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THE EVOLUTION TREND OF THE THERMO-PLUVIOMETRICAL COMPLEX IN COTNARI (1961-2020)

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Abstract: The main elements that define the climate of a place are air temperature and atmospheric precipitation. Through this study, we aim to highlight the significance and extent of the trends of the two climatic elements for the interval 1961-2020 at the Cotnari meteorological station compared to those at the territorially neighboring stations Botoșani, Iași and Roman. For this purpose, we identified the basic thermo-pluviometric peculiarities at the Cotnari meteorological station for the period 1961-2020 and analyzed the evolution of the thermo-pluviometric parameters on interdecadal and interannual periods. We then applied the Mann-Kendall test combined with Sen's slope to estimate the trend over the reference period. Following

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these analyses, in Cotnari, taking as a reference the average annual temperature of 9.6°C and the average annual amount of precipitation of 543.8 mm, we found that after the year 2000, the trend of these two elements was positive, which shows an increase in air temperature and quantitative atmospheric precipitation. In total, the annual thermal averages increased statistically significantly by 0.33°C/decade. Annual precipitation increased during 1961–2020 by 2.2 mm/decade and showed modest statistical significance.

Key words: Cotnari, decennial period, air temperature trend, Mann-Kendall test

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INTRODUCTION

The analysis of temperature and atmospheric precipitation parameters, knowledge of their trends, is of scientific and practical interest. At the level of the European continent, climate analysis report (IPCC 1. , 2013) and climate change highlight the increase in air temperature by more than 1 °C (1880-2012) compared to the global average increase of 0.85 °C, the intensification of episodes of torrential precipitation, and the droughts became more intense, covered larger areas and longer periods of time, especially after 1970.

The (IPCC 2. , 2022) report mentions the increasing trend of heat waves in Central Europe (2003, 2007, 2020, 2014, 2020, 2021, 2022), the high frequency of warm days and nights especially in the transitional seasons: spring and autumn. The high variability of atmospheric precipitation, the magnitude and the sign of the observed trends, however, depend on the study region and the analyzed time interval. (Blöschl, et al., 2017), (Blöschl, et al., 2020) noted that in Central Europe, in the last three decades (1990-2019), summers with extreme temperature values and torrential precipitation also had the highest number of floods in the last 500 years (55% flood frequency). A warming climate brings changes in the frequency and intensity of natural processes and phenomena: late winter storms, rapid warming and sudden melting of snow, lack of water in the soil. Specialized studies have highlighted characteristic features for the climate in the northern half of the Moldavian Plateau. (Mihăilă & Briciu, 2012), highlighted, based on the analysis of the thermal and pluviometric trends of the climate in the north-eastern region of Romania, a slight warming of it. (Piticar, 2013) mentions the increase of the average annual temperature in the north-east of Romania, between 1961-2010, by 0.16 - 0.33°C/decade and an average of 0.25°C/decade for the four meteorological stations. (Cotnari 0,27°C, Roman 0,27°C, Botoşani 0,23°C, Iaşi 0,25°C). In the Siretului Corridor, (Sfîca, 2015) for the Roman weather station, highlighted a linear trend of temperature increase by 0.88°C/century, and precipitation did not show a clear trend from his analyses. (Bojariu, și alții, 2015), found significant statistical increases in the average air temperature in the north-east of the country, in the interval 1961-2013 for the Botoşani, Cotnari, Iași, Roman stations in the winter, summer and spring seasons. Autumn stood out as the only thermally stationary season. In the space between the Carpathians and the Dniester (Jibu & Mihăilă, 2021) highlighted a general warming trend, the average annual temperature increase during the period 1961-2010 for the meteorological station Iași being 0.27 °C / decade. Regarding thermal extremes, the decrease in the number of frosty days and the increase in the number of heat waves in the northeast of the country are confirmed by: (Busuioc, et al., 2014), (Croitoru & Piticar, 2012), (Dumitrescu, et al., 2014), (Marin, et al., 2014). In the case of precipitation amounts, they showed a linear trend of decrease in winter, while in summer they were stationary (Apostol, 2004); (Mihaila, 2006). (Piticar, 2013) mentions, based on some statistical tests, the upward trend of atmospheric precipitation in the north-east of Romania, in the period 1961-2010, and the extreme changes in terms of their intensity and frequency. The

precipitation trend was increasing, between 5.40 - 18.21 mm / decade, in the summers and autumns. Only in Iasi was recorded a decrease in the amount of precipitation by -11.02 mm/decade. Analysis of trends in seasonal rainfall variability for the interval 1961-2013 (Bojariu, et al., 2015), reveals statistically insignificant increases at Botoşani, Cotnari, Iasi and Roman stations, the regime being a stable one (Jibu & Mihăilă, 2021), researched the spatial distribution and evolution of the water balance in the territory between Carpathians and Dniester, for the period 1961-2010. According to this study, the climate of the region between Carpathians and Dniester recorded a slight decrease in precipitation. In Iași, precipitation decreased especially in the winter, spring and summer seasons. The present study aims to identify the significance, magnitude and statistical relevance of air temperature and atmospheric precipitation in the period 1961-2020 for the meteorological stations: Cotnari, Botoșani, Iași, Roman located in the northern half of the Moldavian Plateau.

STUDY AREA

By geographical position, the selected stations collect meteorological observations from the contact between the Suceva Plateau and the Moldavian Plain (Cotnari), from the level of the Moldavian Plain (Botoșani, Iași) and from the Siretului Corridor (Roman).

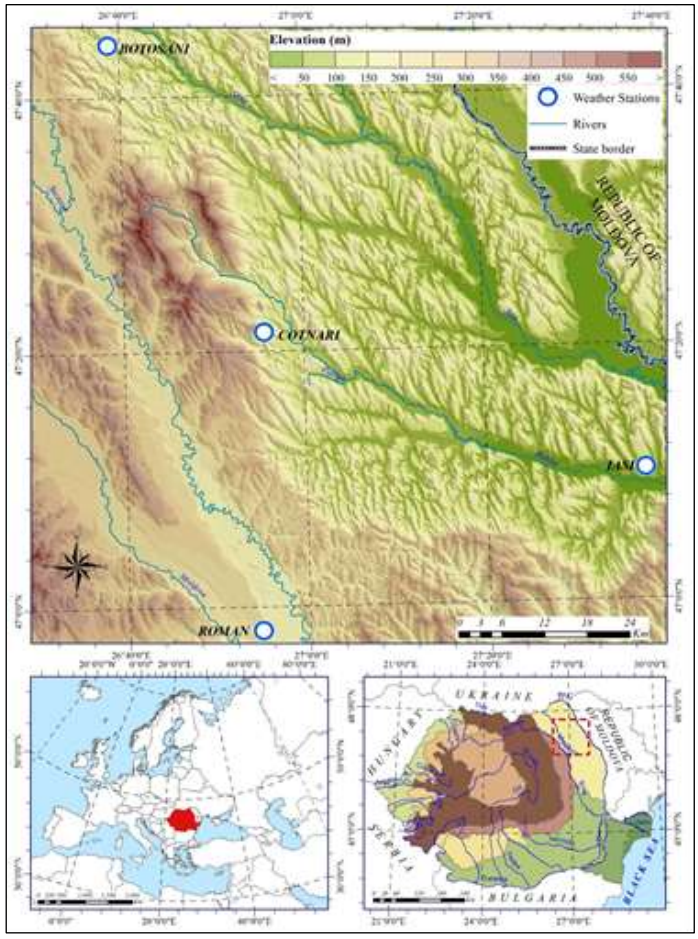

Figure 1. Geographical location of meteorological stations whose data were used in the trend study (Source: Authors)

Details of the weather stations (location, observations) can be found in the supplementary material for the study area (Table A1). The representative area of the study is approximately 2500 km2 and the meteorological station Cotnari occupies a central position (Figure 1). The neighboring stations are located equidistant at approx. 60 km north (Botoşani), southeast (Iaşi), south (Roman).The climatic characteristics of the studied area are the result of the interference of the Eastern European air masses with the Scandinavian-Baltic ones, the type of climate is temperate continental with aridity influences ((Mihaila, 2006), where winters are harsh and cold, and summers have frequent hot and dry intervals in the months of July-August.

DATA AND METHODS

The study is based on the analysis, the chronological series of air temperature and atmospheric precipitation collected at 4 stations in the interval 1961-2020, a representative interval according to WMO recommendations. The results from Cotnari were compared with those from the territorially neighboring stations Botoșani, Roman and Iași. Temperature and precipitation were used to calculate monthly, seasonal, seasonal, annual, and decadal averages (temperature) and mean sums (precipitation). The decadal analysis simplified the meaning to a 10-year time scale and the trend parameters of the two meteorological elements over the 60 years. The year-to-year analysis and the one based on the statistical tests reinforced in detail the meanings and the magnitude of the trends.

In determining the increasing or decreasing trend of the two elements (temperature, precipitation) a special emphasis was placed on the Mann-Kendall tests (Mann, 1945); (Kendall, 1975), combined with the Sen (Q) slope, developed by researchers of of the Finnish Meteorological Institute ((Salmi, și alții, 2002) in the MAKESENS calculation program. In these tests the statistical significance (S) levels α are: 0.001 / ***, 0.01 / **, 0.05 / * and 0.1 / +. The major advantage in applying Mann-Kendall tests is that the data do not need to be associated with a particular distribution.

RESULTS AND DISCUSSIONS

Trend in air temperature

Information about the basal thermal statistics of the investigated area can be found in the supplementary material - Thermal characteristics (Tables A2 and A3).

The main source of atmospheric air heating is solar radiation, but the transformation of this energy into heat is achieved through the active surface. The climatic parameters through which we analyzed the air temperature regime are: the annual and monthly averages, the extreme values, the duration of the intervals with characteristic values, calculated from the data of meteorological observations from the interval 1961-2020.

Trend of average air temperature over the interdecanal period

Considering the thermal context in the four meteorological stations, in the period 1961- 2020 (Tables A2 and A3), by analyzing the interdecadal trend of the average temperature (annually, from the months of January and respectively July in Cotnari) and its trends, reproduced in Figure 2, I highlighted several aspects.

All three thermal parameters (averages with the lowest values, averages, averages with the highest values) registered a continuous increase during the six decades at all the analyzed stations. The thermal increases of the annual values between the extreme decades (1961-1970 / 2011-2020) were between 2.1 ºC (Cotnari, Botoșani, Roman) and 1.9 ºC in Iași (Figure 2, Figures A1 a, b and c – the supplementary material).

The most pronounced thermal increase was recorded in January in Iași from -5.3 ºC / 1961-1970 to - 1.5 ºC in 2011-2020, followed by Botoșani, Roman (3.7 ºC) and Cotnari (3.2 ºC). In July, the increases were 2-2.5 ºC (Figure 2, Figures A1 a, b and c - supplementary material). At the level of the temporary sets of minimum and maximum annual temperature, from January and July in

Cotnari, the trend was warming throughout the period 1961-2020, an aspect also observed by analyzing Figures 3a and 3b.

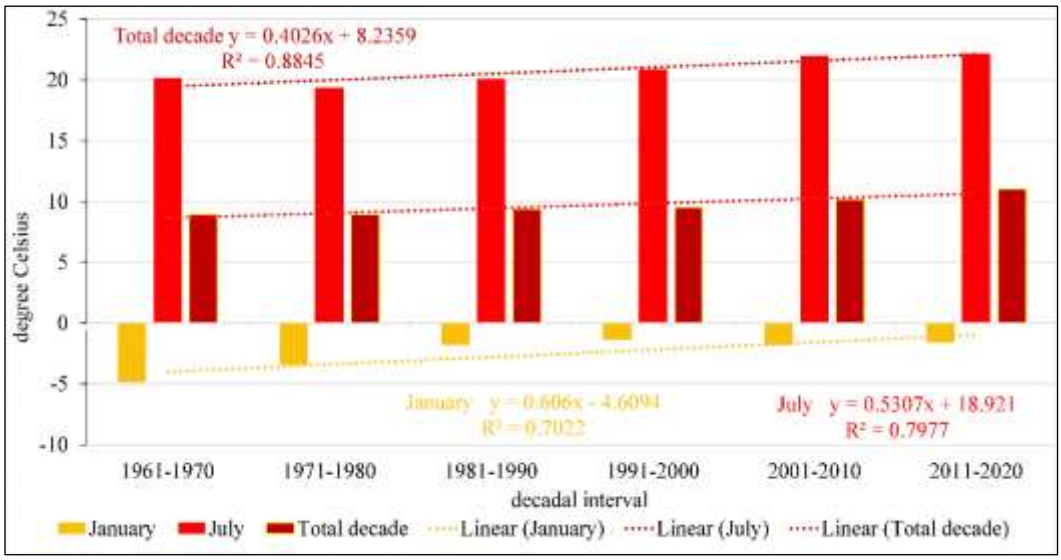

Figure 2. The interdecadal regime of the average annual temperature (ºC), from the coldest month and from the warmest month of the year at Cotnari between 1961 and 2020.
(Source: Authors)

At the level of the temporary sets of minimum and maximum annual temperature, from January and July in Cotnari, the trend was warming throughout the period 1961-2020, an aspect also observed by analyzing Figures 3a and Figures 3b.

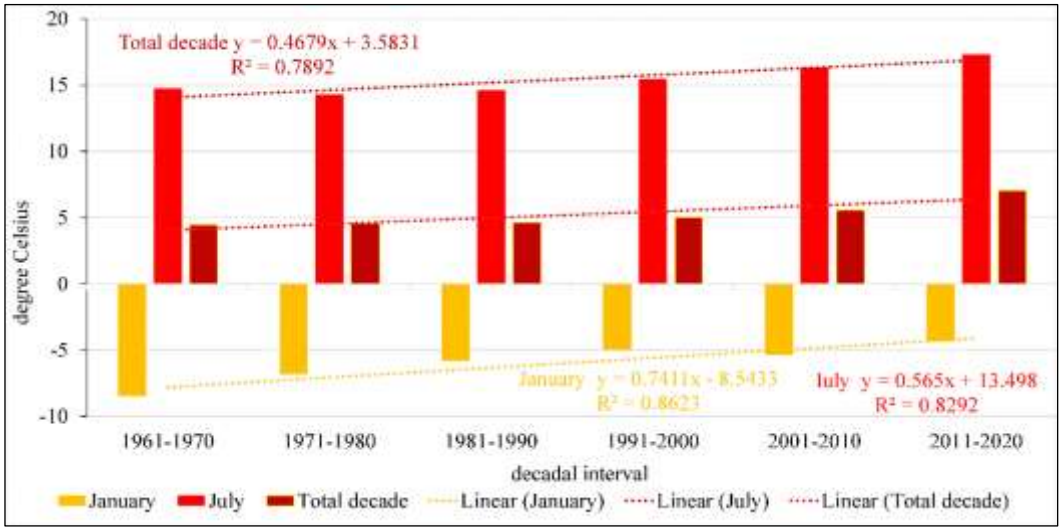

Figure 3a. The interdecadal regime of the minimum temperature from January, July and annual (ºC) at Cotnari between 1961 and 2020.
(Source: Authors)

Interdecanal values of annual minimums were below 5 ºC before 2000 and above 5 ºC after 2000 at Cotnari. At the level of thermal minimums, January remains the month with the largest thermal jumps of 4.2 ºC (-8.5 ºC / 1961-1970; -4.3 ºC / 2011-2020) and in July the thermal jump of minimum values was smaller (Figure 3a).

The interdecadal values of the annual temperature maxima were below 14 ºC before the year 2000 and above 14ºC after 2000. The greatest increase in thermal maxima occurred in January with over 3.1 ºC (-1.8 ºC / 1961-1970; 1, 3 ºC / 2011-2020), this increase in maximums being more attenuated in the decades belonging to July (by 2.3 ºC) (Figure 3b).

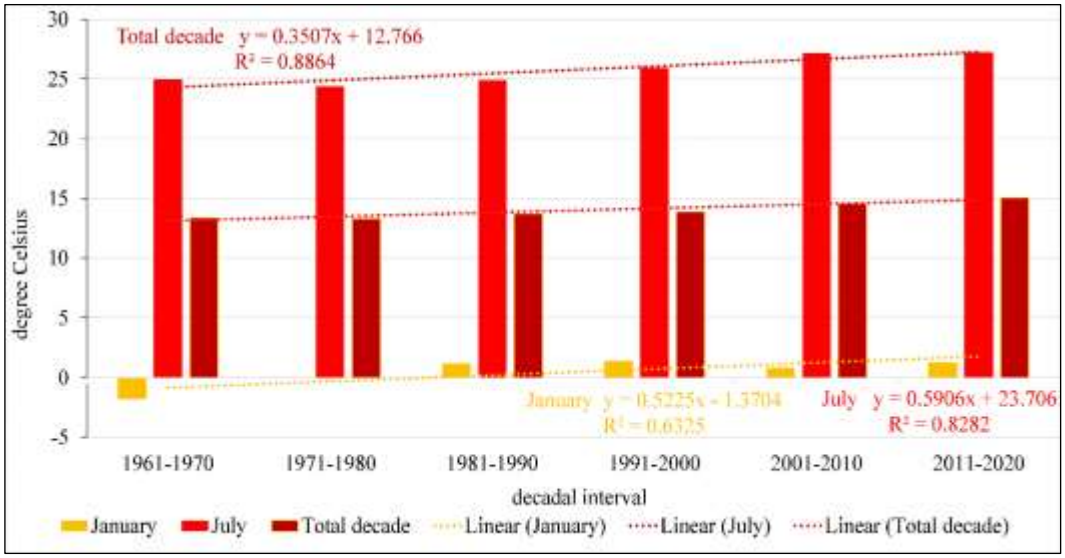

Figure 3b. The interdecadal regime of the maximum temperature from January, July and annual (ºC) at Cotnari between 1961 and 2020.
(Source: Authors)

Air temperature trend on interannual values

Following the analysis of the interannual variability of the average, minimum and maximum annual temperature values at the four weather stations, in the period 1961-2020 and the evolutionary trends of these thermal parameters (presented in Figures 4, A2, A4) - the supplementary material), aspects of general similarity are highlighted.

All three thermal parameters (annual averages - Figure 4, minimums - Figure A2 and annual maximums - Figure A4) registered an increase during the sixty years at the four analyzed stations. On average annual temperature values (Figure 4), compared to the multiannual averages of the interval 1961-2020 (Cotnari 9.6 ºC, Botoşani 9.5 ºC, Iaşi 9.9 ºC, Roman 9.1 ºC), the last five years (2015-2020) were distinguished by important annual average thermal increases, so that at the four stations, the thermal averages exceeded 11.0ºC. For 2020, the average thermal values were 12.3 ºC in Iaşi, 12 ºC in Cotnari and 11.7 ºC in Botoşani and Roman.

Detailing the average monthly values in Cotnari, figure 5 shows a pronounced thermal variability for the month of January from -11.4 ºC/1963 to 5 ºC/2007 (Figure 5).

For the month of July, on average monthly values, a lower thermal variability is observed in Cotnari (6.8 ºC-7.3 ºC) from 17.8 ºC / 1984 to 24.7 ºC/2012 Cotnari (Figure 5).

A pronounced thermal variability, related to the dynamics of air masses during the winter, we notice in Cotnari for the thermal minimums and maximums in January (Figure A3 and Figure A5). All variability is grafted onto an upward thermal trend. In July, the variability of thermal minimums and maximums is attenuated against the background of the dominance of anticyclonic time (Figures A3 and A5), but the increasing temperature trend is preserved.

A warming trend is evident throughout the study area and period. The warming trend is observed by analyzing all thermal parameters and at all meteorological stations analyzed.

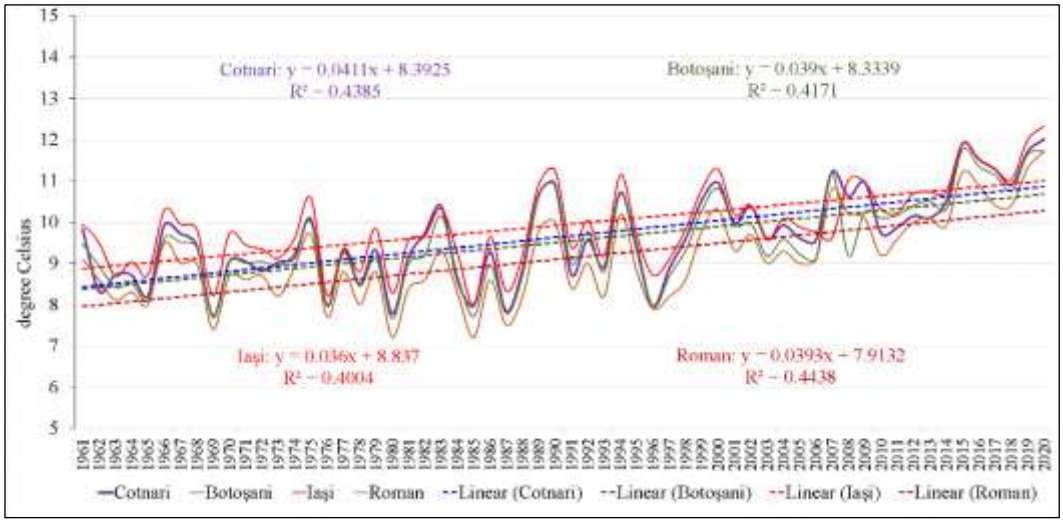

Figure 4. The annual regime of the annual average temperature (°C), at Cotnari, Botoşani, Iași and Roman between 1961 and 2020 and the evolutionary trends of this parameter.
(Source: Authors)

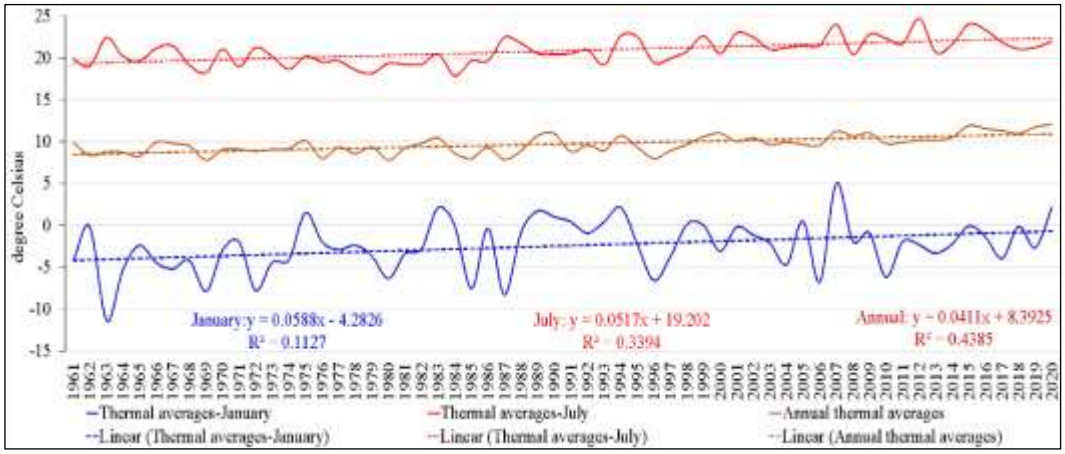

Figure 5. The inannual regime of the annual average temperature, from January and July (°C) at Cotnari between 1961 and 2020 and the evolutionary trends of this parameter.
(Source: Authors)

Trends in the evolution of the number of frosty nights and tropical days

Frosty nights (with minimum temperature ≤ -10 ºC) can occur between November and March, with January accumulating over 40% of the annual average. Among the four weather

stations, Cotnari records the least number of frosty nights per year, with an average of 15 frosty nights over the entire period 1961-2020, while the neighboring weather stations have an annual average of 18-19 frosty nights (Table 1). These results can be explained at Roman by the role of the Siret Valley in the thermal stratification of the air and the increase in the number of frosty nights on the lower river terraces, compared to the hilly heights of Cotnari, where air dynamics are more pronounced and is the place where air heating is favored on the eastern slopes (Sfîca, 2015).

Table 1. Average monthly and annual number of frosty nights (minimum temperature ≤ -10 ºC) at Cotnari, Botoșani, Iași, Roman stations during 1961-2020
(Sourse: Authors)

Station	I	II	III	IV	VI	VII	VIII	IX	X	XI	XII	Annual
Cotnari	6.7	4.2	0.8	-	-	-	-	-	-	0.4	3.1	15.1
Botoşani	8.1	5.2	1.3	-	-	-	-	-	-	0.6	4.1	19.3
Iaşi	7.7	4.8	1.3	-	-	-	-	-	-	0.5	3.8	18.0
Roman	7.9	5.5	1.4	-	-		-	-	-	0.7	4.0	19.4

The analysis of the interdecadal evolution of the monthly number of frosty nights highlights a reduction in the number of frosty nights at the four considered stations. The cumulative number of frosty nights decreases from the decade 1961-1970 (from 230 frosty nights in Cotnari, 278 in Botoșani, 250 in Iași, 277 in Roman) to the decade 2011-2020 (to 96 frosty nights in Botoșani and Cotnari), Iași, Roman (Figure 6 and Figures A 6a, b, c - the supplementary material).

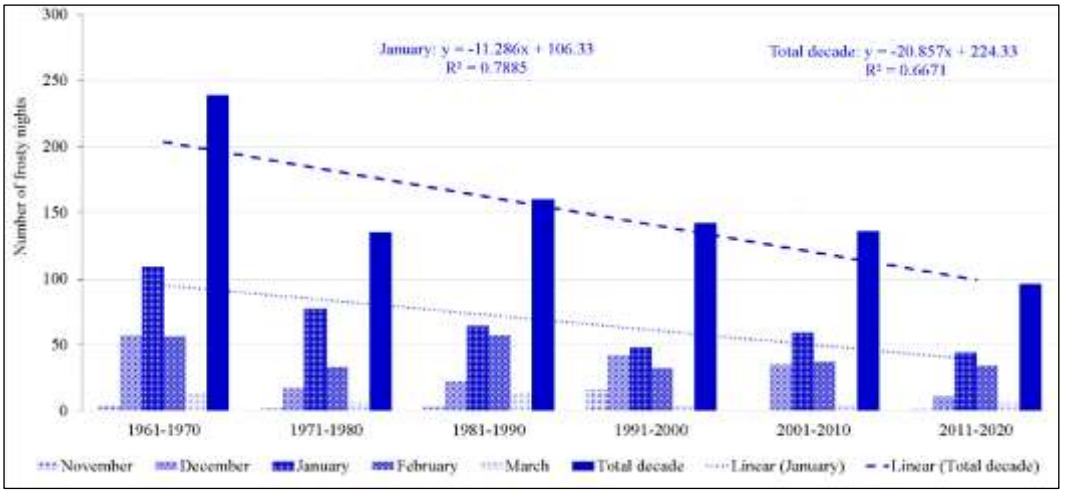

Figure 6. The interdecadal regime of the monthly number of frosty nights in Cotnari from November to March in 1961-2020 and the evolutionary trends of this parameter.
(Source: Authors)

Table 2. The average monthly and annual number of tropical days (maximum temperature ≥ 30 ºC) at Cotnari, Botoșani, Iași, Roman stations between 1961-2020
(Sourse: Authors)

Station	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Annual
Cotnari	-	-	-	0.0	0.6	2.3	4.9	4.9	0.7	0.0	0.0	-	13.5
Botoşani	-	-	-	0.1	1.0	3.9	6.6	6.5	1.3	0.1	0.1	-	19.4
Iaşi	-	-	-	0.1	1.6	6.0	9.5	9.6	2.0	0.0	0.1	-	28.8
Roman	-	-	-	0.1	0.9	3.5	6.3	6.5	1.1	0.0	0.1	-	18.5

Tropical days (maximum temperature ≥ 30 ºC) are specific to the warm season, the favorable interval for reaching and exceeding these thermal thresholds is May-September. The high incidence of tropical days occurs in the months of July and August, with an average of 5 days in Cotnari, 6 - 7 in Botoşani and Roman and 9 - 10 days in Iași. The average annual number of tropical days is 13.5 days in Cotnari and exceeds 28 days in Iași (Table 2).

Analysis of the interdecal regime of the monthly/annual number of tropical days (maximum temperature ≥ 30ºC) reveals a steady increase in the number of monthly and annual days reaching or exceeding the specified thermal threshold after 1970. Thus, in the interval 1971-1980, a cumulative number of 45 tropical days was recorded in Cotnari - Figure 7, 62 in Botoşani, 79 in Roman and 114 in Iași - Figure 7a, b, c. In the decade 2011-2020, 245 tropical days were cumulated at Cotnari – Figure 7, over 300 tropical days at Botoşani, Roman and 508 tropical days at Iasi (Figure A 7a, b, c – the supplementary material).

Figure 7. The interdecadal regime of the monthly number of tropical days at Cotnari from May to September in the interval 1961-2020 and the evolutionary trends of this parameter.
(Source: Authors)

Analysis of pluviometric trends

Information on the basal statistics of the area pluvometry can be found in the pluviometry characteristics - the supplementary material and Tables A4 and A5.

Interdecenal pluviometric trends

The analysis of the interdecadal trends of atmospheric precipitation (annually, from the months of January and June respectively) and the trends of the three variables, presented in Figure 8 and 8a, 8b, 8c, highlight some particularities. During the six ten-year intervals, from the 4 representations, an inconsistency in the meaning of atmospheric precipitation trends during the period 1961-2020 for the 4 stations is observed. Decades 7 and 9 of the 20th century and 2 of the 21st century were characterized by a pluviometric deficit, and the other decades recorded a pluviometric plus (Figures 8, Aa, b, c – the supplementary material). In Cotnari, the surplus years after 1990 (1991-1996, 1998, 2008, 2014, 2016-2020) represent 1/3 of the study period, with an average amount of precipitation of 660 mm / year. This situation imposed a general trend of interdecadal growth at Cotnari, which is not repeated at the neighboring weather stations Botoşani, Iaşi and Roman (Figure A 8 a, b, c - the supplementary material). The interdecadal trends of rainfall increase are evident in Cotnari, through an average increase of 24.1 mm / decade (Figure 8), while in Iaşi the rainfall registered a decrease of 12.2 mm between the first and last decade of the studied

interval (Figure A8b – the supplementary material). A moderate interdecadal trend of increase in atmospheric precipitation is observed in Roman and more attenuated in Botoșani (Figures A 8c and a - the supplementary material).

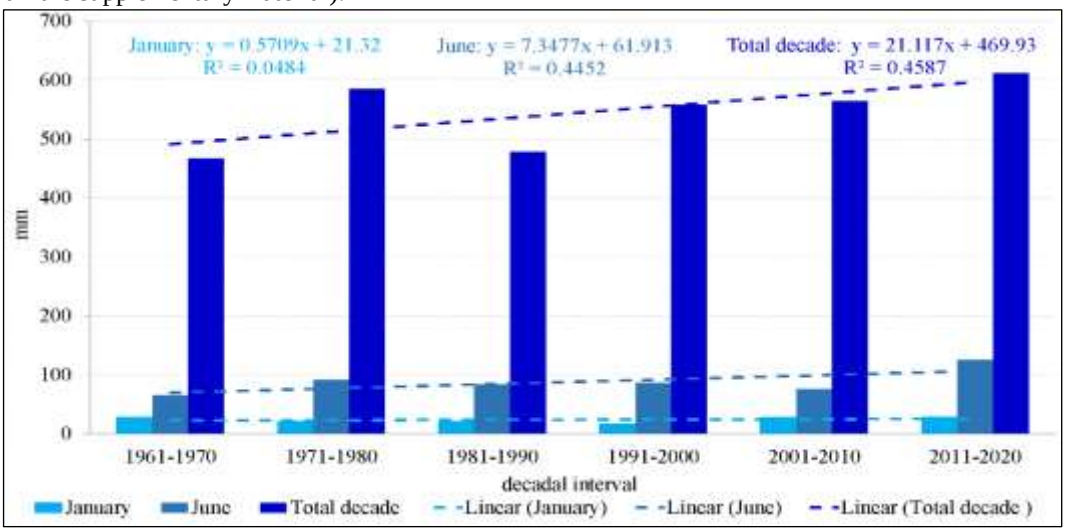

Figure 8. The interdecenal regime of the annual amounts, from January and June of their precipitation (mm) at Cotnari in the period 1961-2020 and the evolutionary trends of this parameter.
(Source: Authors)

For months, quantitative increases are evident in June. In Cotnari, the average amount of precipitation doubled in June (from 64.5 mm in the period 1961-1970 to 125 mm in the last decade 2011-2020) (Figure 8). In January the increases were imperceptible. The interdecadal trends of rainfall increase are mitigated in Botoșani (5.1 mm / decade in the interval 1961-2020) compared to the results obtained by (Piticar, 2013), who mentioned an increase of 12.3 mm / decade in the interval 1961-2010. This aspect is explained by the decrease in precipitation after 2010.

Precipitation trend on interannual values

Peculiarities regarding the specificity of the atmospheric precipitation regime result from the analysis of the annual fluctuationsof the annual and monthly quantities (January and June) of the precipitations for the period 1961-2020 and from their trends (Figure 9). The interannual regime and the trends of the annual amounts of precipitation registered, from a statistical point of view, an increase in Cotnari, Roman, lower in Botoșani, with the exception of the Iași station, where the tendency was to decrease. In average annual values, precipitation increases were between 2.4 mm / year in Cotnari, 1.2 mm/year in Botoșani and Roman, and the decrease was in Iași by -1.2 mm / year (Figure A9- the supplementary material). In many years, large amounts of precipitation fell in short periods of time, were accompanied by storms and had a torrential character due to the intensification of thermal convection of the air, which led to intervals and years with excess rainwater (1991, 1998, 2001, 2005, 2006, 2008, 2010, 2014, 2016, 2019), followed by intervals and years with water deficiency (1994, 1997, 2000, 2003, 2015, 2020). Although the values of R2 do not have a real statistical significance, they highlight pronounced pluviometric variability for all temporal entities analyzed (Figure 10). The variability of atmospheric precipitation amounts and their trends at the Cotnari, Botoșani and Iași stations is convergent with the distribution mentioned in the specialized literature: (Geografia, 1983); ((Mihaila, 2006). 2/3 of the amount of precipitation is attributed to the warm season, against the background of the dynamics of air masses in the western sector and thermo-dynamic convection. The pluviometric deficit in the months of January and February is attributed to

the invasions of dry and cold continental air with frequent temperature inversions. The heavy rains in June and July are due to westerly circulation, moist air of Atlantic origin and thermodynamic convection that increase the moisture supply.

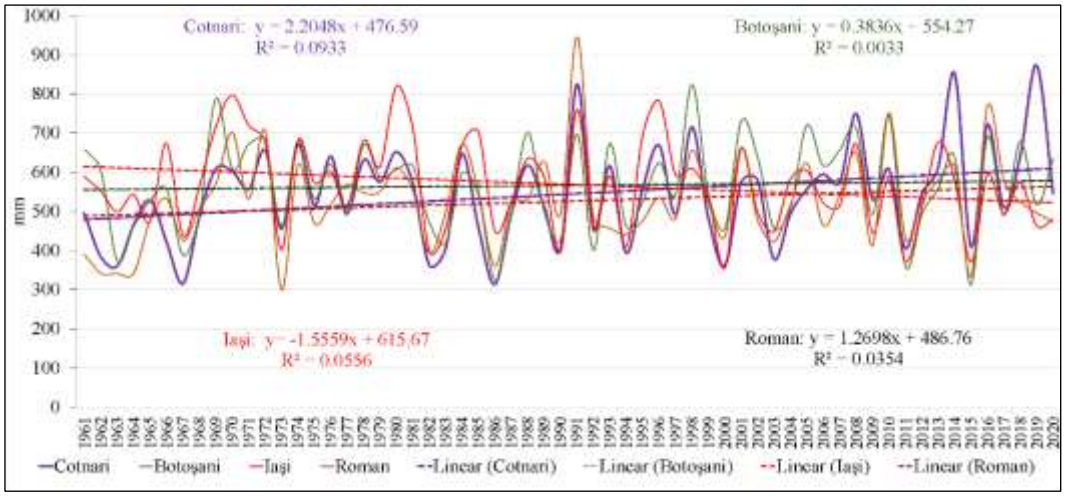

Figure 9. The annual regime of the annual amounts of atmospheric precipitation (mm) at Cotnari, Botoşani, Iaşi, Roman stations in the period 1961-2020 and the evolutionary trends of this parameter.
(Source: Authors)

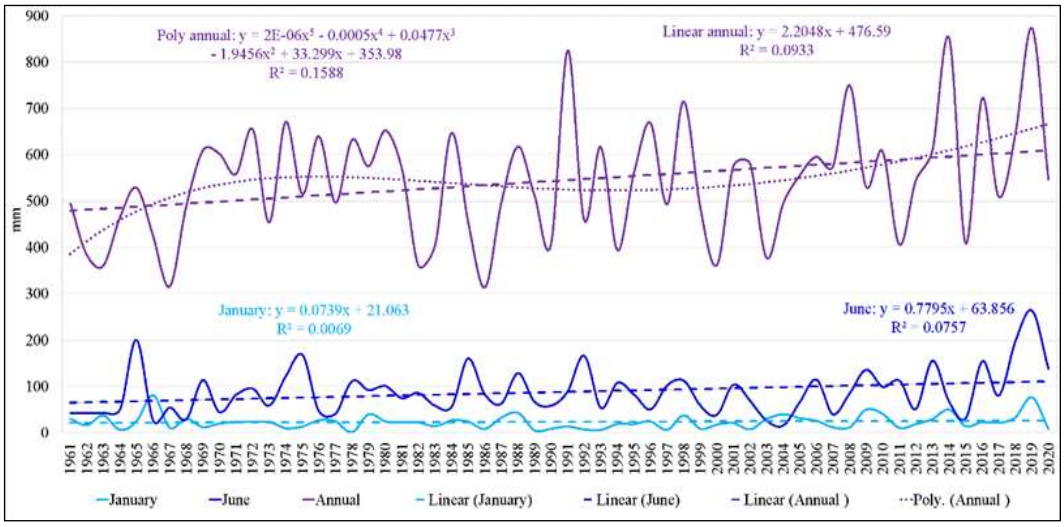

Figure 10. The annual regime of the annual and monthly amounts (January and June) of precipitation (mm) at the Cotnari meteorological station during 1961–2020 and the trends of this parameter.
(Source: Authors)

The pluviometric trends of January are negative for Botosani, Iasi and Roman stations and positive for Cotnari station (Figure A9- supplementary material).The rainfall trends in Iași outline a quantitative reduction, for all selected rainfall indicators, in agreement with (Jibu & Mihăilă, 2021). The rainfall trends of June (Figure A10 - supplementary material) are in agreement with the annual ones, the only difference being the lower value scale in which they fall.

Air temperature trends according to the Mann-Kendall test

A more comprehensive picture of air temperature data series trends for different temporal subsets (annual, seasonal, seasonal and monthly) is provided by applying the Mann-Kendall test combined with Sen's slope , at the four stations for the period 1961-2020. A statistically significant increase ($\alpha = 0.001$) in the air temperature (annual and seasonal) is highlighted at all stations taken into account (Table 3). The increase in air temperature is statistically significant and uniform at all stations in spring and summer ($\alpha = 0.001$), winter ($\alpha = 0.01$) and less statistically significant in autumn ($\alpha = 0.05$) (Table 3).

Table 3. Trends in annual, seasonal and seasonal values of average air temperature (°C / decade) at Cotnari, Botoşani, Iași, Roman stations for the period 1961-2020.
(Source: Authors)

The MK test		Annual	Winter	Spring	Summer	Autumn	Cold season	Warm season
Cotnari	S	***	**	***	***	*	***	***
	Q	0.41	0.51	0.51	0.48	0.19	0.40	0.44
Botoşani	S	***	**	***	***	*	***	***
	Q	0.38	0.46	0.42	0.46	0.21	0.37	0.38
Iaşi	S	***	**	***	***	*	***	***
	Q	0.36	0.41	0.37	0.41	0.23	0.35	0.35
Roman	S	***	**	***	***	*	***	***
	Q	0.39	0.45	0.45	0.48	0.25	0.40	0.41

The summer months have a statistically significant increase at the level of the four meteorological stations, an increase explained on the basis of the high frequency of stable meteorological conditions, in an anti-cyclonic regime, the emphasis of dryness and the reduction of humidity in the soil and in the air (Sfîca, 2015). The autumn months show moderate increases without strong statistical significance. The winter months, especially January and February, recorded increases with average statistical significance ($\alpha = 0.05$) against the background of episodes with temperature inversions, accentuating the dryness of winters in the low regions of the Moldavian Plain (Table 4).

Among the spring months, March stands out with a significant growth trend ($\alpha = 0.01$) followed by April and May with a large variation from one station to another, under the influence of local thermo-genetic factors (exposure and inclination of the slopes, proximity to hydrographic units, local air dynamics).

The trends of the thermal extremes were also evaluated, the results being in the expected evolutionary pattern on all tested temporal entities - (Tables A6, A7, A8, A9 - the supplementary material).

Table 4. Trends in the monthly values of the average air temperature (°C / decade) at Cotnari, Botoşani, Iași, Roman stations for the period 1961-2020.
(Source: Authors)

The MK test		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Cotnari	S	*	*	**	**	*	***	***	***				*
	Q	0.5	0.6	0.7	0.5	0.3	0.5	0.5	0.8	0.3	0.2	0.1	0.4
Botoşani	S	*	*	**	*	*	***	***	***	*			+
	Q	0.6	0.5	0.6	0.3	0.3	0.5	0.5	0.5	0.3	0.1	0.1	0.4
Iaşi	S	*	*	**	+		***	***	***	*			*
	Q	0.5	0.5	0.6	0.3	0.2	0.4	0.4	0.6	0.3	0.2	0.1	0.4
Roman	S	*		**	*	*	***	***	***	*	+		*
	Q	0.5	0.6	0.7	0.3	0.3	0.5	0.5	0.6	0.3	0.2	0.1	0.4

Applying the Mann-Kendall test to determine frosty night trends shows a general decrease in the number of frosty nights with slight differences at the four stations during the analysis period (Table 5). Monthly, decreases are recorded in January, February (except Iași) and December.

Table 5. Trends in the monthly number of frosty nights (nights / decade) at Cotnari, Botoşani, Iași, Roman stations for the period 1961-2020.
(Source: Authors)

The MK test		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Annual
Cotnari	S	+	+	+	-	-	-	-	-	-	-	+	+	**
	Q	-0.68	-0.21	0.00	-	-	-	-	-	-	-	0.00	0.00	-1.82
Botoșani	S	+	+	*	-	-	-	-	-	-	-	+	*	**
	Q	-0.71	-0.47	0.00	-	-	-	-	-	-	-	0.00	-0.42	-2.00
Iași	S	+		+	-	-	-	-	-	-	-		+	*
	Q	-0.81	0.00	0.00	-	-	-	-	-	-	-	0.00	-0.42	-1.67
Roman	S	+	+		-	-	-	-	-	-	-	+	*	*
	Q	-0.59	-0.43	0.00	-	-	-	-	-	-	-	0.00	-0.48	-2.05

The increase in the monthly and annual number of tropical days is also demonstrated by the result of applying the Mann-Kendall test for this parameter (Table 6).

Table 6. Trends in the monthly number of tropical days (days / decade) at Cotnari, Botoşani, Iași, Roman stations for the period 1961-2020
(Source: Authors)

The MK test		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Annual
Cotnari	S	-	-	-	-		+	***	***	+	-	-	-	***
	Q	-	-	-	-	0.00	0.00	1.00	1.21	0.00	--	-	-	3.00
Botoșani	S	-	-	-	-	+	***	***	***	*	-	-	-	***
	Q	-	-	-	-	0.00	0.71	1.53	1.83	0.00		-	-	4.55
Iași	S	-	-	-	-		***	***	***	*	-	-	-	***
	Q	-	-	-	-	0.00	1.10	1.70	2.09	0.00	-	-	-	5.81
Roman	S	-	-	-	-		*	***	***	+	-	-	-	***
	Q	-	-	-	-	0.00	0.42	1.09	1.43	0.00	-	-	-	3.33

We observe a statistically significant annual increase in the number of tropical days, for the four stations in the interval 1961-2020, but also for the months of July, August, June, September.

Table 7. Tendințe ale sumelor anuale, sezoniere și anotimpuale ale cantităților de precipitații (mm / deceniu) la stațiile Cotnari, Botoșani, Iași, Roman pentru perioada 1961-2020
(Source: Authors)

The MK test		Annual	Winter	Spring	Summer	Autumn	Cold season	Warm season
Cotnari	S	*						+
	Q	22.17	3.13	6.63	3.76	4.40	3.94	7.99
Botoșani	S							
	Q	5.58	-2.40	-2.09	-4.92	-0.0.06	4.81	-0.50
Iași	S	+	+		+			*
	Q	-5.36	-5.74	-2.48	-7.48	-5.49	-9.25	-10.87
Roman	S							
	Q	9.55	-0.68	1.59	1.12	5.66	6.26	1.53

Precipitation trends according to the mann-kendall test

The analysis of the results of applying the Mann-Kendall test in the case of atmospheric precipitation values shows statistically significant trends of their increase at the annual level.

Decreasing trends are recorded at the Iași stations throughout the year (except October). The trends of slight increases in Cotnari are specific to the months of May and September, and in Botoșani and Roman the increases are statistically insignificant except for the months of October (Tables 7 and 8). At the monthly level, October is distinguished by a statistically significant upward trend (α = 0.01). According to the applied test, the amount of precipitation increased every 10 years in October (in Cotnari September) by 4.9 mm in Roman, 4.8 mm in Botoşani and 5.0 mm in Iași.

Table 8.Trends of the monthly amounts of precipitation amounts (decade mm) at Cotnari, Botoșani, Iași, Roman stations for the period 1961-2020
(Source: Authors)

The MK test		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Cotnari	S					*				***			
	Q	1.3	1.2	0.2	0.7	6.9	-1.8	-2.5	2.6	5.7	7.9	1.2	1.2
Botoșani	S										**		
	Q	-0.6	0.6	0.0	-1.2	-0.0	-1.6	-2.9	-2.9	2.1	4.8	0.2	-0.7
Iași	S										**		
	Q	-0.6	-1.4	-0.5	-1.7	-0.3	-3.2	-5.1	-1.8	-0.5	5.0	-0.7	-0.5
Roman	S										**		
	Q	-0.3	1.0	0.5	0.6	1.4	3.0	0.1	-1.8	2.8	4.9	0.7	0.5

Even if the results regarding precipitation trends do not lead to a specific direction, they are convergent with those highlighted by previous studies for Moldova or for all of Romania by : (Busuioc, et al., 2014) or by (Croitoru & Piticar, 2012) et al. (2012b). The variability of precipitation amounts led in some situations to a succession of deficit years (1961-1965; 1999-2001), surpluses (1968-1972) or stationary pluviometric years (1970-1980) for the Romanian station (Ciulache & Ionac, 1993), 1993, cited by (Sfîca, 2015). The cold season showed a clear trend of decreasing amounts of precipitation in Iași (α = 0.05) and the extreme seasons, winter and summer, also (α = 0.1), in agreement with those observed for Moldova de . The clearest exception was the Cotnari station, with increasing annual precipitation amounts and good statistical assurance.

CONCLUSION

The air temperature at Cotnari and nearby stations registered a statistically significant increase in the period 1961-2020 for all methods of analysis addressed: interdecadal and interannual analysis with the author of linear trends and, analysis throughout the period, in a compact manner, by means of Mann Kendall tests. On all temporal samples analyzed (from decade to month) the increase in temperature was clear and unequivocal. The increase was indicated by the trends of all thermal indicators taken into analysis (averages, thermal extremes, categories of days or nights with a certain thermal specificity, etc.). The annual temperature increased on averages during the analyzed period with values between 0.41°C / decade at Cotnari and 0.36°C / decade in Iași. On the seasons, the average air temperature increased the most during the winter with values between 0.51°C/ decade at Cotnari and 0.41°C/ decade in Iași. In August, the temperature averages increased the most, with values ranging from 0.8°C/ decade at Cotnari and 0.5°C/ decade at Botoșani. The increasing trends in values are also highlighted in the case of the minimum temperature values, as well as the maximum ones (annual, seasonal, seasonal, monthly). During the study period, a statistically significant decrease in the number of frosty nights (by two nights/decade) and an increase in the number of tropical days was observed in all data series for all four meteorological stations (the annual number of tropical days of increased by 3 / decade in Cotnari and 5.8 / decade in Iași).

The analysis of the pluviometric trend at the decennial and interannual level through linear trends clearly indicates the increase in the amount of precipitation in Cotnari and the decrease in Iași. The results of the statistical tests indicate an increase in the annual amounts of precipitation by

22.17 mm/decade during the entire period in Cotnari and a decrease by 4.8 mm/decade in Iași. In the warm season of the year (April-September) the increase was of 7.99 mm / decade for Cotnari, and the decrease was of 10.87 mm / decade for Iași. At the other two stations, the increase in precipitation amounts over different time intervals has no statistical assurance. On Monday, statistical trends of increased precipitation were outlined for September at Cotnari and for October at the other 3 stations.

Unfortunately, the clear trend of temperature increase combined with slightly increasing precipitation in Cotnari and Roman, almost stationary in Botoșani and decreasing in Iași, but which are unevenly distributed over time, negatively affects the trends of the water balance, which tends to be more frequent to the deficit.

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