# THE IMPACT OF THE TORRENTIAL PRECIPITATIONS IN THE FORMATION OF FLOODS IN THE METROPOLITAN AREA OF SATU MARE

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**Abstract. The impact of the torrential precipitations in the formation of floods in the metropolitan area of Satu Mare**. The study wishes to carry out an analysis of the maximum daily rainfall in the Satu Mare metropolitan area, its role in the formation of floods in the urban perimeter. The rain-drain process is complex in an urban area due to the qualitative changes of the topographic surface. The predomination of impermeable and quasi-impermeable surfaces determines the increase of the drainage coefficients on the urban surface. Corroborated with the reduced interception of highly anthropically modified vegetation and reduced retention due to the dominance of concrete or asphalt surfaces, floods occur on urban subbasins at high intensity rainfall. The maximum daily rainfalls in the Satu Mare metropolitan area exceeded 50 mm / 24 hours in some years, with the period 2007-2009 being noticed, such as values being recorded consecutively. As a case study, was analysed the downpour on May 13, 2017, when rainfall was 48.2 mm between the hours 11:10 - 16:40. The most important part of the rain in the downpour was recorded between 14:00 and 15:20. The high intensities of up to 0.53 mm/min, have generated in conjunction with drainage coefficients above 0.70, characteristic for impermeable surfaces, floods in various urban subbasins of Satu Mare metropolitan area. Comparative analysis of the data obtained from four pluviometric stations located on a 10 km radius in the proximity of the studied metropolitan area revealed a possible influence of the city on the amount of precipitations falling in the area.

**Keywords:** torrential rainfalls, floods, urban areas, flooding, Satu Mare

## 1. INTRODUCTION

The Satu Mare urban area is situated in the north-western extremity of Romania, at the intersection of the parallel 47°47' N latitude with the meridian 22°52' E longitude, in the central section of Someș River's low plain (Geografia României, IV, 1992) an average altitude of 126 m (NMN). From the physical and geographical point of view, the urban area occupies the Someș' meadow and low terraces, extending along both banks of the river, at a distance of about 13 km, on the border with Hungary to the west and about 28 km of frontier with Ukraine to the north. Hydrographic, the city is located in the lower sector of Someş River, at a distance of about 15 km upstream of the river's exit from Romania and about 40 km upstream of the confluence with Tisa River. The city has developed into a meandering area of Someș in the low plains sector, away from relief units with different physical-geographic features. The relatively small dimensions of the analysed area and the geographical location do not reveal spectacular physical-geographic features. The geological, geomorphological, climatic-hydrological, phyto-edaphic features have a feature dominated by monotony specific to the plain areas. The landscape is heavily anthropogenic, characteristic of the heavily transformed urban areas, the original natural features being preserved exceptionally on narrow surfaces.

## 2. DATA AND METHODS

The data were obtained from the Someş - Tisa Water Administration from Cluj Napoca and from the National Meteorological Administration, as well as various bibliographic sources. The images were made by the author in the field. The research methods approached consisted in the direct observation in the field, the elaboration, analysis and interpretation of graphic, tabular and written materials. The Office Excel program was used to process statistical data. In the future scenarios we chose the variant of the six-degree polynomial equation for the alleviation of errors and a better loyalty fidelity. The rain intensity is the ratio between the amount of water expressed in mm (p) and the rainfall duration in minutes (t) and calculated from the relationship:

$$i = \frac{p}{t} (mm/min)$$

The study of torrentiality is important because it is used in the dimensioning of the street network, the rainwater take-off and drainage network and in the design of hydro-technical constructions in the urban perimeter. The torrential nature of a rainfall has been determined by duration and intensity according to the Hellmann criterion (Table 1)

**Table 1.** Classification of torrential rains according to the Hellmann criterion,

| Duration (minutes) | Intensity (mm/minute) |
|---|---|
| 1-5 | at least 1 |
| 6-15 | at least 0,80 |
| 16,30 | at least 0,60 |
| 31-45 | at least 0,50 |
| 46-60 | at least 0,40 |
| 61-120 | at least 0,30 |
| 121-180 | at least 0,20 |
| >180 | at least 0,10 |

## 3. RESULTS AND DISCUTIONS

The urbanization process determines ample changes in the physical and geographic factors reflected in the quantitative modification of the dome effect, qualitative modifications of the aerosols, and changes in the radiative balance. Reducing vegetation interceptions, mitigating the role of natural topographical microdepressiosn and reducing infiltration cause high rainfall, urban floods of pluvial nature. The analysis of the torrential precipitation rate in the Satu Mare metropolitan area reveals a 30% main maximum in the maximum daily precipitation gap of 30-34.9 mm / 24 hours. The maximum rainfall rate reached 0.53 mm/min, resulting in a pluvial flood on different urban river basins. The urban area under study determines some influence on the amount of precipitation in correlation with adjacent pluviometric stations. The undeniable assertion of this fact remains a subject of future geographic research.

### 3.1. The impact of torrential rainfalls on urban floods formation.

The study analyses the correlation between rainfalls in the urban perimeter and the dynamics of internal rainwater on the surface of the urban area. The precipitations on the surface of the hydrographical basin come in contact with the vegetation cover, which retains a small amount representing the interception, and the depressions on the surface, without leakage, constitute the retention (I. Giurma, 2000, Water Management Systems, p. 18).

The rain-drain process is extremely complex in an urban area. In non-anthropic areas, the rain-drainage process is controlled by the nature of the vegetation, the rate of soil infiltration, the nature of the soil, and the conformation of the topographic surface (slope, microdepressions, etc.). In the case of urban areas, the infiltration is reduced due to the predominance of impermeable surfaces resulting in a reduction of the water flow concentration times and a quantitative increase of the drainage coefficients. The vegetation in the urban areas is rare, discontinuous thus reducing the interception made by the vegetation coronation. V. A. Stănescu (Hidrologie urbană-1995, p. 17) states that the formation and circulation of rainwater is closely related to the increase in the degree of torrentiality caused by the change in heat and radiation balance, the dome's effect on the city and aerosol anomalies. Osman Akan and Robert J. Houghtalen (2003) appreciate that the natural drainage network in anthropogenically untransformed regions is replaced by a much shorter drainage network consisting of gullies and collectors characteristic for urban areas resulting in a concentration of rainwater flows. In hydrology studies it is important to know the maximum daily precipitation for the design and calibration of the rainwater drainage network.

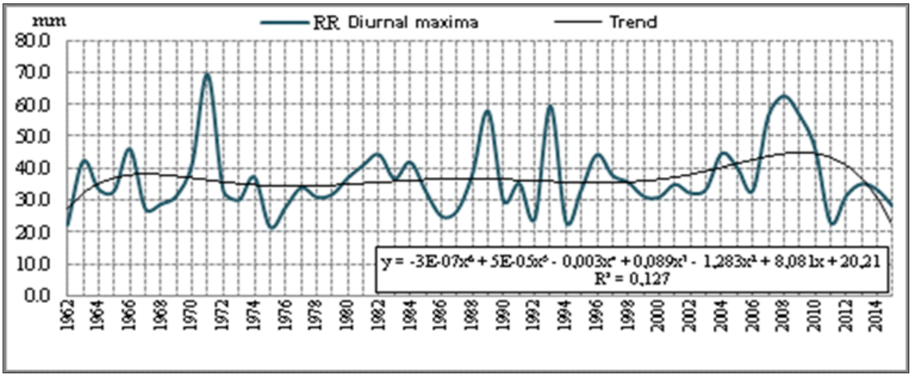


**Fig.1.** The distribution of the maximum annual rainfall amounts in 24 hours and the trend of evolution (1961-2015) at the Satu Mare mathematical station. (Source: ANM Archive).

The distribution of the maximum daily volumes during the period 1962 - 2015 shows a relatively constant trend until 2010, after which the trend is of slight regression, probably the gradient following the general trend of mitigation of the annual average rainfall in the Satu Mare urban area. Low annual rainfall values below 25 mm were recorded in July 1962 (22.3 mm), July 1975 (21.6 mm), July 1992 (24.2 mm), October 1994 (23,4 mm) and 2013 (23.0 mm), due to a diminished frontal activity and the dominance of more dry or stable air masses. High amounts of over 50 mm / 24 hours were recorded in the years 1971, 1989, 1993, 2007, 2008 and 2009. It is worth mentioning the years 2007, 2008 and 2009, consecutive years with high values of the maximum daily rainfall.

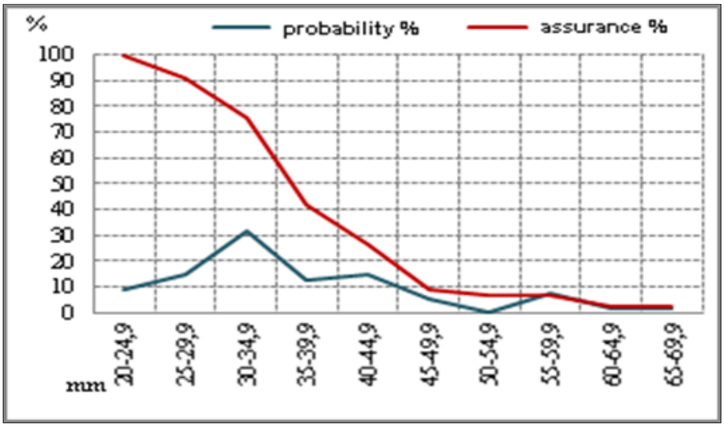


**Fig. 2.** The likelihood of production and the maximum daily subsistence level at the meteorological station Satu Mare (1961-2015). (Source: ANM Archive).

To differentiate the return periods, the probability traceability and the maximum daily precipitation rate are used, underlining the values corresponding to each precipitation interval. The probability curve analysis of the frequency indicates that a main maximum of 30% occurs in the maximum daily precipitation 30-34.9 mm / 24 hours.

Values greater than 35 mm have a probability of less than 10%. The degree of insurance decreases progressively with the increase of the maximum daily precipitation values. To determine the maximum daily precipitation frequency on different value ranges, maximum daily precipitation over 10 mm / 24 hours has been selected, as these may raise problems related to the exceeding of the water evacuation capacity rainwater from the urban perimeter of Satu Mare with the pertinence of the risk of internal pluvial floods in the hydrographic subbasins of the city.

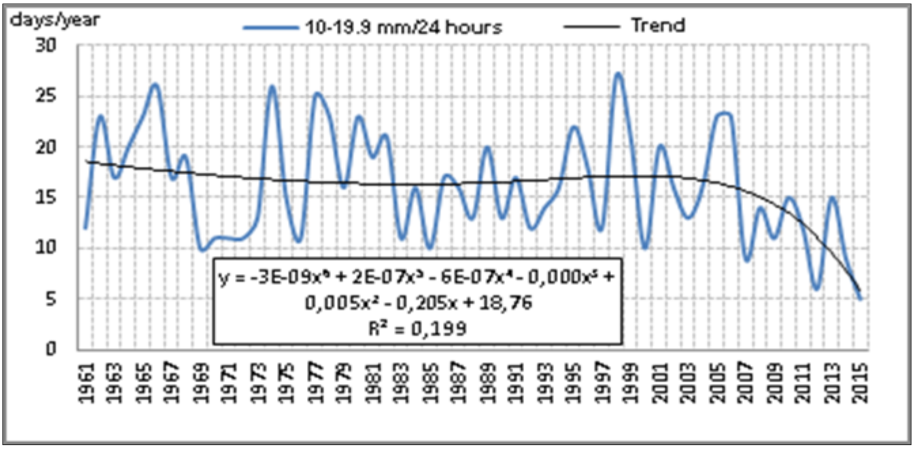


**Fig. 3.** Frequency of days with maximum precipitation amounts of 10-19,9 mm / 24 hours at the meteorological station Satu Mare (1961 - 2015). (Source: ANM Archive).

The years with the highest frequency of daytime precipitation ranging from 10 to 19.9 mm / 24 hours were 1966, 1974, 1978 and 1998, in which over 25 cases per year were recorded. After 2001 there is a reduction of the frequency to less than 15 cases / year, probably correlated with the general trend of reducing the average annual precipitation in the studied area.

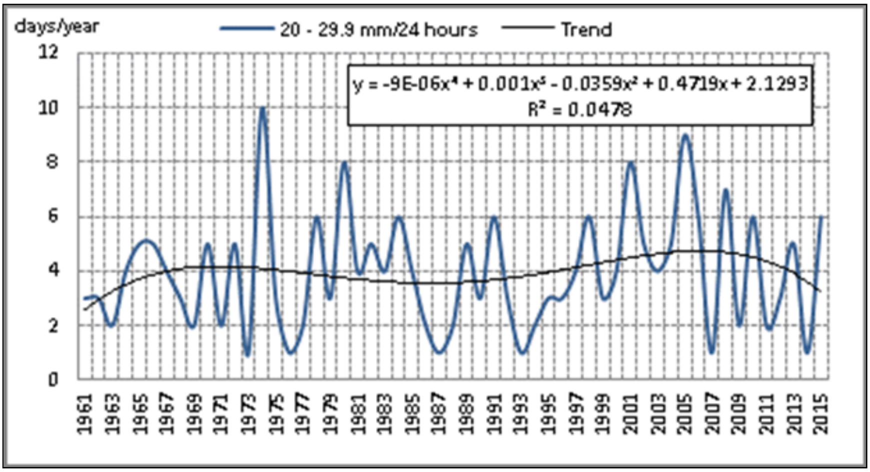


**Fig. 4**. The frequency of the days with maximum precipitation amounts of 20-29,9 mm/24 hours at the meteorological station Satu Mare between 1961 and 2015. (Source: ANM Archive)

The years with the highest frequency of daytime precipitation ranging from 20-9.9 mm / 24 with over 8 cases/year were 1974, 1980, 2001 and 2006. It is noted two periods of exacerbation of the rainfall frequency included in this gap and three periods of attenuation.

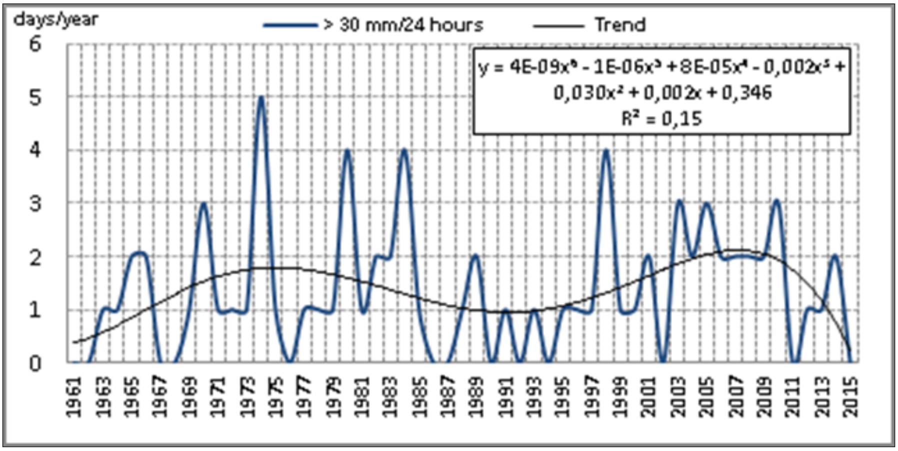


**Fig. 5**. Frequency of days with maximum precipitation over 30 mm / 24 hours at Satu Mare meteorological station between 1961 and 2015 (Source: ANM Archive).

For the maximum daily rainfall values exceeding 30 mm / 24 hours, the following years are noted with frequencies of 5 days/year, such as 1970, 1974, 1980, 1984 and 1998. From 2011 there is a decrease in the torrentality for this interval.

In urban hydrology studies, torrent analysis is frequently used. Torrential rains are characterized by high amounts of precipitation falling within a short period of time.

In Satu Mare, a torrential rain falling on May 13, 2017 amid the advection of a mass of wet and unstable air in the area, causes the flooding of the city's low sections due to its high intensity. The recording was carried out by the automatic pluviometer integrated into the Satu Mare hydrometric station located in the central sector of the urban area at the latitude 47°47'40" N, the longitude 22°49'31" E and the 123 m NMN average altitude on the right bank of the Someș River. Thus, in the interval of 11:10 - 16:40, 48.2 mm of rainfall fell. The most important aspect was recorded between 14:00 and 15:20.

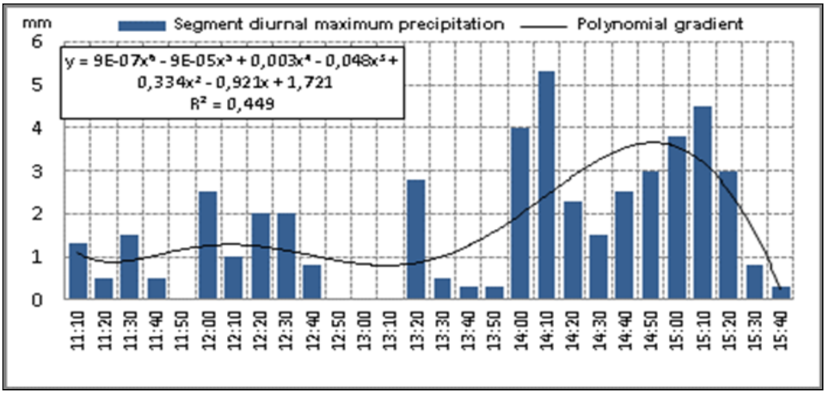


**Fig. 6.** The maximum precipitation rates recorded on 13 May 2017 at the Satu Mare hydrological station. Source: Archive (ABA Someș-Tisa, Cluj Napoca)

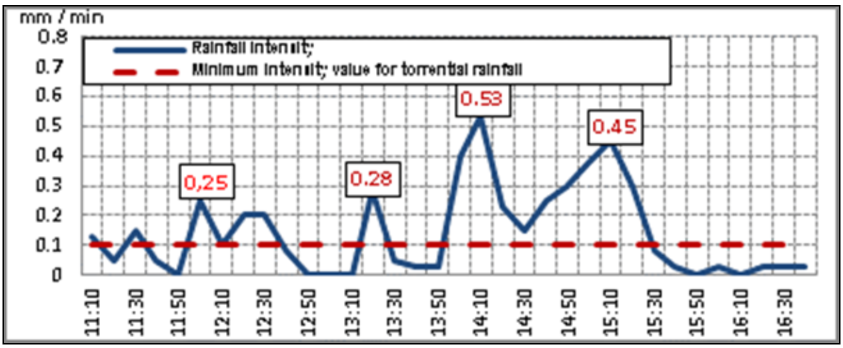


**Fig. 7.** The intensity of precipitation recorded on 13 May 2017 at the Satu Mare hydrological station (Source: ABAST Cluj Napoca Archive)

The maximum intensity of the torrential precipitation ranged between 0.25 mm/min and 0.53 m/min. Due to the downpour's high intensity, combined with the dominance of the impermeable surfaces characteristic to the urban areas, were obtained high values of the drain coefficients with the formation of a flood in certain subbasins integrated into the urban basin. Where the intensities exceeded 0.1 mm/min, there is a quantitative pluvial surplus that turns into free drainage on the surface of the river basin. The drainage coefficient is an important factor used to determine the net rain along with the interception value and the intensity of the infiltration. The drainage coefficient is defined as the ratio of the drained water layer *h* (net rainfall) and the *hp* water layer (Stănescu, 1995). The values of the drainage coefficient are expressed either according to the type of soil cover or by the socio-economic use of the urban area (Table 2).

**Table 2.** Values of the leakage coefficient according to the use of the urban territory (V. Al. Stănescu, 1995).

| Use of urban territory | Flow coefficient |
|---|---|
| Comercial areas:<br>-downtown<br>-in other city areas | 0.70 – 0.95<br>0.50 – 0.70 |
| Residential areas:<br>-buildings with courtyards<br>-block apartments<br>-suburban areas | 0.30 – 0.35<br>0.50 – 0.70<br>0.25 – 0.40 |
| Medium industrialised areas | 0.50 – 0.80 |
| Highly industrialised areas | 0.60 – 0.90 |
| Parks | 0.10 – 0.25 |
| Sports grounds and recreational areas | 0.20 – 0.35 |
| Green areas | 0.10 – 0.30 |

There are high values of drainage coefficients of 0.70 to 0.95 in the areas where pluvial floods occurred in domestic waters in different urban subbasins integrated in the Satu Mare metropolitan area (Table 2). At the high intensity of the flood, combined with the raised drainage coefficients, a low drainage slope of less than 1% characteristic of urban morphometry grafted on the relief of the Someș Plain (fig.8) was added.

**Fig. 8**. Floods formed in the urban suburban suburbs of Satu Mare metropolitan area registered on 13 May 2017. (Source: personal photo archive)

### 3.2. Influence of the Satu Mare metropolitan area on the variation of the amount of rainfall.

In order to devalue the influence of the Satu Mare urban area on the annual rainfall, a comparison was made between the meteorological station Satu Mare and the pluviometric stations of Hrip, Dara and Micula, located in a 10 km perimeter in the proximity of the municipality.

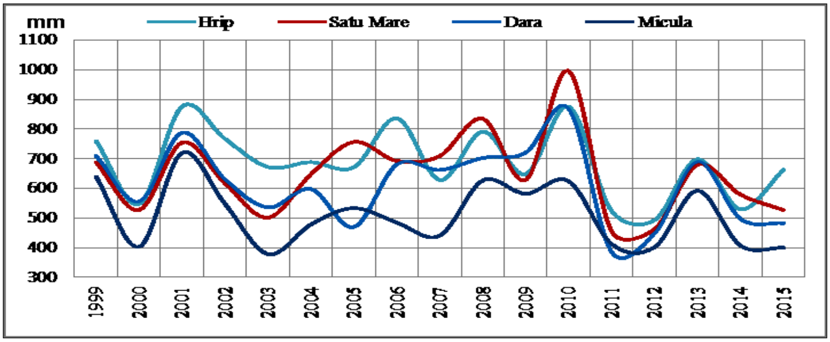


**Fig. 9**. Variation of the average annual rainfall quantities at the pluviometric stations Hrip, Satu Mare, Dara and Micula, (1999 - 2015). (Source: ABA Someş-Tisa, Cluj Napoca Archive).

**Table 3.** Annual average rainfall rates at the pluviometric stations Hrip, Satu Mare, Dara and Micula (1999 - 2015). (Source: ABA Someş-Tisa, Cluj Napoca Archive)

| Year | Hrip | Satu Mare | Dara | Micula |
|---|---|---|---|---|
| 1999 | 759,5 | 687,8 | 709,3 | 639,5 |
| 2000 | 547,3 | 527,6 | 555,7 | 403,1 |
| 2001 | 876,5 | 755,1 | 788,5 | 720,1 |
| 2002 | 767,3 | 617,5 | 629,6 | 547,9 |
| 2003 | 672,3 | 501,7 | 536,2 | 378,8 |
| 2004 | 688,8 | 647,8 | 598,1 | 478,9 |
| 2005 | 671,7 | 756,9 | 470 | 533,8 |
| 2006 | 837 | 692,8 | 681 | 485.0 |
| 2007 | 628,2 | 709,9 | 662,5 | 44,0 |
| 2008 | 791,5 | 835.0 | 703.0 | 626,9 |
| 2009 | 647,9 | 628,9 | 720,6 | 582,0 |
| 2010 | 875,6 | 995,6 | 868,8 | 624.8 |
| 2011 | 523,8 | 455,4 | 386,4 | 412,7 |
| 2012 | 493,2 | 462,6 | 448,9 | 402,1 |
| 2013 | 698,8 | 679,9 | 690,5 | 592,3 |
| 2014 | 530,2 | 579,4 | 497,7 | 407,3 |
| 2015 | 663,1 | 527,5 | 482,8 | 400,3 |
| Multian. average | 686,6 | 650,7 | 613,5 | 510,3 |

On the whole, the highest quantity is recorded at the Hrip station, with 663.1 mm, probably due to the situation in front of the orographic barrier formed by Codru Hill. The Satu Mare Meteorological Station records an average value close to 650.7 mm with a maximum of 995.6 mm in 2010 (Table 3). Follow the stations Dara with 613.5 mm and Micula with 510.3 mm (Fig. 10). We consider that the higher precipitation from the Satu Mare meteorological station compared to the Dara and Micula pluviometric stations, as well as the peak in 2010, could have been influenced the presence of the urban area. However, it is difficult to estimate the magnitude of urban influence in relation to the spatial-temporal variations in precipitation.

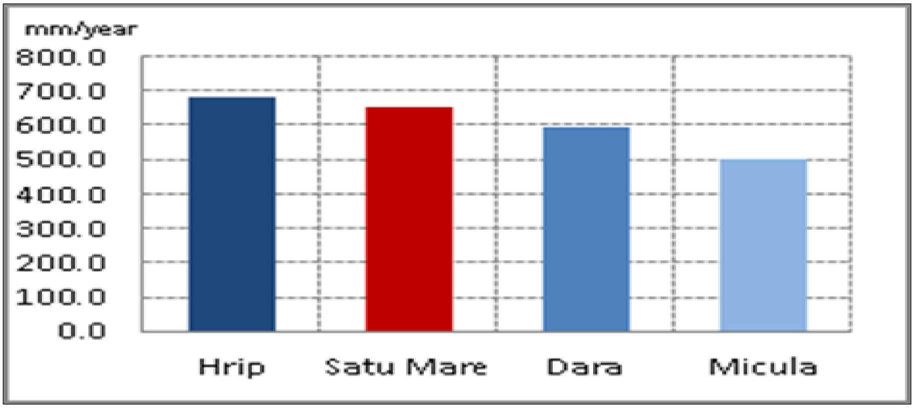


**Fig. 10.** Distribution of the annual average rainfall quantities at the pluviometric stations Hrip, Satu Mare, Dara and Micula (1999 - 2015) (Source: ABA Someş - Tisa, Cluj Napoca. Archive)

## 4. CONCLUSIONS

The rain-drain process is extremely complex in an urban area due to significant changes in the active surface;

In non-anthropic areas, the rain-drainage process is controlled by the nature of the vegetation, the rate of soil infiltration, the nature of the soil, and the conformation of the topographical surface.

In urban areas, infiltration is reduced due to the predominance of impermeable surfaces resulting in a reduction in water flow concentration times and increased drainage coefficients.

High volumes of maximum daily rainfall over 50 mm / 24 hours were recorded in 1971, 1989, 1993, 2007, 2008 and 2009.

The probabilistic curve analysis of the frequency indicates that a main maximum of 30% occurs in the 30 - 34.9 mm / 24 hour maximum precipitation range.

The maximum intensities of torrential rainfalls from the 13 of May, 2017 ranged between 0.25 mm/min and 0.53 m/min, causing urban floods.

Comparative analysis between the four close pluviometric stations shows that the highest recorded value was at Hrip station, with 663.1 mm, probably due to the situation in front of the orographic barrier formed by Codru Hill. Satu Mare records an average value of 650.7 mm in the period 1999 - 2015, with a maximum of 995.6 mm in 2010, the peak representing the maximum value of the four stations, followed by Dara with 613.5 mm and Micula with 510.3 mm.

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