depending on the main climate indices – Donciu, Thornthwaite, de Martonne,
Thornthwaite global humidity, and Lang – the years 2013 and 2014 were moderately humid, semi-humid or humid;

- The Topor index shows that the year 2013 was droughty and the year 2014 was less rainy.

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