COMPARATIVE STUDY OF THE FLOODS OCCURRED IN THE HYDROGRAPHICAL BASINS OF BISTRA MĂRULUI AND ŞUCU RIVERS (2005 and 2010)

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ABSTRACT. – Comparative study of the floods occurred in the hydrographical basins of Bistra Mărului and Şucu rivers (2005 and 2010). Bistra Mărului and Şucu rivers spring from Ţarcu Mountains and are tributaries of the accumulation lake of Poiana Mărului, being the main rivers transporting significant quantities of water to the lake. In order to perform an analysis from a morphometric point of view of the hydrographical network within the hydrographical basins of the two rivers, we have used the Horton - Strahler classification system, because, having a genetic basis, this classification system allows a comparative analysis of the hydrographical basins. By using this classification system, we have noticed that the two rivers have the same order and we have proved, what has already been known as a general rule, that the hydrographical basins with the same order, that are located in similar physical and geographical conditions, have on average approximately the same size of the reception basin surfaces, of the water flows, of the average slopes, of the course lengths etc. Moreover, we have proved that the two hydrographical basins have approximately the same shape and that the floods that they may generate are approximately identical as magnitude and manifestation.

Keywords: Bistra Mărului, Şucu, river, hydrographical basin, classification system, order, liquid flow, flood.

1. INTRODUCTION

The purpose of the study herein is the demonstration of the hypothesis related to the Horton-Strahler classification system of the drainage network, according to which: *"the rivers that belong to the same order and are located in similar physical and geographical conditions have on average approximately the same size of the reception basin surfaces, of the water flows, of the average slopes, of the course lengths, etc."* (Zăvoianu, 1978).

In order to perform this comparative study, firstly we have tried to set forth several criteria, necessary for the choice of the appropriate hydrographical basins. Thus, the two hydrographical basins selected have had to fulfil the following conditions: to be located in similar physical and geographical conditions, the size order of the two main rivers has had to be identical and to be hydrologically monitored. The most suitable hydrographical basins, according to the set criteria, are those of the rivers: Şucu and Bistra Mărului up to the confluence with the first. Both

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hydrographical basins are located in the western part of the country, more exactly in the Retezat-Godeanu group of the Middle Carpathians, their main rivers having the same size order (order 5), according to the Horton-Strahler classification system of the drainage network. Both rivers are hydrologically monitored near their confluence, at hydrometrical stations, bearing their names (Şucu and Bistra Mărului).

2. THE WORKING METHODOLOGY AND RESULTS

The drawing up of the hydrographical network map for the two hydrographical basins (fig. 1) could be possible by using the topographical maps with a scale of 1:25.000, supplemented and adjusted by drawing the elementary talwegs and by digitizing the rivers for each hydrographical basin, according to the Horton-Strahler principle, starting with the ones belonging to order 2. The hierarchy of the rivers in the Horton-Strahler system allowed the emphasis of 5 size orders for the valleys within both hydrographical basins, presenting specific morfometric and morphologic features, according to the evolution stage and the local physical and geographical features (belonging to one or more morpho-structural units, to the litological and structural conditions, the shape of the basin, its surface, the basic local level, the climatic and hydrological regime, the vegetal and edaphic layer, etc.).

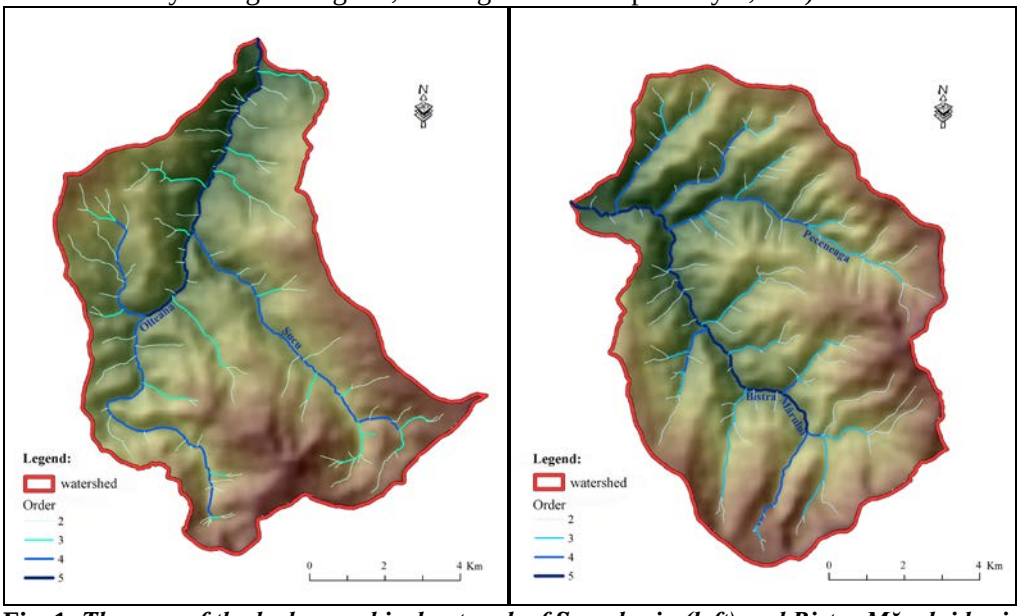

Fig. 1. ***The map of the hydrographical network of Şucu basin (left) and Bistra Mărului basin (right) (Domăşneanu, Andreea, 2011).***

After the delimitation of the reception basins for both rivers, we have calculated their surface and we have found out that the two basins have almost the same surface, Şucu basin having a surface of 79.6 km^2, and Bistra Mărului basin having a surface of 87.02 km^2, this difference not being very large (Domăşneanu, Andreea, 2011).

Regarding the average slope of the two hydrographical basins, the things are a little bit different because the Şucu basin has a larger average slope (7.9 ‰) than the one of the Bistra Mărului basin (7.1 ‰).

The morphometric model of the drainage has been performed taking into account the numbers of river segments, belonging to different orders, accounted for each basin, and by calculating their different morphometric features, whose values have been presented in tables 1 and 2. The number of river segments, belonging to order 1, has been obtained according to the calculation principle defined by *the law of the number of river segments*, which refers to the fact that the number of segments of ascending order tends to form a descending geometric progression, where the first term N_1 is given by the number of order 1 segments and the progression ration is given by the confluence report R_c (Grecu, Comănescu, 1998).

The confluence report (R_c) has been calculated as a weighted average of partial ratios $R_{ci} = N_i/N_{i+1}$; partial weight $P_i = N_i+(N_i+N_{i+1})$; $R_c = \Sigma(R_{ci}*P_i) / \Sigma P_i$, because this method gives better results (Zăvoianu, 1978).

Thus, the confluence report for Bistra Mărului basin is 5.09, and the confluence report for Şucu basin is 5.53. Using the ratio obtained in this manner the first term of the series has been calculated starting from the general formula within a descending geometric progression, as follows: $N_s = N_1/R_c^{s-1}$. In the case of the Bistra Mărului hydrographical basin, the value obtained has been 0.75, and in the case of the Şucu hydrographical basin has been 0.53.

Table 1. Features regarding the morphometric model of the drainage of the Şucu basin.

The calculated parameter according to the progression ratio	Order					Progression ratio	The sum of the progression terms
	1	2	3	4	5		
Number of river segments (N)	500	91	20	3	1	$R_c = 5,53$	$\Sigma_N = 615$
	500	90,42	16,35	2,96	0,53		
Segment length L (km)	70	47,66	17,84	20,29	8,94	$R_L = 1,79$	$\Sigma_L = 164,72$
	70	39,11	21,88	12,20	6,82		
Average length of segments l=L/N (km)	0,14	0,52	0,89	6,76	8,94	$r_l = 3,09$	$\Sigma_l = \Sigma_L/\Sigma_N$ 0,27
	0,14	0,43	1,34	4,13	12,76		

Table 2. Features regarding the morphometric model of the drainage of the Bistra Mărului basin

The calculated parameter according to the progression ratio	Order					Progression ratio	The sum of the progression terms
	1	2	3	4	5		
Number of river segments (N)	503	94	23	7	1	$R_c = 5,09$	$\Sigma_N = 628$
	503	98,82	19,41	3,81	0,75		
Segment length L (km)	85	53,48	26,09	15,93	11,12	$R_L = 1,71$	$\Sigma_L = 191,62$
	85	49,71	29,07	17	9,27		
Average length of segments l=L/N (km)	0,17	0,57	1,13	2,28	11,12	$r_l = 2,98$	$\Sigma_l = \Sigma_L/\Sigma_N$ 0,31
	0,17	0,51	1,51	4,50	13,41		

As we may notice in both cases, the value is subunitary, revealing that, under the physical and geographical conditions given and according to the existing confluence report, Şucu river is formed in proportion of almost 53 % of the accumulation of inferior order courses (table 1), and Bistra Mărului river up to the confluence with Şucu is formed in proportion of 75 % of the accumulation of inferior order courses (table 2).

In order to calculate the other terms of the progression, we have used the formula:

$$N_i = N_s * R_c^{s-1}$$

Thus, for the Şucu basin the values obtained are: 500; 90.42; 16.35; 2.96; 0.53, and for the Bistra Mărului basin, the series of values calculated is represented by: 503; 98.82; 19.41; 3.81; 0.75.

ΣN_c has been calculated with the help of the descending geometric progression feature that requires that the sum of the terms to be given by the formula: $\Sigma N_c = N_s(1-R_c^s) / (1-R_c)$. We must mention that N_s has been introduced in the formula as an exact value not as a unitary value, because otherwise a parallel line with the real one would be obtained, as well as larger values than the real ones (Zăvoianu, 1978).

For the Şucu basin, the value obtained is 626, compared to 615, representing the sum of the river segments, obtained through direct counting, and for Bistra Mărului, the value obtained is 605, close to 628, representing the sum of the segments obtained through direct counting.

The real size order of the two basins has been calculated using the formula:

$$s = 1 + (\log L_1 - \log l_1) / (\log R_L + \log r_l)$$

For Şucu basin, the value obtained is 4.65, and for Bistra Mărului basin, the value obtained is 4.86, values that are close to order 5, obtained in the case of both rivers, through the hierarchy of the rivers within the Horton - Strahler system.

The lengths of the river segments have been calculated taking into account the *law of the lengths of river segments,* which states that the sums of the lengths of the river segments of ascending successive order tend to form a descending geometric progression, where the first term L_1 is given by the sum of the lengths of the order 1 segments (Grecu, Comănescu, 1998).

For the Bistra Mărului river basin, as well as for the Şucu river basin, these values are presented in tables 1 and 2 and from their analysis we may notice that the total sum of the length of the river segments is a lot higher in the case of Bistra Mărului basin (191.62 km), than in the case of Şucu basin (164.72 km).

By comparing the sum of the length of river segments to the number of river segments, there results a new series $l_i = L_i/N_i$, which is also a geometric progression, but this time it is ascending (Zăvoianu, 1978). By analysing tables 2 and 3, we may notice that the average length values of the segments for the two basins are similar.

In the second part of the study, we have performed a comparative analysis of the manner of manifestation of a flood within the two hydrographical basins. The starting point of this analysis have been the monthly values of the multiannual average flows, calculated for the period 1958-2002 and for the two hydrometric stations. For

the Şucu hydrometric station, the multiannual average monthly flows from this period have larger values than the ones from the Bistra Mărului station (fig. 2).

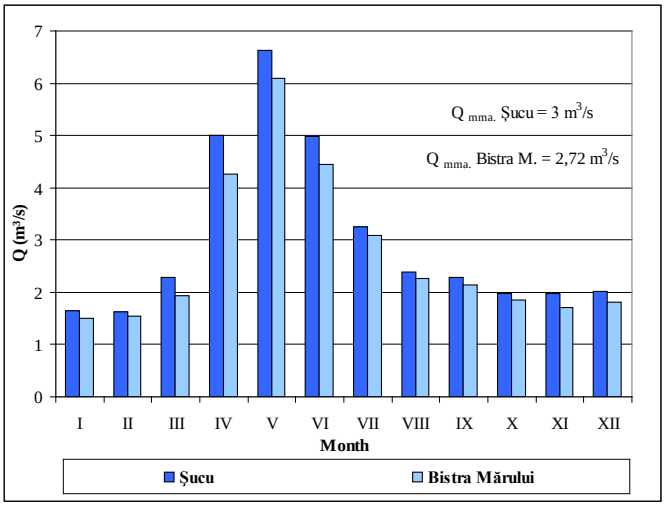

Fig. 2. ***The variation of the multiannual average monthly flows at both stations (1958-2002)***

This fact is due to several specific features of the Şucu basin in comparison with the Bistra Mărului basin, such as: a western location, a lower forestation coefficient (0.55, compared to 0.71) and a higher value of the slope (7.9 ‰, compared to 7.1 ‰).

For a correct analysis of a flood's parameters, we have had to consider the variables involved in its genesis and its evolution. Thus, the values of the morphometric elements specific to the two hydrographical basins have been calculated (table 3).

Table 3. ***The morphometric elements of the two hydrographical basins***

Hydrographical basin	**F (km²)**	**H_{med} (m)**	**L (km)**	**b_{med} (km)**	**I (‰)**	**P (km)**
Şucu	79,7	1434	16,0	4,28	7,9	43,5
Bistra Mărului	87,0	1442	14,0	6,21	7,1	40,4

Another determining factor in the propagation of the flood is represented by the shape of the hydrographical basin. Following the calculations, we have noticed that the two hydrographical basins have a moderately elongated shape, the Şucu hydrographical basin having a slightly elongated shape compared to the one of the Bistra Mărului hydrographical basin (table 4).

Finally, in order to demonstrate that the two basins analysed, that belong to the same order, have almost the same flows and the almost the same morphometric features, have the same behaviour regarding the manner of manifestation of the floods. We have performed a comparative analysis of two floods produced within the two hydrographical basins.

Table 4. ***The values calculated for the determination of the hydrographical basin shape***

Hydrographical basin	**Development coefficient** $\varphi = \frac{b_{med}}{L}$	**Coefficient of Gravelius** $K = \frac{P_{bh}}{2\sqrt{\pi \cdot S}}$	**Form factor** $R_f = \frac{S_{bh}}{L^2}$
Bistra Mărului	0,44	1,22	0,44
Şucu	0,31	1,37	0,31

The atmospheric precipitations are the main factors triggering the flood. The geographical location of the two basins, in the way of the oceanic masses of air and of the Mediterranean cyclones, as well as at a high average altitude, give the area significant quantities of precipitations with direct influence on the discharge.

The flood from the period 16-20.05.2005

This flood was triggered by rains, resulted from the precipitations with torrential features, which fell in the two basins and which were due to the travel of a Mediterranean mass of air over the western part of Romania.

After performing the hydrographs and the delimitation of the floods, the specific parameters of a flood were calculated, resulting:

- the times to react of the hydrographical basins to the precipitations are close;
- the total duration of the flood (84 hours) was smaller on Şucu river (T_{cr}=44 hours, T_{sc}= 40 hours) than the one (96 hours) on Bistra Mărului (T_{cr} =56 hours, T_{sc}=40 h.);
- the values of the flows at the beginning and at the end of the flood are close, and the maximum flow recorded was larger on Bistra Mărului, because this basin has a larger surface (87.0 km²), compared to Şucu (79.7 km^2) (table 5);

Table 5. ***The stages and the flows of the flood from 16-20 May 2005***

Hydrometric station	**Flood stages**			**Q (m³/s)**			**q (l/s/ km²)**
	Beginning	**Maxim.**	**End**	**Beginning**	**Maxim.**	**End**	
Şucu	17 May 06:00 AM	19 May 02:00 AM	20 May 18:00 PM	10,8	21,5	11,2	270
Bistra Mărului	16 May 18:00 PM	19 May 02:00 AM	20 May 18:00 PM	12,9	30,6	12,9	352

- the basic volume is larger than the flood volume, due to the occurrence of the flood analysed during a period with high waters (table 6);
- the shape coefficient of the flood (δ): 0.55 on Şucu and 0.45 on Bistra Mărului;
- the discharge coefficient (α) is 0.31 on Şucu and 0.49 on Bistra Mărului;
- the average layer of precipitations fallen on the surface of both basins was 25 mm;
- the report between the increase volume and the flood volume is 0.45 on Şucu and 0.56 on Bistra Mărului;
- the values of the report between the increase time and the total time are: 0.52 on Şucu and 0.58 on Bistra Mărului.

Table 6. ***The values of water volumes and of the layer drained in the two basins***

Hydrometric station	Volume (mil.m³)					Discharge layer (mm)		
	W_t	W_{viit}	W_{cr}	W_{sc}	W_b	total	viitura	bază
Şucu	3,61	0,612	0,274	0,338	2,99	45,2	7,68	37,6
Bistra Mărului	4,72	1,06	0,595	0,465	3,66	54,3	12,2	42,1

The flood from 24.12.2009 – 17.01.2010

This flood was a complex one, being formed of 3 peaks, determined by the oscillations from the evolution of the discharge, due firstly to the precipitations under liquid form (coming from the Adriatic Sea) and, secondly, to the thermal regime with values over the average of December, leading to the melting of the snow layer (fig. 3).

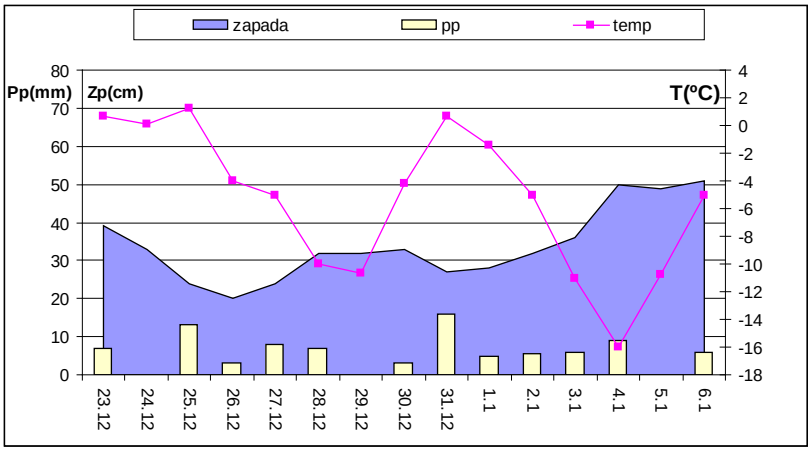

Fig. 3. ***The evolution of the snow layer according to temperature and precipitations at Ţarcu station (23.12.2009 – 06.01.2010)***

The distribution of the flows from a long period of time and the occurrence of 3 peaks of the flood together with the purpose of the paper and the restricted space for debating the subject has made that the analysis of this flood be done only according to the total volumes of water flown in the two basins.

By analysing the values resulted from the calculation based on the flow hydrographs (fig. 4), there have resulted the following:

- the total time of the flood was 24 days in both basins, and the total volume of water in the Şucu basin was larger (11.9 mil. m³), than the one in the Bistra Mărului basin (10.7 mil. m³);
- the summed up volumes of the 3 peaks of the flood were 6.53 mil. m³ on Şucu and 6.05 mil. m³ on Bistra Mărului and the basic volume of the flood is larger on Şucu (5.37 mil. m³, compared to 4.65 mil. m³);
- the discharge coefficient (α) on Şucu was higher (0.44), than the one on Bistra Mărului (0.38) and the average precipitation layer on the two hydrographical basins was 185.9 mm, value obtained by considering the water equivalent from the snow.

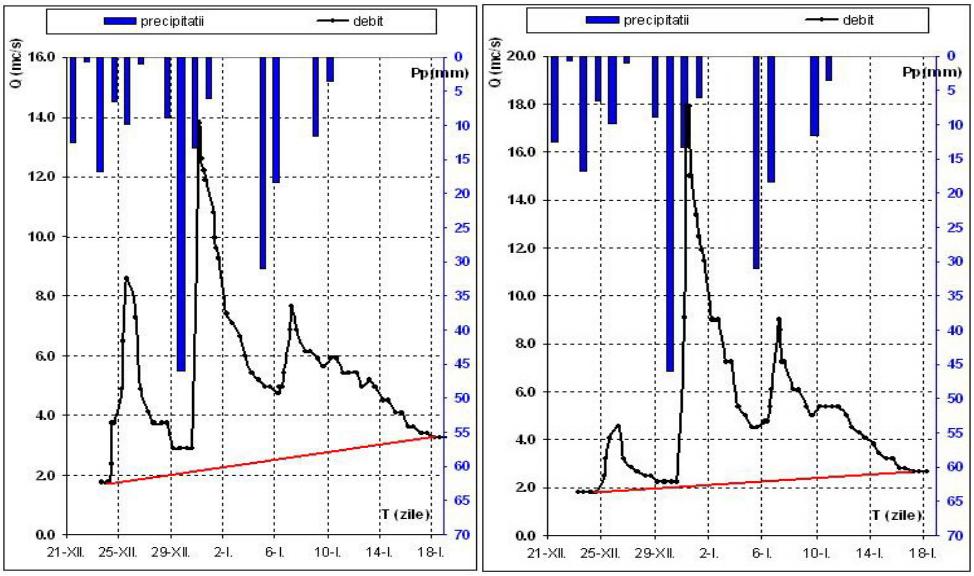

Fig. 4. ***The hydrograph of the flood and the precipitat***

3. CONCLUSIONS

The two hydrographical basins which have the same order and are located in similar physical-geographical conditions, have on average approximately the same size of the reception basin surfaces, of the water flows, of the average slopes, of the course lengths and they may generate floods with the same magnitude and manifestation.

The floods occurred within the two hydrographical basins have generally the same triggering factor, and the beginning, climax and end stages of the flood are approximately the same. The differences that occur in the case of the volumes discharged or in the case of the reaction and propagation time, are due to the exposure to the masses of air (Şucu is the most exposed to the masses of air coming from the south-west), the small difference in the shape of the two basins, of the slightly different degree of forestation, as well as the different value of the relief energy.

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