THE INFLUENCE OF ATMOSPHERIC CIRCULATION, SHAPE AND POSITION OF THE HYDROGRAPHICAL BASIN ON AMPLITUDE AND EFFECTS OF THE FLOODS– CASE STUDY OZANA AND CRACAU BASINS

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ABSTRACT. – The influence of atmospheric circulation, shape and pozition of the hydrographical basin on the amplitude and effects of the August 2005 flood in Ozana and Cracău basins. This paper examines the extent to which the shape of the Cracău and Ozana's watersheds (tributaries of Bistrita and Moldova), and their position in relation to Stânişoarei Mountains chain influenced the amplitude and effects of the flood event that took place in August 2005. Another important aspect was the influence and particularities of the atmospheric circulation on the rainfall quantities in the two basins, in the 17th to 20th of August period. Moreover, this study takes into consideration the characteristics of the flood-related elements and it also quantifies the damages produced by the flood itself.

Key words: basin shape and position, flood, atmospheric circulation, Ozana, Cracău, August 2005

1. Introduction

Hydrographical basins shape, along with other morphometric characteristics play a major role in the propagation of flood waves. Thus, in a basin that has an elongated shape, the concentration of water in the riverbed is more difficult than in basins with a circular, fan shape (Zăvoianu, 1978). This factor influences the magnitude of the flood waves and their effects. Also, the position of the basins in

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relation to the nearby mountain ranges influences the movement of air masses, and thus, the dynamic of cloud systems that generate rainfalls.

In hydroclimatic terms, the study area is part of the Eastern Europe climate zone, since is has a transitional temperate-continental climate, characteristics that affect the eastern part of Romania, the east of the Eastern Carphatians and Moldavian Plateau (Romanescu et al. 2012a,b, Stefanache 2007, quote by Cojoc et al.2015, 1426 pp.)

2. Study area

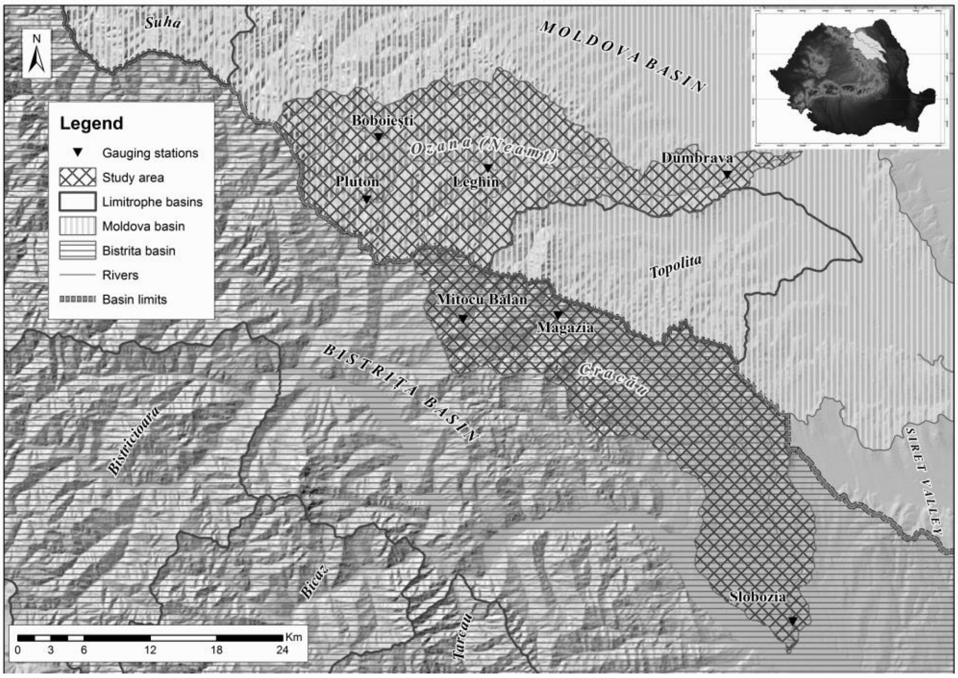

Fig. 1. The localization map of the study area compared with the national territory

Regarding the location of the study area, both hydrographical basins are located in the Neamt County. From a geographical point of view, Ozana’s basin overlaps the relief unit represented by the Ozana-Topolița Depression (Neamt), while Cracău’s basin is located in the Cracău-Bistrita Depression. Upper sectors have developed in the mountainous unit represented by Stânişoarei Mountains, mountains that are a "[...] part of the Carpathian flysch geosyncline that evolved between Lower Cretaceous and Upper Miocene [...]" (Ichim, 1979 16 pp).

Geologically, the two basins are characterized by a petrographic mosaic, crossing deposits of limestone-sandstone flysch, marls, conglomerates etc.

Also, in the study area, slope values are high, the upper sectors exceeding, in some parts, the value of 25 degrees, a factor that influences the water propagation velocity. Other morphometric characteristics are given in Table 1.

3. Database and methods

The database used in this study consists in hydrological data obtained from the archives of Water Management System, Piatra Neamț and contains liquid flows from four hydrometric stations of the two basins, recorded during the flood of August 17th to 20th, 2005.

Not only, it was necessary to collect meteorological data on rainfall recorded at the hydrometric stations, but also from the most significant meteorological stations for the study area. Therefore, the precipitation quantities that fell between 16.10.2005, 06 GMT and 20.10.2005,06 GMT, have been graphically represented.

At the same time, thematic maps regarding the distribution of the surface pressure level and the geopotential field distribution at 500 hPa were consulted. Also, there were used visible satellite images that emphasized the cloud systems which affected the study are. Through www.esrl.noaa.gov website we determined the spatial distribution of L.I. (Lifted Index). Microsoft Excel was used to work-up the numerical data.

The coefficient of circularity was calculated using the Xtools Pro extension of the ArcGIS 10.2 program. With its help, the watershed area and perimeter were obtained, and then used in the circularity coefficient’s formula. Furthermore, the centroids of the watersheds were determined and used to graphically represent the coefficient of circularity.

Flood hydrographs were obtained using the CAVIS software (for the determination of singular flood waves), followed by the interpretation and the extraction of characteristic elements.

Finally, the table regarding the effects of the flood was drawn up on the basis of data taken from the summary report on development of hydrological phenomena for August 2005, obtained from the "Romanian Waters” National Administration, Bucharest.

4. Results and Discussion

4.1. The influence of basin shape

Zăvoianu, 1978, mentioned that the assessment of the basin's shape as round, fan-shaped, elongated or oval is only qualitative and remains subjective as long as no quantitative estimations are considered. Over time, many quantitative assessments have been developed.

Sorocovschi and Serban, 2012, quote several indicators used to determine the basin shape, as follows: form factor, Rf (R.E. Horton, 1932), circularity ratio, Rc (V.C.Miller, 1953), elongation ratio, Rl (S.A. Schumm, 1956) etc. Another shape ratio mentioned belongs to Zavoianu, 1978, which has the square as reference figure:

$$R_f = \frac{F}{(P/4)^2} \quad \text{where,}$$

F = area in km2; $(P/4)^2$= the square with the perimeter equal to the perimeter of the basin,in km.

This ratio denominator is represented by the square perimeter equal to the perimeter of the basin, not by the square of the maximum lenght of the basin, as in Horton`s 1932 ratio.

Rădoane et al., 2006, quote by Bilașco, 2008, uses the coefficient of circularity for determining the basin shape, calculated by the formula:

$$C = \frac{L_c}{2\sqrt{\pi F}} \quad \text{where,}$$

L_c = length of the watershed, perimeter in km
F = catchment area, in km2

As highlighted by the same author, the value of C is dimensionless, C≥1. It is considered that a river basin that owns a coefficient of circularity close to 1 has more of a circular shape.

For the studied basins, we determined the surface of the two catchments areas using the Xtools extension from Arc.GIS.The software generated two new columns in the attribute tables of the both watersheds, from which resulted the values of the area and perimeter watershed, finally used in order to calculate the coefficient of circularity.

After a quantitative assessment on the shape of the two basins, the graphic representation of the coefficient was achieved (Fig. 2). Thereby, the Cracău basin (Fig. 2.A), with a coefficient of 1.97 in the upper sector and 1.96 in the lower sector has a more elongated shape than Ozana basin (Fig. 2. B), with a value of 1.70 in the upper sector, respectively 2.42 in the lower sector.

Tabel 1. Some morphometric characteristics of basins (according to *Atlasul Cadastral al Apelor din România*, 1992, with additions)

No.	Rank	Basin name	Slope (0/00)	Aver.altit(m)	Sectors	Area (km²)	Perimeter(km)	C (≥1)
1	3	Ozana	12	683	Upper Sector	347.81	112.97	1.70
					Lower Sector	65.66	69.7	2.42
2	3	Cracău	10	567	Upper Sector	215.6	102.7	1.97
					Lower Sector	214.5	101.9	1.96

As can be noted on the representation (Fig.2. B), Ozana`s upper sector has a coefficient of circularity by 1.70, so Ozana has a better developed catchment area in the mountain and SubCarpathian zone, which in conjunction with more precipitation translates into a more important input of water, which is also proved by the maximum discharge value recorded at the related hydrometric stations, being recorded on the 20th of August 2005, 06 GMT at the Dumbrava hydrometric station, 456 mc/s, which also represents the historical maximum discharge value for the mentioned station.

A B

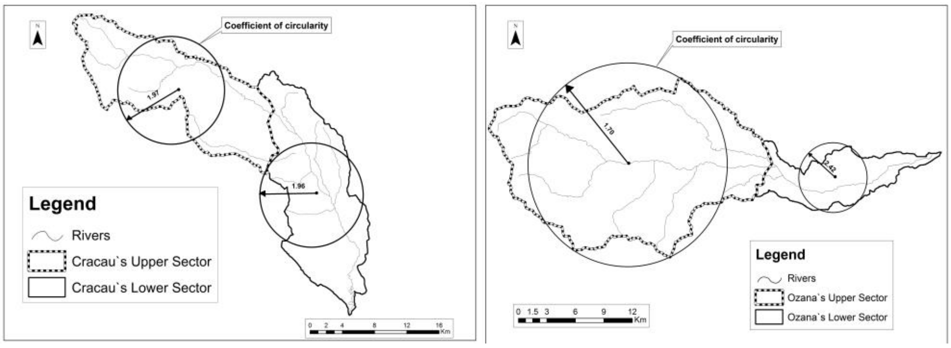

Fig. 2. Graphical representation of the coefficient of circularity for Cracău (A) and Ozana (B) basins, realized with XTools Pro extension

4.2. The influence of the hydrographic basin`s position

A quantitative assessment on how the position of the watershed in relation to the nearby mountain chain influences the amplitude and the effects of a flood is difficult to conduct. However, a couple of qualitative considerations can be mentioned. As can be seen in Figure 1, the Ozana basin has an initial west-east position, a position which is continues over the entire length of the course, to its junction with Moldova collector.

On the other hand, although Cracău basin has a west-east initial direction, after passing the mountainous area and crossing the Subcarpathians, it takes a NW-SE direction, reaching, near the confluence with Bistrița, a north-south direction.

Due to Cracău's basin position, amid advections from south-east of hot and moist air masses (Fig. 5, left), the phenomenon known as "train effect" was highlighted. This process implies that over the same point, from downstream to upstream, more intense convective cells succeed (Doswell, 1996). In this way, the quantity of rainfall in a particular spot is influenced, the water from their fall playing an important role on the discharge, and therefore on its effects.

4.2. The influence of the atmospheric circulation

The synoptic analyses of the 17th to 20th of August 2005 period highlights two major processes that influenced the weather into the South-East part of Europe: the passage of a Mediterranean depression, in the first part of the period and the advection and intensification of some Mesoscale Convective Complexes, in the second part of it, in the presence of an upper cut-off low.

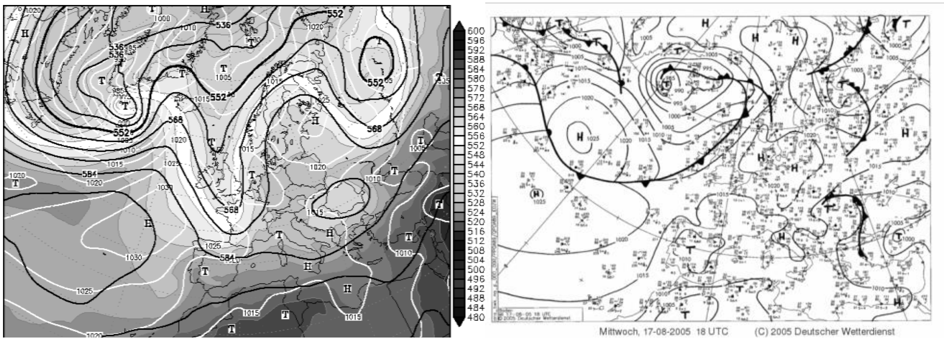

Fig. 3. left. Distribution of the geopotential field at 500 hPa level (gpdam), surface pressure level (hPa) and the relative topography 500-1000 hPa, on 19.08.2005, 12:00 UTC; Fig. 3, right. Distribution of the surface pressure level and associated frontal systems on 17.08.2005, 18:00 UTC (Source: www. wetter3.de)

At 500 hPa pressure level an upper trough is located above the Scandinavian Peninsula, evolving gradually eastward to the northern part of Russia. A second upper trough present above Island is about to deepen and extend to south-east, into the eastern part of the north Atlantic Ocean, covering the entire west part of Europe. The pre-existing trough over the central part of Europe is transforming into an upper cut-off low that is moving eastward, over the northern part of Balkan Peninsula to the Black Sea (fig. 3, left). At the beginning of the studied period a low pressure system is formed into the Mediterranean Sea and moves eastward, over the Dinaric Alps and Lower Danube Plain area at the same time with the upper cut-off low. The north-central part of Europe is under the influence of some mobile anticyclones, evolving on the western flank of the upper trough that affects the area (Fig. 3, right).

The rainfall quantity in the first half of the period was significant, the maximum value being recorded in Ozana basin, 63.9 mm, at Pluton gauging station (Fig. 4, left).

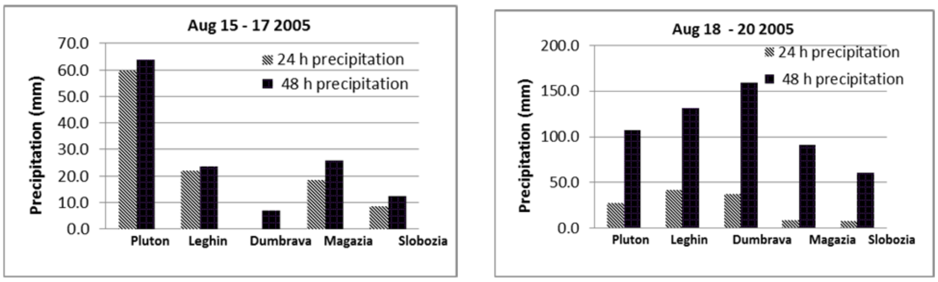

Fig. 4 Recorded rainfalls at the gauging stations in 15-17 august 2005 period (left) and 18-20 august 2005 period (right)
(Source: "Romanian Waters" National Administration, Bucharest)

For the south-east part of Europe, the persistence of low level pressure field (about 1010 hPa) and the presence of the upper cut-off low into the second part of the studied period (18-20.08.2005) facilitated wet and warm air advection from the east part of Mediterranean Sea and west part of Black Sea to the east and south-east part of Romania and the growth of cloud formations (fig. 6, left).

This aspect is highlighted by the rainfall quantities recorded at the gauging stations related to the neighboring basins. In the 5th figure are displayed the recorded rainfall quantities between 15 – 20 August 2005, according to INHGA ,Bucharest.

As can be noted on the graphical representation, in the first half of the analysed period (15-17 august), the highest precipitation quantities were recorded at the Bistrita gauging stations, especially to west – south-west of the study area, in Bicaz basin. The maximum value was recorded at Bicaz Chei gauging station by 106.2 mm in 48 hours (Fig. 5 , up)

In the second half, the maximum rainfall quantity was recorded at Dumbrava gauging station of 158.6 mm in 48 hours (Fig. 4, right) and at the southernmost than it gauging station, Pastraveni, by 159.1 mm in 48 hours (Fig.5, down).

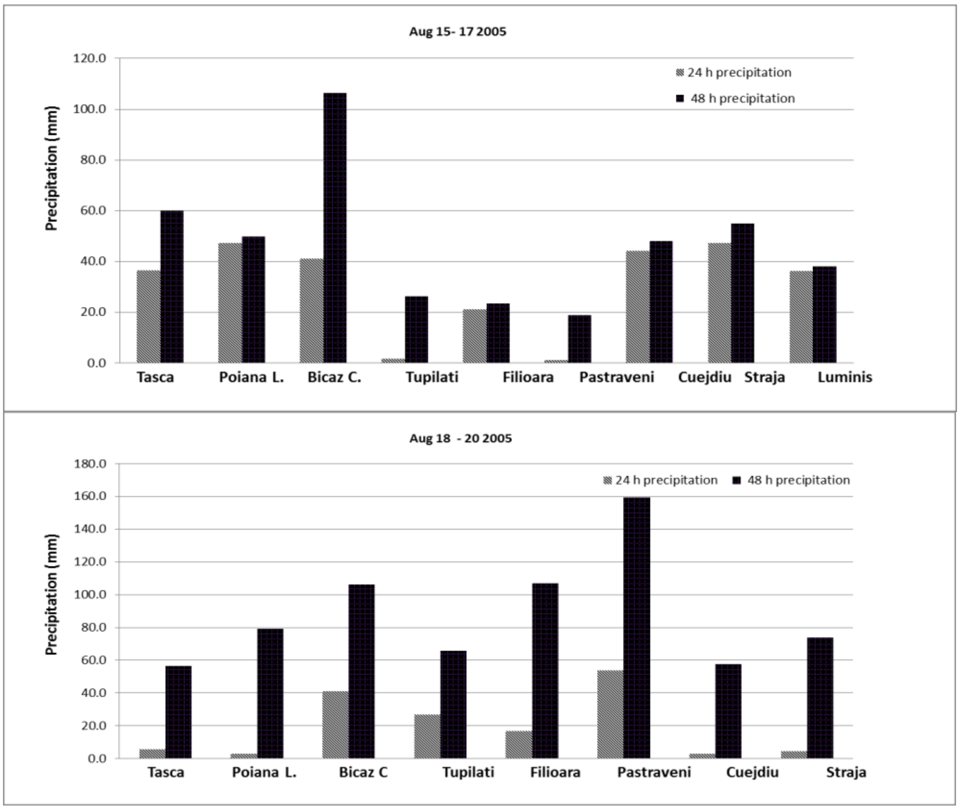

Fig. 5. The rainfall quantities recorded at the gauging stations related to the neighboring basins in the first half (up) and the second half (down) of the analysed period (15 – 20 August 2005)

A mesoscale analysis shows for the 18th of august high level CAPE values (over 2500 J/kg), an intense shear (20 m/s) in the 0-6 km above ground level lair and an intense air instability expressed by values under -4 of Lifted Index (Fig. 6, right). In the last day of the studied period the air instability gradually reduces itself as the CAPE values shows (less than 500 J/kg), low level shear is only up to 10 m/s and LI slightly negative, but the moisture advection continues, being an important ingredient for high precipitable potential.

In this conditions, the rainfall quantity was higher than in the first half, recording 158 mm at Dumbrava gauging station, in the lower sector of the Ozana basin (Fig.4, right)

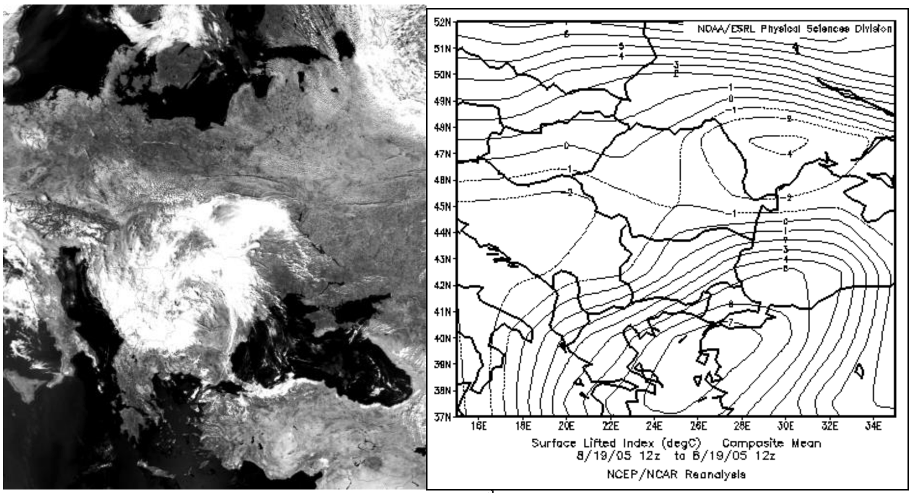

Fig. 6. Visible satellite image for 18th of August 2005, 11.25 GMT (http://www.wettergefahren-fruehwarnung.de) (left) and the Lifted Index values distribution into Balkan Peninsula, on the 19th of August 2005 at 12.00 GMT (http://www.esrl.noaa.gov) (right)

4.3. The characteristic features of the flood

We made the flood hydrographs using CAVIS software with which we determined the amplitude and the flood specific features, as shown in Table 2

The characteristic features that describe a flood event are numerously, but there are a few elements frecquently used in hydrology. Those elements are: the maximum discharge value (Q_{max}), the highest reached level, the total volume (W_t), the volume formed during increasing time (W_c) and decreasing time(W_d), runoff layer (H_s), the total duration (T_t), increase time phase (T_c) and decrease time phase (T_d) (Bătinaș et al., 2014) .

The four hydrometric stations located in the study area present significant differences of the maximum discharge values. So, Ozana basin, with a better developed cathcement area than Cracău basin, recorded the highest maximum discharge value of 456 m^3/s. According to the mentioned facts, the highest reached level was 210 cm, overruning by 60 cm the alert level.the total volume recorded was 46.63 mil m^3, with a runoff layer reaching 109 mm.

On the other hand, the maximum discharge values recorded in Cracău basin were much lower; the highest value was recorded in the upper sector at the Magazia hydrometric station, 54.7, with a total volume of 5.03 mil m^3.

Tabel. 2. The characteristic features of the flood recorded in 17-20 August 2005 period (Source: Water Management System, Neamț County)

Gauging station-River	Qmax m^3/s	Wc mil. m^3	Wd mil. m^3	Wt mil. m^3	Hs mm	Tc hours	Td hours	Tt hours	q(l/s.km²)
Leghin-Ozana	250	4.47	14.42	18.89	67.46	80	15	216	1269,03
Dumbrava-Ozana	**456**	18.63	28.0	46.63	109.71	72	10	216	1302,85
Magazia-Cracău	54.7	1.20	3.82	5.03	12.32	12	9	108	497,27
Slobozia-Cracău	116	2.01	2.99	5.0	41.37	31	41	240	264,84

*****according to Bătinaș, Șerban pattern, with subsequent changes

The specific flow values recorded at the gauging stations were much higher in Ozana basin, with a maximum value of **1302** l/s.km² at Dumbrava station, while in Cracau basin specific flow values have not reached 500 l/s.km² (Table. 2).

4.4. The relation between rainfall quantities and the allure of the flood`s hydrographs

Using Microsoft Excel the flood`s hydrographs and the rainfall quantities graphical representation were made.

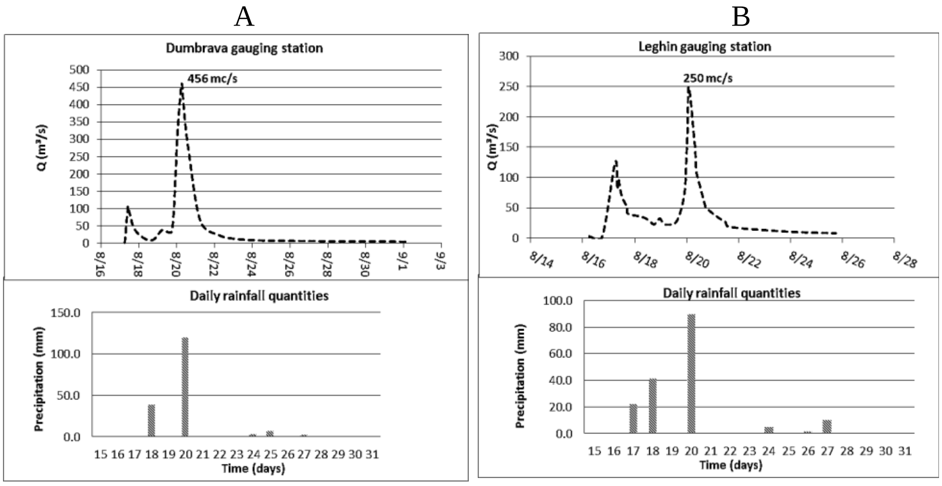

Fig.7. The relation between daily precipitation quantities and flood`s hydropraphs for Ozana basin (A-Dumbrava; B-Leghin gauging station)

As we can see, the rainfall quantities maximum values were recorded in 19 august 2005 at all the studied gauging stations, Dumbrava recorded the maximum value of almost 120 mm.

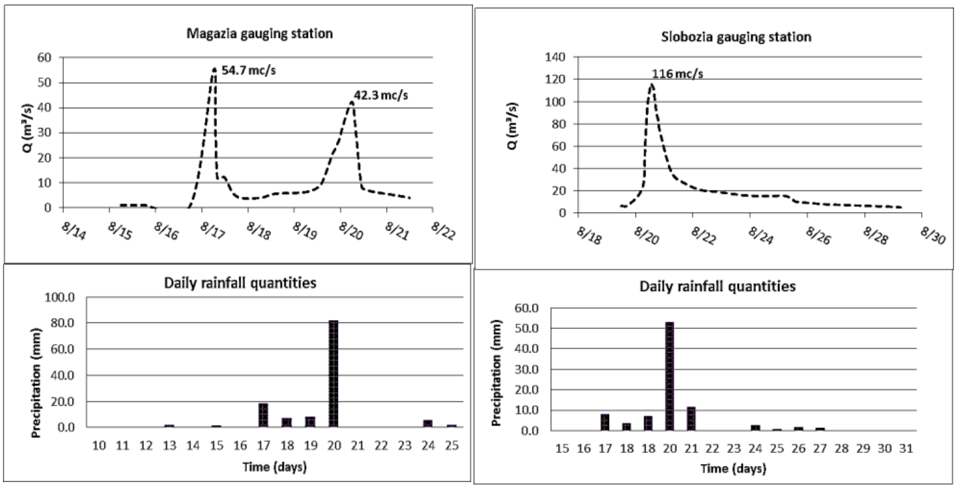

Fig.8. The relation between daily precipitation quantities and flood`s hydropraphs for Cracau basin (left-Magazia; right-Slobozia gauging station)

4.5. Hydrological parameters recorded at the limitrophe gauging stations

Table.3. Maximum discharge values recorded at the gauging staions related to neighboring basins (Source: National Institute of Hydrology and Water Management, Bucharest)

Neighboring basins	Gauging St.	Date	Hour	AL (cm)	FL (cm)	DL (cm)	Hmax (cm)	Qmax(m³/s)
Bicaz	*Tașca*	20.08	3:00	*			250	104
Tarcău	*Cazaci*	20.08	10:00	*			220	84.5
Topolița	*Păstrăveni*	20.08	6:00		*		250	482
	Filioara	20.08	4:00			*	300	89.5
Moldova	*Tupilați*	20.08	12:00		*		270	1160
Bistrița	*Frunzeni*	20.08	14:00			*	300	1039
	Straja	20.08	17:00	*			316	356

* AL – alert level; FL – flood level; DL – danger level;

During the 15 – 20 august 2005 flood, many gauging stations related to the neighboring basins important maximum discharge values were recorded especially during the 20th day. For all the stations the water levels had reached and overpassed the alert level. The danger level of 300 cm was reached at two stations: Filioara and Frunzeni (Tabel. 3)

5. THE EFFECTS OF THE FLOOD

Tabel. 3. Recorded damages at settlements from Cracău and Ozana catchment areas (Source: "Romanian Waters" National Administration, Bucharest)

Settlements			Crăcăoani	Bodești	Roznov	Pipirig	Vânători	Târgu-Neamț	Timișești	Total
Houses	no.	A			8	1				**9**
		D				1				**1**
Annexes	no.	A			16	2	1			**19**
		D								
Transp. Infrast.	km	NR				0.17				**0.17**
		CR					2			**2**
		VR	0.3							**0.3**
		Streets		2	1					**3**
Bridges	no.	A	1	1	1	4			1	**8**
		D	1			1	1			**3**
Footbridges	no.	A	1			2	1			**4**
		D				2	1	1		**4**
Arable land	ha	A		100	50	3	10.4	26	38	**227.4**
Pastures	ha	A		7	20	10	175	20	350	**582**
Dams	km	D	0.15		0.13	0.44			0.85	**1.57**
Wells	no.	flooded			117	37	54	31	42	**281**
Financial	**mil.**	**RON**	**0.1057**	**0.592**	**0.292**	**0.91**	**0.72**	**0.146**	**0.281**	**3.0467**
		USD	**0.361**	**0.202**	**0.10**	**0.311**	**0.249**	**0.05**	**0.096**	**1.369**

* A = affected; D =destroyed; NR=national road; CR= county road; VR= village road;
1 US Dollar = 2.9246 RON, by NBR (National Bank of Romania, 17-20 aug 2005)

The final paper stage consisted in the quantification of the total recorded damages produced by the flood. There were 9 houses and 19 households affected by the outpour, those being the most significant recorded damages. From the nine damaged houses, 8 belongs to Roznov settlement, locate in the lower sector of Cracău basin, near the confluence with Bistrita. This aspect emphasize the effect of the so called "train effect", many intense convective cells passing over the same spot, from downstream to upstream.

Among the recorded damages, we also counted the high number of the flooded wells, 281, most of them in Cracău basin.

Also, an extended area of arable land and pastures were flooded, its value reaching aproximately 820 ha. We should mention the number of affected bridges, 8, and the 3 bridges destroyed in Crăcăoani, Pipirig and Vânători settlements.

The total costs were estimated to 3.0467 mil. RON, representing 1.369 mil. USD , according to the exchange of the National Bank of Romania, from 17th to 20th august 2005.

CONCLUSIONS

To sum up, this paper proved that that the basin's shape represented a real impact to the study area. Both rivers presented high maximum discharge values. .

Besides that, the circularity coefficient, 2.34 for Ozana and 2.44 for Cracau which imposed an elongate shape, played an important role in order to raise the concentration time, resulting in mitigating the effects.

Moreover, the coeficient of circularity difference between the uppper sector (1.70 comparing to 1.97) and the lower one (2.21 comparing to 1.96) for Ozana and Cracău basins have determined the flood`s different amplitude and the related effects.

Basin's position influence is very obvious, the Cracau basin being positioned on the direction of warm and wet air advection from eastern mediteraneean basin and western part of Black sea, air which advected towards East and Southeast of Romania. As a result the cloud systems intensified afterwards above Moldavia region.

Another important fact is the amplitude and effects of the studied flood. The levels for each hydrometric station overrun the alert level, discharging important volumes of water, the maximum being recorded at Dumbrava gauging station, 46.63 mil m^3. The damages were estimated more or less up to 1.369 mil USD, damages that were mitigated by the factors we already mentioned.

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