CHARACTERISTICS OF HEAVY RAINFALL PARAMETERS IN THE NORTH-WESTERN ROMANIA

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ABSTRACT. - Characteristics of heavy rainfall parameters in the north-western Romania. The paper analyzes the frequency, duration, intensity and quantity of heavy rains in north-western Romania, based on data from 14 meteorological stations in that area, located in different terrain conditions, using 1975-2009 period. Identification of the torrential rains was made on Hellmann's criteria. In the review period were identified 271 torrential rainfall events, representing only 0.89% of all precipitation cases with significant intensity in generating liquid surface flow. During the year, the highest frequency of occurrence is from June to August (between 61.5 and 90% of cases), with a slight predominance of June. In terms of duration, the highest shares of torrential rains have 3-6 hours (37.3%), followed by those of 1 to 2 hours (25.1%), this structure revealing different genetic conditions. Diurnal variation shows maximum occurrence of heavy rains in the afternoon and evening (between 13 and 20 Romanian Summer Time - RST), the phenomena starting earlier in mountainous areas (11-12 RST) and later in the lowlands (16-17 RST). Water amounts varies quite large, with values ranging between 1.2 and 82.7 mm, and their average intensity is between 0.12 and 1.80 mm/min, being noticed a strong correlation between average duration and intensity of rainfall, it ultimately reducing the growing period.

Keywords: heavy rain, diurnal variation, intensity, Northwestern Romania

1. INTRODUCTION

Taking into account the spatial and temporal manifestations of heavy rains characteristics, these are extreme precipitation events, whose analysis is important because of their effects (floods, spills on the slopes and intense training material, etc.). In order to improve the knowledge of the event, there were made a series of studies aimed at the phenomenon as a whole or its particularities. Gorbatchev (1923), studying the relationship between the duration, intensity and frequency of rains, showed that each region had a maximum potential for precipitation of a rain event, which depends on the system that generates it and the landscape features.

Predescu (1937), in a study of the rain events over 20 mm per hour fell to Cluj in the summer months (April-October) during 1929-1936, analyzed the statistical characteristics of rainfalls, observing a series of correlations between their duration, frequency and intensity.

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Popovici et al. (1998), studying torrential rains from Oradea, based on Wussow criteria, concluded that the highest frequencies of heavy rains with the average intensity between 0.32 and 0.40 mm/min. (equivalent to an amount of 19.2-24.0 mm/hour) belong to the 50.2-79.5 min. class period.

Bogdan and Niculescu (1999), studied the torrential rains in Romania in the 1933-1975 period, using the Hellmann's criteria, pointing out that the longest and quantitatively more significant events are frontal torrential rainfalls (over 4 hours), and that the frequency of rains has "a great non-periodic variability" (p. 101).

Dragotă (2006), used Hellmann's adapted criteria in order to extract heavy rain events from 130 Romanian weather stations, located up to 1500 m high, in the 1961-1996 period, emphasizing the same uneven territorial distribution.

2. DATA AND METHODS

This study approaches some statistical characteristics of heavy rains in north-western Romania, using data on rainfall intensity during the warm season (April-October), for the mountain stations warm season was considered June to September, due to the dominant solid precipitations in the other months. The analyzed period is 1975-2009, during which it were identified based on Hellmann's criteria a total of 271 torrential events, representing only 0.89% of total rainfall cases being able to generate sheet flood. There were used data from 14 meteorological stations, their location and altitudinal scale being as follows: Satu Mare (123 m) and Supuru de Jos (159 m) in the lowlands, Baia Mare (216 m), Sighetu Marmaţiei (275 m) and Ocna Şugatag (503 m) situated in Maramureş Depression and Baia Mare Depression, Cluj-Napoca (410 m) and Dej (232 m), located along the Someşului Mic Valley; Huedin (560 m) located in Huedin Depression, Turda (424 m), located in the Alba Iulia-Turda Corridor, Zalău (295 m), and Bistriţa (366 m) located in the hilly area; Băişoara (1384 m, Muntele Mare Mountains), Vlădeasa 1800 (1836 m, Vlădeasa Massif) and Iezer (1785 m, Rodnei Mountains).

In order to perform the analysis, the statistical facilities offered by Microsoft Excel program were used. On this basis, sums, averages, hourly, monthly and multi-monthly frequencies were calculated. On some data sets a series of nonparametric tests were applied to identify their homogeneity and the presence of the temporal trend. In this respect, it has been used tests offered by the XLSTAT trial version program: Mann-Kendall and Homogeneity test, which were applied to the following heavy rains parameters: amount of water during the rain event, average and maximum intensity, duration of maximum intensity. The analysis concluded that processed data sets did not show a trend or temporal jumps, which could influence the outcome of the research.

3. RESULTS

Torrential rains structure reveals their highest frequency in Maramureş and Baia Mare Depression (between 6.6 and 9.6%), followed by mountain area (6.3-10.3%), hilly and valley regions (4.4-8.5%). The highest percentage values are

specific to summer's months, reaching up to 87.1% cumulative frequency, with the highest values in June (30.3%) and July (29.9%). The regional structure is relatively uniform, standing out the mountain area (23.2%), followed by the Maramureş and Baia Mare Depression (20.7%) and some isolated places in the hilly area. An important aspect of structure is the low monthly frequencies of torrential rainfalls in late spring (April, 0.7%) and autumn (October, 1.1%).

Regarding the duration, the predominant heavy rains are those of 3 to 6 hours (37.3%), followed by those less than one hour (25.1%) and 1 to 2 hours (20.3%). The spatial distribution shows that, in the case of heavy rains with duration of 3-6 hours, the highest frequencies are strictly in the mountain area (11.1%), followed by those from Maramureş and Baia Mare Depression (9.2%) and by the eastern valley corridors of Apuseni Mountains (7.0%). Torrential rains lasting less than an hour have the highest percentage values isolated in the analyzed area: Baia Mare Depression (Baia Mare, 4.4%), the depression and valley areas situated north-east and east of the Apuseni Mountains (Turda, 2.6%, Cluj-Napoca, 2.2%, Huedin 2.2%) and mountain area (Iezer, 2.6%).

3.1. Diurnal variation

The diurnal variation structure of torrential rains beginning moment shows the highest percentage values in the afternoon and in the evening, their timing being differentiated as follows: the earliest heavy rains start in the mountain area of Apuseni (11 to 12 RST), where the maximum frequency is recorded in the afternoon (14-15 RST); the rest of the studied area has the highest frequencies of the beginning of the heavy rain events between 16-19 RST, standing out some isolated depression and valley areas from north-east and east part of the Apuseni Mountains (Huedin, Cluj-Napoca, Turda), hilly area (Zalău) and Baia Mare Depression. There is a second maximum occurrence of high torrential rain frequencies, between 22-24 RST, more prominent in the lowlands.

In relation to the duration of rainfalls, it is remarkable that in the case of those under one hour the frequency of occurrence is higher in the afternoon and evening, but the spatial distribution is uneven, standing out the plain area and some depression areas (Baia Mare, between 16-18 RST), the mountain area of Apuseni and some valley areas next to it. A similar situation was recorded in the case of rain events that lasted 1 to 2 hours and of those longer than 3 hours, the highest recorded frequencies being during daytime.

3.2. Rainfall intensity

As torrential rains have been selected by a principle that establishes the relationship between duration and average rain intensity their structure class is directly influenced by the selection criteria, therefore, the average intensity class <0.17 mm/min has no cases of heavy rains less than 3 hours (Table 1). On the other hand, it is observed an inverse correlation between duration and intensity of rains; the events with high average intensities have reduced durations.

Table 1. ***The frequency of heavy rains intensity classes, according to their duration (%)***

Duration	Average intensity (mm/min)			Maximum intensity (mm/min)		
	<0.17	**0.17-0.41**	**>0.41**	**<0.5**	**0.5 – 1.0**	**>1.0**
< 1 hour	-	0.7	24.5	-	1.5	23.6
1-2 hours	-	14.0	6.3	-	1.5	18.8
2-3 hours	-	14.8	0.7	-	1.5	14.0
3-6 hours	26.9	10.3	-	0.4	9.2	27.7
> 6 hours	1.8	-	-	-	0.7	1.1
Total	**28.7**	**39.8**	**31.5**	**0.4**	**14.4**	**85.2**

Analysis of average intensity torrential rains variation depending on their duration notes that this decreases with the increase in duration, heavy rains with high average intensity (more than 1 mm/min) have, generally, less than 20 min duration. Using the Curve Expert program, it was determined the nature and value of regression coefficient (r) between duration and average intensity of heavy rains, standing out that it is statistically significant, with it's values between 0.86 and 0.98 (Table 2). The correlation type is logarithmic or power.

Table 2. ***Regression equations and coefficient values of time-average intensity of heavy rains***

Weather station	Regression equation	Coefficient values			Weather station	Regression equation	Coefficient values		
		a	**b**	**r**			**a**	**b**	**r**
Satu Mare	$y = ax^b$	69.37	-1.16	0.86	Dej	y = a + blnx	1.26	-0.20	0.95
Supuru	y = a + blnx	1.72	-0.29	0.93	Cluj-N.	$y = ax^b$	7.75	-0.68	0.87
Baia Mare	$y = ax^b$	5.03	-0.60	0.96	Turda	y = a + blnx	1.45	-0.22	0.88
Sighetu M.	$y = ax^b$	11.20	-0.80	0.98	Huedin	y = a + blnx	1.31	-0.20	0.88
Ocna Ş.	$y = ax^b$	11.41	-0.76	0.88	Băişoara	$y = ax^b$	6.56	-0.66	0.87
Zalău	y = a + blnx	1.69	-0.29	0.94	Vlădeasa	y = a + blnx	1.27	-0.20	0.92
Bistriţa	$y = ax^b$	5.48	-0.62	0.97	Iezer	y = a + blnx	1.45	-0.23	0.94

Maximum intensity of heavy rainfall has the highest percentage values of the occurrence time in the afternoon and in the evening, with an occurring peak between 17-20 RST in the low area, respectively between 14-19 RST in the mountain area (Fig. 1).

Diurnal variability of maximum intensity time occurrence varies depending on the rainfall length: those with time length to an hour have the highest frequencies in the afternoon and in the evening throughout the unit (between 13-22 RST), with higher values in the mountain area, in the Maramureş and Baia Mare Depression, hilly and valley areas; a similar structure presents rains whose duration is between 1 and 2 hours, except that the highest frequencies occur in the mountains, in the hilly and valley areas. The rainfall events lasting more than 2 hours have one maximum of occurrence in the afternoon and another one in the night, whose length grows with increasing time duration of the rainfall.

Maximum intensity torrential rains class structure reveals the predominance of the >1.0 mm/min class (85.2%) followed by the 0.5-1.0 mm/min, respectively the <0.5 mm/min class (Table 2). Data show the growth of the maximum intensity at the same rate as their frequency.

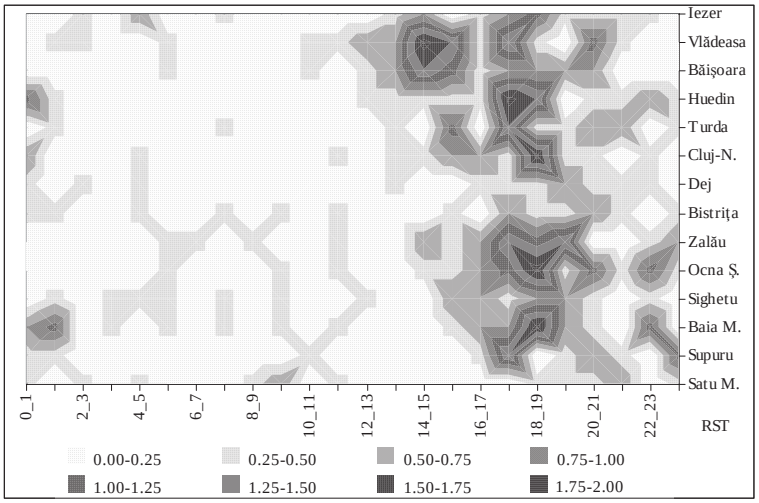

Fig. 1. ***Diurnal variation in the frequency of occurrence time of maximum intensity (%)***

Analysis of the intensity classes according to the duration of the rainfall shows that, regardless of the class, the highest frequency of rainfall is when duration exceeds 3 hours for the class 0.5-1.0 mm/min (9.9%), while those of more than 1.0 mm/min have 28.8% (the frequency decreasing with the duration's growth) (Table 2).

Diurnal variation of maximum intensity occurrence moment regarding the analyzed intensity class reveals that in the case of 0.5-1.0 mm/min class, the time of its occurrence is relatively random, not having a well individualized structure, the only exception being in the mountain area, where it occurs mainly in the afternoon (13-17 RST). In the case of heavy rainfalls with the maximum intensity higher than 1.0 mm/min, the highest frequencies appear only in the afternoon and evening, especially in marginal east and north-east areas of the Apuseni Mountains (Huedin, Cluj-Napoca and Turda), between 14 and 20 RST, respectively in the Maramureş and Baia Mare Depression, and in some hilly areas (Zalău), where they occur between 17 and 20 RST.

Torrential rainfalls have maximum intensity structure with the highest percentage values belonging to 2-5 min class (55.4%), followed by the 1 min (24.0%) and 6-10 min (18.1%), while over 30 min class is missing. The spatial distribution shows that the highest frequencies of 2-5 min appear isolated in some depression areas (Baia Mare, 5.5%) and on a larger scale in the mountain area of Apuseni and in its marginal east and north-east areas (Huedin, Cluj-Napoca, Turda, with values ranging between 4.4 and 5.9%).

The time of occurrence of maximum intensity from the beginning of the torrential rain event (in minutes), is an important element in both the dynamics of its activity and prognosis. It is characterized by a relatively heterogeneous structure, the highest frequencies belonging to the 11-20 min time class (19.2%), followed by 21-30 min (12.6%) and 1-5 min (11.1%). The spatial distribution

shows the highest values in the lowlands, hilly and valley areas, for the 11-20 min class, respectively in the depression area of Maramureş and in the valley one, for the 1 to 5 min class.

The distribution according to the duration of the heavy rainfall shows that events lasting under an hour have the largest percentage in the case of 11-20 min class (7.3%), followed by the one of 0 min; for 1 to 2 hours duration, the highest ratio belong to the 11-20 and 21-30 min classes, totaling 8.5%, and in case of 2-3 hours, rates are relatively evenly distributed (Fig. 2).

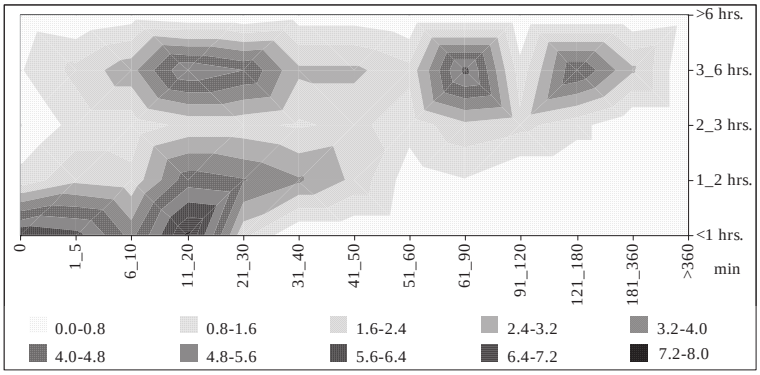

Fig. 2. ***The time appearance frequency (%) of torrential rain's maximum intensity (min), according to rainfall duration (hours)***

Rains of 3-6 hours duration have the highest percentage values for the 11-20 and 21-30 min classes, totaling 10.3%, respectively for those of 61-90 min (5.9%) and for 121-180 min class (4.8%), while events lasting more than 6 hours have an uneven distribution, the starting point moment of the rain being random (Fig. 2).

3.3. The torrential rainfall amounts

The average hourly water amount varies quite widely (between 1.1 and 28.4 mm/event), with the highest values in the afternoon and during the night. Diurnal variation of hourly average amounts/torrential rain event notes values higher than 9.0 mm between 12 to 23 RST in the valley and depression areas of the region; between 14 and 23 RST in the mountains, the Maramureş and Baia Mare Depression and in the hilly areas, and between 15 and 23 RST in the plain area. A second less contoured maximum is present in the nighttime (from 23 to 05 RST), especially, in the hilly area, partly in the valley and mountains area, and between 00 and 04 RST in the plains and in Maramureş and Baia Mare Depression. The structure shows a series of higher isolated values (above 18.0 mm/hour) in Baia Mare Depression (between 15-17 RST), in the hilly and valley area (17-19 RST, Bistriţa and Dej), in mountainous area (22-03 RST, Iezer, Vlădeasa 1800) and in the plains (19 to 21 RST, Satu Mare), as a result of extreme torrential events, which led to significant amounts of water.

The average hourly maximum intensity varies between 1 and 18 min, the temporal distribution of their maximum values being random, standing out, however, higher values during the afternoon and night. Compared to spatial and temporal structure of the duration of maximum intensity, the average hourly maximum quantities of water determined by the intensity of these rains is more homogeneous, the mean values being between 0.8 and 12.0 mm/hour.

The highest amounts of water are registered in the afternoon and the beginning of the night, particularly in the Maramureş and Baia Mare Depression, hilly area, the valley and the depression area located in north-east of the Apuseni Mountains (Fig. 3).

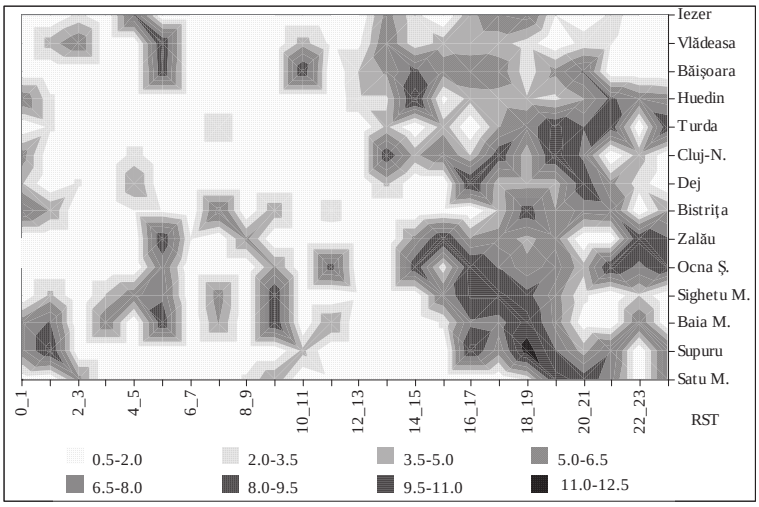

Fig. 3. ***Hourly average amounts of water (mm/hour) of maximum intensity heavy rains***

Hourly significant amounts of water (between 5.0 and 11.0 mm) are recorded during the night too, especially in the Maramureş and Baia Mare Depression, and partially in the hilly and mountainous area (Fig. 3).

4. CONCLUSIONS

Torrential rains' structure notes the highest frequency in the Maramureş and Baia Mare Depression and in the mountains area (more than 6.6% for each analyzed station). Rains have this feature less frequent in the lowlands. Throughout the year, their highest share belongs to the summer season (87.1%), with the highest frequency in the mountain area. Considering duration, rainfall of 3 to 6 hours are dominant (37.3%). The occurrence of rainfall is more frequent in the afternoon and evening, up to 3-4 hours earlier in the mountain areas than the plains and depression. The second maximum occurs at midnight, in Maramureş and Baia Mare Depression, the hilly and valley areas.

Regarding the average intensity, the ruling classes are those with mean and high values (above 0.17 mm/min), due to the principles of selection used.

Maximum rainfall intensity occurs most often in the afternoon and in the evening. The highest values of the frequency are delayed in the plain area. The intensity class structure shows that those over 1.0 mm/min are dominant (85.2%). Diurnal variation shows the highest frequencies in the afternoon and in the evening, with a slightly uneven spatial structure, regardless of the category class. Duration of maximum intensity ranges between 2 and 5 min (55.4%) followed by the 1 min class (24.0%). Maximum intensity duration up to 5 min holds up almost 80% of the events.

The beginning moment of maximum intensity from the torrential rain's time start totals almost half of the events in the first 30 min, the 11-20 min time class being dominant. It is noted that there are two secondary maximum (61-90 and 181-360 min), which belong to the torrential events that last over 2 hours.

Heavy rains average hourly water amounts ranges quite widely. The diurnal variation has the highest values in the afternoon and evening, due to short rain events, higher in number and intensity. For maximum intensity, the hourly average water amounts are recorded throughout the afternoon and evening, but the spatial distribution is uneven, as torrential rain are precipitation events with a large territorial discontinuity.

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