THE RAINY AND DROUGHT YEARS OF THE PERIOD 1961-2021, IN ORADEA

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RESEARCH ARTICLE

Abstract
To highlight the rainy, normal and drought years at the Oradea meteorological station, the annual amounts of precipitation were analyzed for the period 1961-2021 (61 years), using the method of Standardized Precipitation Anomaly (SPA). The method highlighted the positive and negative annual anomalies of precipitation. Later, based on the percentile method, the intervals of climatic risk associated with the excess or deficit of precipitation were established. The decennial amounts of precipitation were also analyzed, as well as the polynomial and linear trend of the annual SPA values. The result was that in Oradea, during the period 1961-2021, the annual amounts of precipitation showed a slight increase. The rainiest decade was the 5th (2001-2010), and the driest decade was the 6th (2011-2020). Most of the extremely dry/rainy years occurred in the 1990-2021 interval, which coincides with the increase in the frequency of climatic extremes in recent years, reported at the planetary level. Using the percentile method, 9 intervals of pluviometric risk were established. Thus, the very high risk generated by excess can occur from annual SPA values higher than +1.56 and annual amounts of precipitation over 800 mm. The very high risk generated by deficit can occur from annual SPA values lower than -1.35 and annual amounts of precipitation below 450 mm. The interval without risk is represented by annual SPA values between -0.29 and +0.15 and annual amounts of precipitation between 578 and 630 mm.

Keywords: standardized precipitation anomaly; precipitation excess; precipitation deficit; climate risk; trend.
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INTRODUCTION

Oradea City is the residence of Bihor County and is located in western Romania, along the Crișul Repede River. The city is located in the contact region of the Crișurilor Plain with the Piedmont Hills of Oradea. The Hills of Oradea, with altitudes of about 300 m, are situated in the north-east of the city, part of the city's hearth being located on these hills. The Crișurilor Plain stretches to the west, north-west and south, being characterized by its smooth relief. The Oradea-Bratca Depression opens to the east, drained by the Crișul Repede River. It falls into the category of "gulf-depressions", which are typical of the western limit of the Apuseni Mountains (Pop, 2000, 2005; Posea, 1997; Șerban, 2010).

The climate of Oradea City is temperate-continental, with predominant oceanic influences, typical of north-western Romania (Bogdan & Niculescu, 1999).

In recent years, due to the global warming of the earth's atmosphere, the rains fall more and more unevenly during the year. Thus, the heavy rains falling in short intervals of time, which cause the precipitation excess, but also the droughts are increasingly intense and frequent. This situation also occurs in the territory of Oradea City and the surrounding agricultural lands. These phenomena have negative effects on agriculture, forestry, underground and surface water reserves, electricity production, etc., in a word on the local economy. The increasingly intense humidity excess and droughts represent increasing risks for the population, but also for biodiversity.

The study of these two phenomena – drought and humidity excess – has been done for a long time, being among the most studied climatic phenomena. Thus, in Romania they were studied starting with C. Donciu, N. Topor, continuing with O. Bogdan, C. Dragotă and many others, until the recent studies of different authors. Among the more recent studies of the foreign authors, we list those of Apurv et al. (2017), Luo et al. (2017), Dai & Zhao (2017), Mukherjee et al. (2018), Christian et al. (2021), Naumann et al. (2021) and so on.

MATERIAL AND METHOD

In the present paper, the meteorological data related to the annual amounts of precipitation were used, from the Oradea meteorological station, for the period 1961-2021 (61 years).

The Oradea weather station is located at an altitude of 137 m, having the code 15080 and the following geographic coordinates: 47°02' N latitude, 21°53' E longitude. It is situated in the south-west of the city, in open land covered with cultivated vegetation, near the Oradea-Arad road and the Oradea airport (Șerban, 2010).

To highlight the rainy, normal and drought years at the Oradea meteorological station, the annual amounts of precipitation were analyzed using *the method of Standardized Precipitation Anomaly (SPA)*.

By means of this method of calculation, positive and negative annual precipitation anomalies are highlighted. Based on them, intervals of climatic risk associated with the excess or deficit of precipitation can be established.

The annual standardized precipitation anomalies were calculated with the following formula (Busuioc, 1992):

$$SPA = (x - \bar{x}) / \sigma \qquad \sigma = \sqrt{\frac{\sum_{i=1}^{n} (x_i - \bar{x})^2}{n-1}}$$

where:

$\bar{x}$ - the multiannual average amount of precipitation;

x - the amount of precipitation of a particular year;

σ - the standard deviation (average quadratic deviation) of the annual amount of precipitation;

n - the length of the data set.

The analysis of precipitation using the SPA method is often found in the specialized literature, the authors assigning different pluviometric ratings to the years/months, from "exceptionally rainy" to "exceptionally dry". The thresholds chosen between the classes of values differ from one author to another (Kutiel & Paz, 1998, Maheras et al., 1999, Păltineanu et al., 2000, Dumitraşcu et al., 2002, quoted by Cheval & Dragne, 2003; Holobâcă, 2010; etc.). As a result, for a better highlighting of the risk intervals, *the percentile method* was used to establish the thresholds between the pluviometric ratings, a method considered more efficient (Busuioc, personal communication; Şerban et al., 2008; Şerban, 2010, 2015, 2016; Şerban & Dragotă, 2014; etc.). The method is based on the ascending ordering of the *n* values from a data set and dividing them into a number of *k* equal parts (*n/k*) (Ţarcă, 1998, quoted by Dragotă et al., 2003).

Thus, 10 classes of values were established for the annual SPA. For example, the SPA values of the 90-100% class represented the "extremely rainy" years and the interval of very high risk generated by surplus, and the values of the 0-10% class, the "extremely dry" years and the interval of very high risk generated by deficit. The SPA values of the 40-50% and 50-60% classes represented the "normal" years and the risk-free interval.

All the meteorological data used in the paper came from the database of the National Meteorological Administration of Romania and from the website www.meteomanz.com.

RESULTS AND DISCUSSIONS

The annual amounts of precipitation

At the Oradea meteorological station, the multiannual average amount of precipitation was ***612.7 mm,*** in the period 1961-2021.

The multiannual average precipitation value is slightly higher than at other meteorological stations in the Crișurilor Plain, due to the positioning of the Oradea station at the contact of the plain with the hills, where the oceanic air masses, coming from western Europe, rich in moisture, are forced to escalate the landforms. This forced upward movement contributes to the intensification of cloudiness and, therefore, to the increase of precipitation amounts on the slopes exposed to the advections of air masses.

During the period 1961-2021, the annual amounts of precipitation oscillated between 364.2 mm (in the year 2000) and 884.0 mm (in the year 1996) (Figure 1). The highest amounts of precipitation exceeded 750 mm. There are 8 years with more than 750 mm of precipitation. These are the rainiest years, when the cyclonic activity persisted. Five of them recorded very high amounts, over 800 mm. Most of these years were reported in the period 1996-2010.

The lowest annual amounts of precipitation were ≤ 450 mm. There are 6 years with amounts ≤ 450 mm. These are the driest years, when the anticyclonic activity predominated. Most of them were reported in the period 1990-2021. Only one year recorded a value below 400 mm. It is the year 2000, which stands out for its very low value compared to the values of the other years.

It should be noted that *both the rainiest years and the driest years occurred in the second half of the analyzed period, i.e. in 1990-2021.*

Figure 1 also shows the linear trend of the annual precipitation amounts. During the period 1961-2021, precipitation showed a slight *increase* in Oradea. The upward trend is due to the higher values since 1996. The cause lies in the increase in air temperature in recent decades, which has amplified the thermal convection.

The decennial amounts of precipitation

In order to highlight the distribution of precipitation over the 6 decades of the analyzed period, the annual amounts were averaged over each decade. The maximum and minimum annual amount from each decade was also extracted (Figure 2).

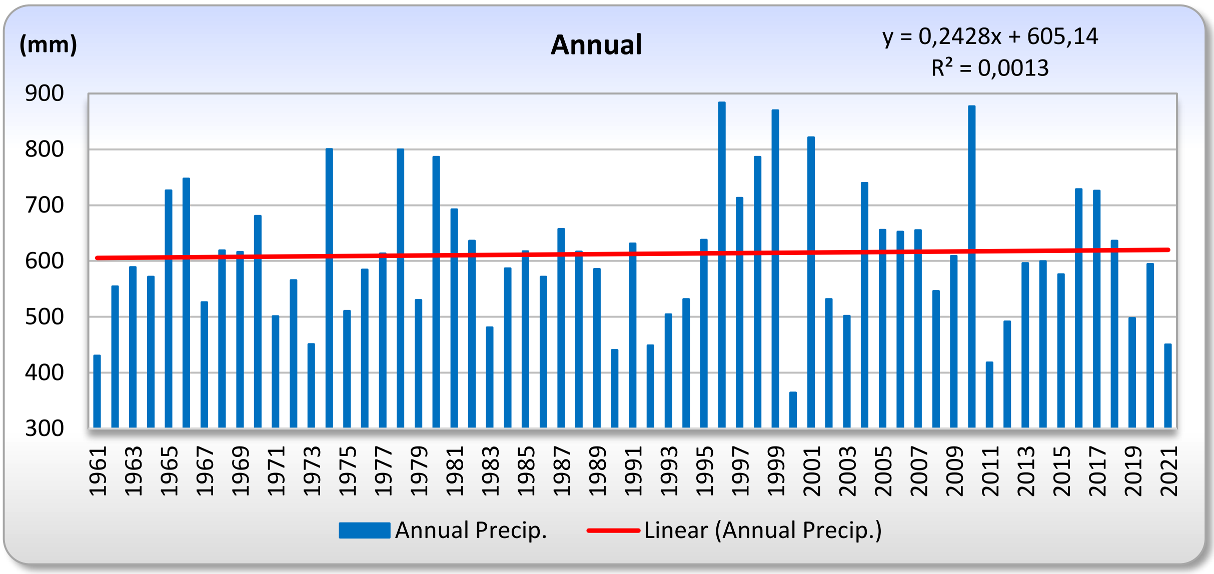

Figure 1 **The annual amounts of precipitation and their linear trend, at the Oradea meteorological station (1961-2021)**

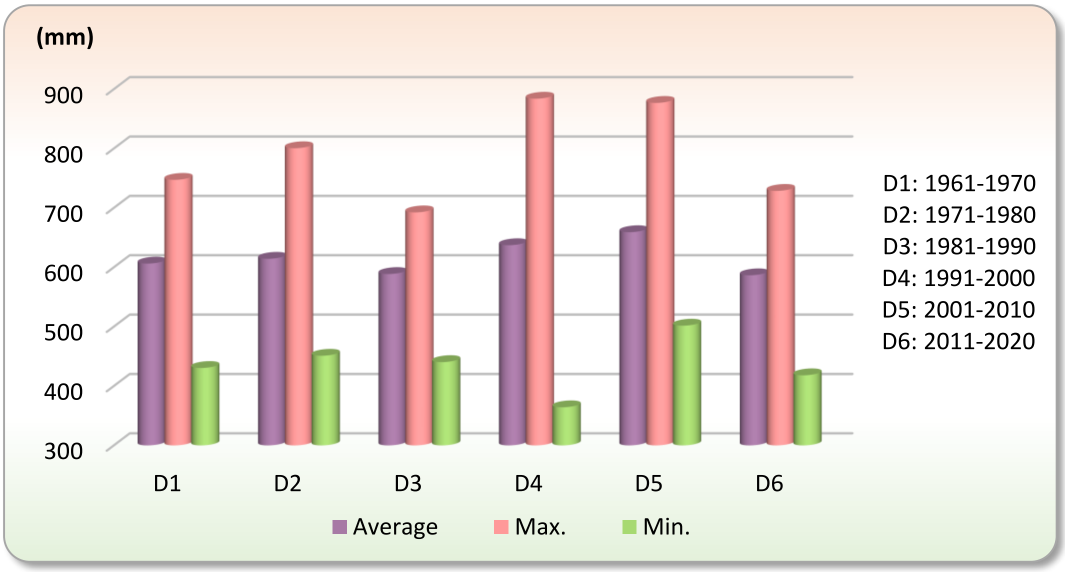

Figure 2 **The average, the maximum and the minimum of the annual precipitation amounts for the six decades of the period 1961-2020, at the Oradea meteorological station**

The result was that the rainiest decade was the 5th (D5), followed by D4 and D2, and the driest decade was the 6th (D6). The 5th decade (2001–2010) recorded an annual average precipitation amount of 659.1 mm, and the 6th decade (2011–2020), an average amount of 586.6 mm. The 3rd decade (1981-1990) was also dry, having an annual average of 588.7 mm.

Overall, there is a trend of increasing annual average amounts in the first 5 decades and a decrease in them towards the last decade. Thus, *the annual precipitation increased from D1 to D5 by 52.9 mm and decreased from D5 to D6 by 72.5 mm.* It is also noteworthy that after the rainiest decade, the driest decade followed. Both occurred at the end of the analyzed period, showing once again the unevenness of rainfall in recent years.

Regarding the maximum and minimum annual amounts from each decade, it is noted that the 4th decade (1991-2000) recorded both the highest and the lowest annual amount of precipitation.

The annual pluviometric anomalies

Using the percentile method, it was possible to establish the classes of values and the pluviometric ratings of the years of the period 1961-2021, in Oradea (Table 1).

The positive precipitation anomalies of the 90-100% class are between +1.56 and +2.26, and the negative ones of the 0-10% class are between -1.35 and -2.07 (Table 2). It is observed that the positive anomalies reached higher values than the negative ones, a sign that the rainfall surplus of the rainiest years from the period 1961-2021 was more intense than the rainfall deficit of the driest years, in Oradea.

Table 1

Rainy, normal and drought years recorded at the Oradea meteorological station (1961-2021)

<table>
<tr><th>STATION/ YEARS</th><th>Extremely rainy</th><th>Very rainy</th><th>Rainy</th><th>Moderately rainy</th><th>Normal</th></tr>
<tr><td>Oradea</td><td>1996
2010
1999
2001
1974
1978</td><td>1998
1980
1966
2004
2016
1965</td><td>2017
1997
1981
1970
1987
2005</td><td>2007
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1991</td><td rowspan="3">1968
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1977
2009
2014
2013
2020
1963
1984
1989
1976</td></tr>
<tr><th>STATION/ YEARS</th><th>Extremely dry</th><th>Very dry</th><th>Dry</th><th>Moderately dry</th></tr>
<tr><td>Oradea</td><td>2000
2011
1961
1990
1992
2021</td><td>1973
1983
2012
2019
1971
2003</td><td>1993
1975
1967
1979
2002
1994</td><td>2008
1962
1972
1986
1964
2015</td></tr>
</table>

Table 2

The extremely rainy/dry years, the SPA values and the annual precipitation amounts corresponding to those years, at the Oradea meteorological station (1961-2021)

YEARS	Year	SPA value	Precipitation amount (mm)
Extremely rainy	**1996**	+2.26	884.0
	2010	+2.20	876.9
	1999	+2.14	869.7
	2001	+1.74	821.8
	1974	+1.56	800.6
	1978	+1.56	799.7
YEARS	**Year**	**SPA value**	**Precipitation amount (mm)**
Extremely dry	**2000**	-2.07	364.2
	2011	-1.62	418.1
	1961	-1.52	430.4
	1990	-1.43	440.3
	1992	-1.36	449.0
	2021	-1.35	450.8

As specified above, the rainiest year was ***1996,*** and the driest was ***2000.*** Most of the extreme years occurred in the 1990-2021 interval. The year 2000 was an extremely dry year throughout the country, with major negative effects on the national economy. In

Oradea, it was preceded and followed by two extremely rainy years: 1999 and 2001. Moreover, it is included in a period of very rainy years (1996-2001). The extremely rainy year 2010 was followed by the extremely dry year 2011. The analyzed period starts and ends with two extremely dry years: 1961 and 2021.

As in the case of the Timișoara meteorological station, it is also observed at the Oradea station that, *in general, the extremely dry years occurred at an interval of about 10-11 years, which coincides with the solar activity cycle* (Şerban & Dragotă, 2014).

Table 3 shows the intervals of pluviometric risk due to excess, pluviometric risk due to deficit, respectively the intervals without risk from the Oradea station. They were obtained using the same method of percentiles. For each risk interval, the classes of SPA values and the annual amounts of precipitation between which that risk is reported can be observed.

Thus, the very high risk generated by excess can occur from annual SPA values higher than +1.56. These values correspond to annual amounts of precipitation over 800 mm. The high risk generated by excess can occur at annual SPA values between +0.95 and +1.55 and annual amounts of precipitation between 726 and 799 mm. Similarly, very high risk generated by deficit can occur from annual SPA values lower than -1.35. They correspond to annual amounts of precipitation below 450 mm. The high risk generated by deficit can occur at annual SPA values between -0.92 and -1.34 and annual amounts of precipitation between 451 and 502 mm. The interval without risk is represented by annual SPA values between -0.29 and +0.15 and annual amounts of precipitation between 578 and 630 mm.

Figure 3 shows the years with positive and negative precipitation anomalies, as well as the periods of consecutive surplus or deficit years.

Table 3

The intervals of pluviometric risk at the Oradea meteorological station (1961-2021)

RISK BY EXCESS	**Very high risk**	**High risk**	**Moderate risk**	**Low risk**
SPA value	+1.56 – +2.26	+0.95 – +1.55	+0.36 – +0.94	+0.16 – +0.35
Annual amount of precipitation (mm)	800 – 884	726 – 799	656 – 725	631 – 655
RISK BY DEFICIT	**Very high risk**	**High risk**	**Moderate risk**	**Low risk**
SPA value	-1.35 – -2.07	-0.92 – -1.34	-0.67 – -0.91	-0.30 – -0.66
Annual amount of precipitation (mm)	364 – 450	451 – 502	503 – 532	533 – 577
WITHOUT RISK	**Without risk**			
SPA value	-0.29 – +0.15			
Annual amount of precipitation (mm)	578 – 630			

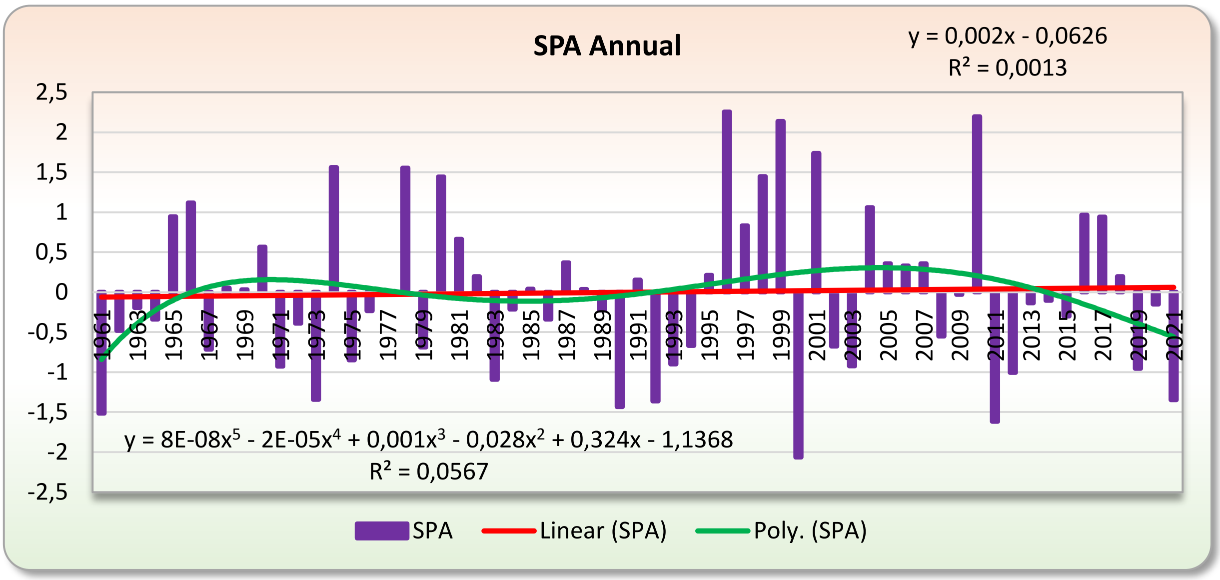

Figure 3 **The linear and polynomial trend of the annual SPA values, at the Oradea meteorological station (1961-2021)**

The longest period of consecutive surplus years (1995-1999) is equal in length to the longest period of consecutive deficit years (2011-2015): 5 years. But the surplus period is much more intense than the deficit period. On the other hand, the periods of consecutive deficit years have a higher frequency (10 periods) than the surplus ones (8 periods).

The polynomial trend of the annual SPA values (Figure 3) shows that, after the drought of the years 1961-1964, there follows a long surplus period of 18 years (1965-1982), then a deficit one of 12 years (1983-1994), a long rainy period of 16 years (1995-2010), followed by a deficit period of 11 years (2011-2021). In the long rainy period 1995-2010, the great drought of the year 2000 can be found.

Normally, if this rainfall distribution will be maintained in the future, as the year 2022 had a large rainfall deficit in Oradea, it would mean that starting from the following years, we would enter a long period of rainfall surplus.

The linear trend of the annual SPA values (Figure 3) is slightly *upward*, for the period 1961-2021. This trend is due to the high SPA values of the last surplus period.

CONCLUSIONS

During the period 1961-2021, the annual amounts of precipitation showed a slight increase in Oradea. The upward trend is due to the higher values since 1996. The cause lies in the increase in air temperature in recent decades, which has amplified the thermal convection and therefore the cloudiness, generating richer rainfalls in favorable synoptic situations, with Atlantic or Mediterranean circulation. Also, through the expansion of the city, the "heat island" effect generated by the built surfaces, overheated in the summer and which amplifies the thermal convection, has been amplified.

The rainiest year was 1996, and the driest was 2000.

The rainiest decade was the 5th (2001-2010), and the driest decade was the 6th (2011-2020). The annual average precipitation amounts increased from the 1st decade to the 5th decade by 52.9 mm and decreased from the 5th decade to the 6th decade by 72.5 mm.

Most of the extremely dry/rainy years occurred in the 1990-2021 interval, which coincides with the increase in the frequency of climatic extremes in recent years, reported at the planetary level.

In general, the extremely dry years occurred at an interval of about 10-11 years, which coincides with the solar activity cycle.

Using the percentile method, 9 intervals of pluviometric risk were established, in Oradea. Thus, the very high risk generated by excess can occur from annual SPA values higher than +1.56 and annual amounts of precipitation over 800 mm. The very high risk generated by deficit can occur from annual SPA values lower than -1.35 and annual amounts of precipitation below 450 mm.

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