THE FLOODS FROM JUNE-JULY 2010 ON THE RIVERS FROM THE SUCEAVA HYDROGRAPHIC BASIN

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RÉSUMÉ. - Les inondations de Juin - Juillet 2010 sur les cours d'eau du bassin hydrographique de Suceava. Le bassin hydrographique asymétrique de Suceava, avec une surface de 2612 km2, est situé dans le nord de la Roumanie, mais il se propage également sur le territoire ukrainien, jusqu'à 47°58' N. Ce bassin hydrographique comprend deux grandes unités de secours avec des caractéristiques géographiques distinctes (montagneuse et plateau), séparés par une zone de transition représenté par un secteur de piemont et une succession de dépressions. L'analyse des crues a été faite en utilisant les données de 8 stations hydrologiques qui surveillent les inondations du cours principal (3) et des affluents les plus importants de la rivière (5). Après avoir analysé les facteurs naturels et humains qui ont produit le inondations de Juin - July 2010, on a déterminé l'espace des ondes de crue, l'heure et paramètres hydriques des cours d'eau surveillés, et à la fin il a évalué l'environnement, les risques sociaux et économiques déterminées par ces inondations.

Key words: inondations, Suceava, precipitations, maxime, débit.

1. Introduction

Suceava River is a tributary of the Siret River, has a length of 172.3 km, it has its source on the northern slope of the Aluniş Peak (1294 m) from Obcina Mestecăniş, and it flows into the Siret River downstream the Liteni Town (232 m). Between Şipot and Ulma it forms the border with the Ukraine.

Situated in the northern part of the country, the Suceava river basin has a surface of 2612 km^2, from which 13% (340 km^2) spreads on the territory of the Ukraine, reaching 47° 58' N. Inside this basin appear two major relief units with distinct characteristics (mountainous and plateau), which are separated by a contact area represented by a piedmont sector and a depression series (Solca, Cacica, etc.).

Suceava river basin is very asymmetric, with its main tributaries (by length, surface and discharge) coming from the right side from Obcina Brodina and Obcina Mare (Nisipitu, Brodina, Putna, Pozen, Suceviţa, Solca, Soloneţ), and from

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the plateau some smaller tributaries (Ilişeşti şi Şcheia). The left side tributaries are much smaller, with surfaces that vary between 33 km^2 (Pătrăuțeanca) and 76 km^2 (Horaițul). Near its confluence, it receives other much smaller tributaries (Salcea and Plopeni).

2. Data and methods

The processed data come from 8 hydrometric stations and 2 meteorological stations (Rădăuți and Suceava), where observations and measurements of water level and rainfall are made (Table 1). From these 8 stations that monitor floods, 3 are on the main course (Brodina 2, Țibeni, Ițcani), and 5 on the most important tributaries (Brodina, Putna, Pozen, Soloneț and Şcheia) (Fig. 1).

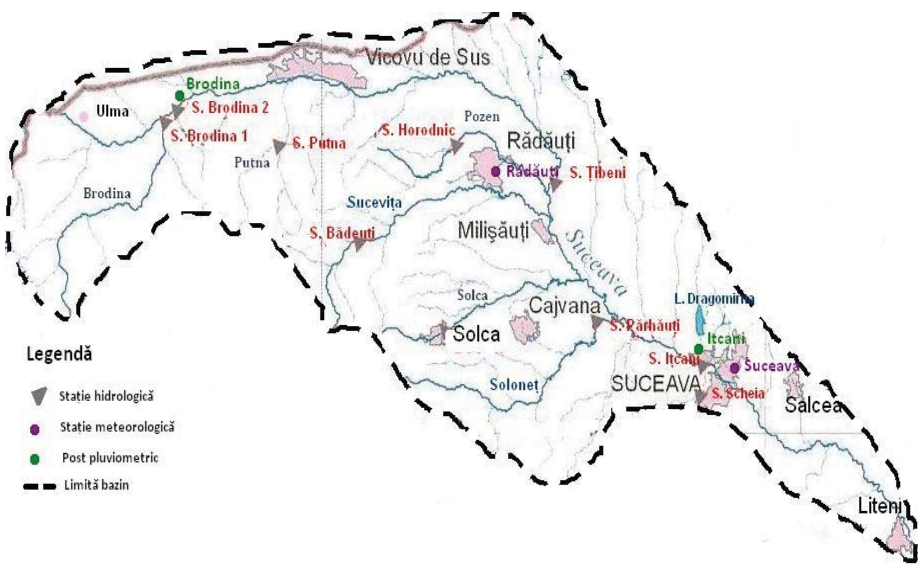

Figure 1. Hydrometric, meteorological and pluviometric stations from Suceava River Basin

The average altitude at the basin's stations ranges between 467 and 989 m, and the basins' surfaces between 33 and 2334 km^2 (Table 1).

For main parameters determination (time, frequency, variability, average, seasonal, monthly and extreme values) there were taken into account some statistical methods, programs and graphics that allowed the identification of central trend, variability and series form parameters. The relations between these parameters were highlighted using correlation matrices.

Table 1 Morphometric and hydrological parameters at the stations from the Suceava water basin

River	Hydro. Station	F (km^2)	Hm (m)	Q (m^3/s)	Cv
Suceava	**Brodina 2**	366	990	4,30	0.49
Suceava	**Tibeni**	1288	730	12,05	0.56
Suceava	**Ițcani**	2334	629	16,99	0.57
Brodina	**Brodina 1**	142	989	1,715	0.52
Pozen	**Horodnic**	67	488	0,533	0.67
Putna	**Putna**	53	847	0,631	0.55
Soloneț	**Părhăuți**	204	467	1,250	0.67
Scheia	**Scheia**	33	388	0,163	0.65

For the determination of flood waves' space, time and hydric parameters and for their graphic representation there was used the CAVIS method (Corbuş, 2010, p. 1).

3. The origin of the June – July 2010 Floods

Some natural and human factors have contributed to the appearance of the June – July Floods. In the category of natural factors must be first mentioned the rainfalls that felt in this period and their intensity, the prior soil moisture, the rivers' high slopes that favour water flowing, and lithological nature that does not allow water infiltration.

In the Suceava river basin have felt high rainfall quantities in 3 time periods (June 21th – 24th, June 26th – 27th, June 28th – July 1st), that generated consecutive floods in a short time period (Fig. 2).

In the first period there were registered rainfalls values between 50 – 150 mm/m^2 in the middle and lower Suceava water course (Straja – 150 mm/m^2, Ițcani – 107,8 mm/m^2).

In the second period, the rainfalls often reached values of 50 and 100 mm/m^2. Over 90% from these quantities were produced in the days June 26th and 27th.

In the last period there registered rainfalls values that totalised over 100 mm/m^2 (Table 2), with very high values in a very short time (33,7 mm/24 ore (27.06.2010 – Brodina 2); 73,3 mm/8 ore (28.06.2010 - Horodnic); 30 mm/6 ore (30.06.2010 - Horodnic); 56.2 mm/ 24 ore (28.06.2010 - Putna); 47.5 mm/24 ore (29.06.2010 - Putna), 82.6 mm (28-29.06.2010 - Părhăuți).

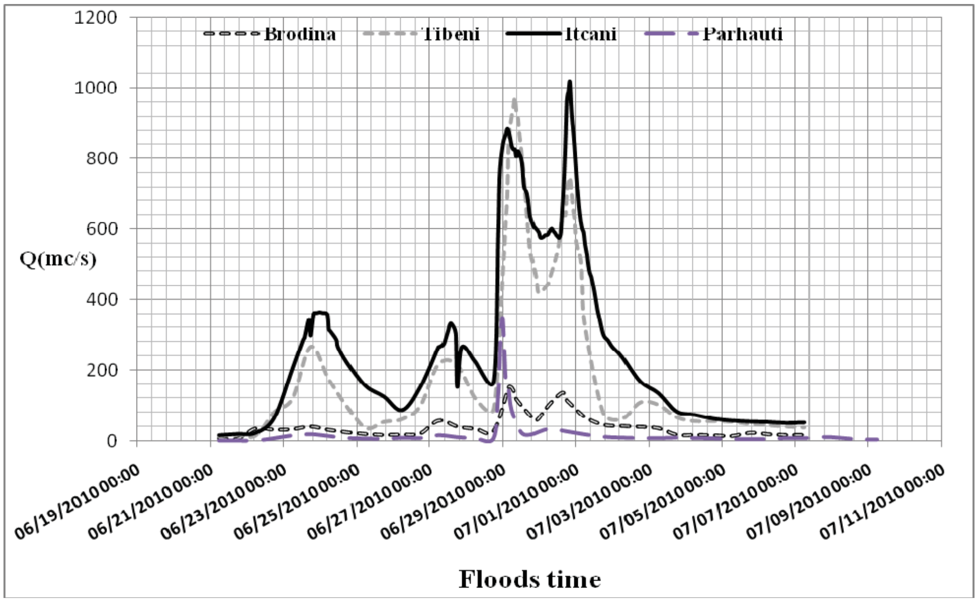

Figure 2. The hydrographs for the June – July 2010 floods on the rivers from the Suceava water basin (* Source: A.B.A. Siret, Bacău, Hydrological Service)

At some hydrometric stations, the rainfalls quantities fallen between June 20th – July 1st 2010 exceeded (Țibeni) or almost reached (Putna) the rainfalls values that generated the catastrophical floods from the period July 23th - August 5th 2008 (Table 2).

Table 2. Total rainfalls that generated floods in the periods July 11th-14th 2005, July 23th – August 5th 2008 and June 20th – July 1st 2010*

River	Hydrometric station	Total fallen rainfalls quantities (l/m^2) in the period:			Mult. average values in June
		11-14.07. 2005	23.07.- 5.08.2008	20.06.- 1.07.2010	
Suceava	Brodina	6.7	284.0	109.1	140.8
Suceava	Țibeni	20,3	86.0	209.7	110.8
Suceava	Ițcani	0.4	66.3	32.8	96.8
Putna	Putna	—	129.3	107.9	—
Pozen	Horodnic	5.3	297.3	115.2	97.2
Soloneț	Părhăuți	1.6	183.5	120.3	90.6

* Source: A.B.A. Siret, Bacău, Hydrologic Station

The rainfalls quantities registered in the period June 20th – July 1st 2010 at the stations from the middle Suceava water basin (Țibeni, Horodnic şi Părhăuți) exceed or almost reach the multiannual average values of June (Table 2).

The rainfalls that felt in the three periods determined the appearance of three floods waves on almost all basin's rivers. Depending on the amount and duration of rainfall, at some stations appeared only one (Horodnic and Părhăuți) or two (Ițcani and Putna) flood waves. About the form of floods can be noted that the first two were simple, in most cases (Fig. 3), while the last flood was composed, very well highlighted at Ițcani and Țibeni hydrometric stations (Fig. 4).

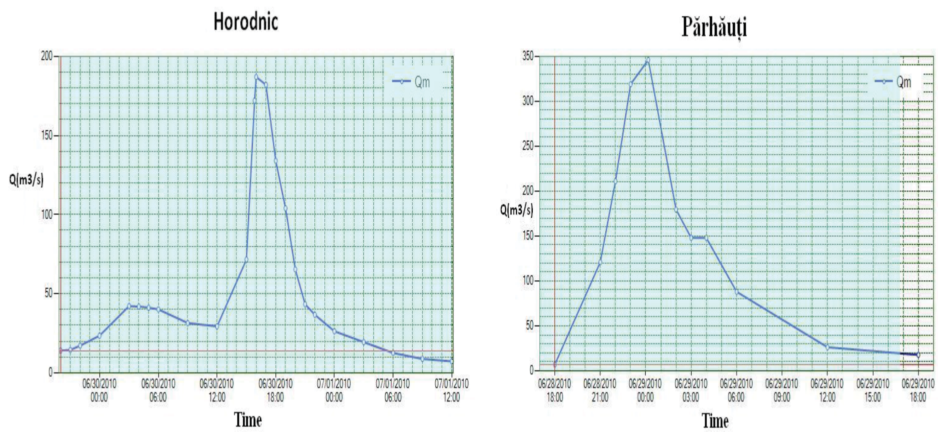

Figure 3. Simple flood hydrographs

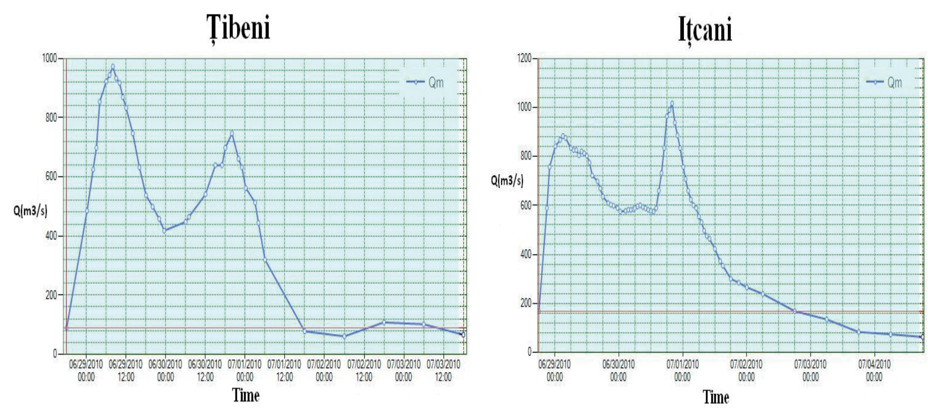

Figure 4. Composed flood hydrographs

Another important natural factor that contributed to floods appearance was the high soil mo isture determine by the frequent rainy and humid periods in the year' first period. This high soil moisture, and the high rainfalls that prolonged very much produced catastrophic floods and flooding on a large portion of Europe, including many countries (Germany, Poland, Czech Republic, Austria, Slovakia, Hungary, Ukraine, Romania, Moldova).

The high enough torrents development in the transition and plateau areas assured rapid transfer of high water quantities into the main collector, creating the possibility for the production of flash floods.

The most important human factor that influenced these floods was the low basins' forestation degree in the transition and plateau areas (Fig. 5).

Beside this factor, another one was the bad maintenance of riverbeds and floodplains. In some places, the riverbeds were narrowed because of bridges' construction, touristic infrastructures and other infrastructures that obstructed water flowing.

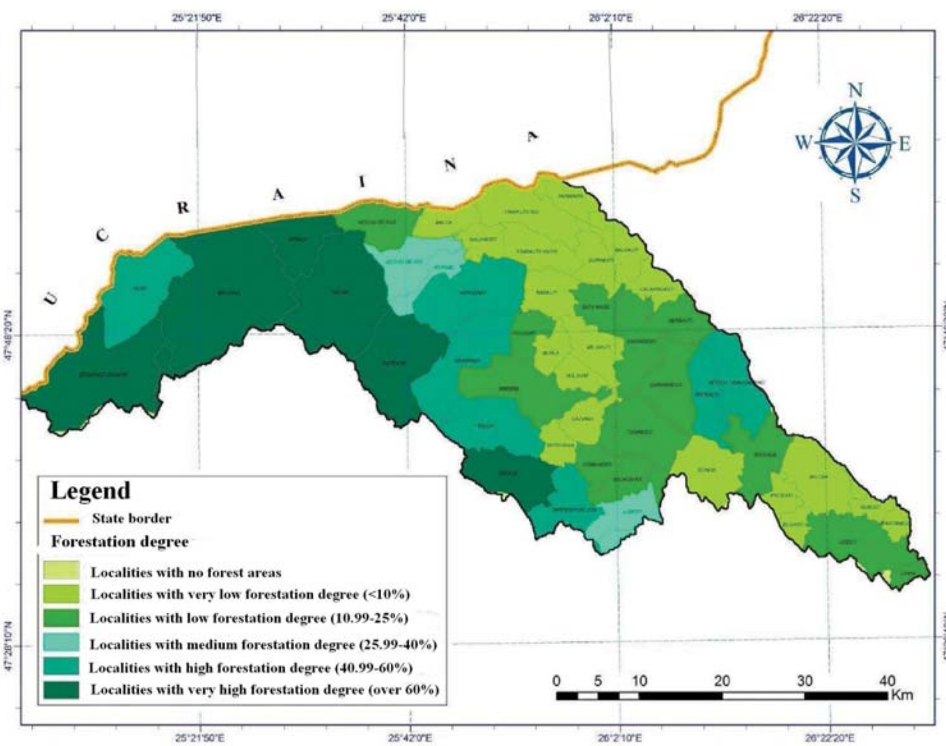

Figure 5. The map of forestation degree inside Suceava water (after Cocerhan, 2012)

4. Flood waves parameters

The flood wave parameters can be categorized into hydric (discharge, level, volume, layer of water drained), temporal (increase, decrease and total time) and mixed (increase, decrease and total volume).

The highest flow discharges were recorded in the third flood, when the flow discharges recorded on most rivers exceeded the carrying capacity of the water course, sometimes reaching historical values (Table 3).

Table 3. Flood waves parameters

Hydro. stations	Period	Q max (m^3/s)	H max (cm)	Date	Wd* (mil.m^3)	Ws** (mil.m^3)	Wt*** (mil.m^3)	Hs (mm)	Tc (h)	Td (h)	Tt (h)
Brodina 2	22-25.06	40.25	147	23.06	5.24	4.43	9.67	26.44	48	48	96
	26-29.06	151.2	224	29.06	3.23	6.53	9.77	26.69	10	18	28
	29.06-01.07	135.5	215	30.06	6.11	6.23	12.44	33.99	17	20	37
Țibeni	22-25.06	266	200	23.06	14.65	18.14	32.79	26.79	36	36	72
	26-29.06	216.2	168	27.06	12.67	20.97	33.65	7.40	36	36	72
	29.06-01.07	973.2	376	29.06	28.42	105.3	133.7	108.9	14	58	72
Ițcani	22-25.06	363.9	398	24.06	27.05	38.10	65.16	27.41	42	54	96
	29.06-01.07	1017	619	30.06	124.5	65.09	189.6	79.75	50	46	96
Brodina 1	22-25.06	38.4	177	23.06	1.36	3.29	5.29	37.28	15	48	63
	26-29.06	52.4	190	27.06	2.34	2.90	5.24	36.94	28	30	58
	29.06-01.07	75.0	210	29.06	0.65	9.50	10.15	71.45	4	56	60
Putna	26-29.06	14.5	105	29.06	0.65	0.22	0.87	16.56	24	10	34
	29.06-01.07	36.6	136	30.06	0.55	0.86	1.41	26.63	18	21	39
Horodnic	22-25.06	12.3	210	27.06	0.59	0.29	0.88	13.26	24	10	34
	26-29.06	192	530	28.06	1.02	6.62	7.64	114.2	4	20	24
	29.06-01.07	187	525	30.06	2.78	2.95	5.73	85.62	20	14	34
Părhăuți	26-29.06	342.1	500	29.06	3.43	5.11	8.55	41.91	6	12	18

* **Wc** – increase volume of the total flood
** **Wd** – decrease volume of the total flood
*** **Wt** – total volume of the total flood

The first flood (June 22th-25th) was characterized by the lowest discharge and level values (Table 3). However, the total flood volume was almost equal with that of the second flood (except Horodnic station), caused by a very long flood total time (with the maximum values at the stations on the main course - 96 hours Brodina 2 and Ițcani, 72 hours at Tibeni).

In the second interval (June 26th-29th) appeared a simple flood wave at all stations in the basin (except Ițcani station located downstream the Mihoveni mobile dam, which mitigated the flood discharges). The discharges reached their highest values at Brodina 2, Horodnic and Părhăuți stations, where the river level has exceeded danger levels (Table 4). The total time of the second flood was the shortest of the three, in most cases with a very short rise time (4-10 hours).

This flood has developed especially on the river's tributaries, forming a simple, one single maximum flood.

The third flood (June 29th – July 1st) was the strongest of the three floods, the discharge and level values recorded in this period were exceeded only by the 2008 historic flood (at the Brodina 1, Horodnic and Tibeni stations, the danger levels were exceeded - Table 4).

The third flood developed equally, both on the mainstream and the tributaries, with one peak on the tributaries, and two on the main course, due to the combination of the tributaries peaks in the main course. This is presented by the longer flood time on the main tributaries than on the tributaries (96 hours at Ițcani, 34 hours at Horodnic).

Table 4. Maximum discharge and level values for the July 2008 and June 2010 floods

Hydro. station	CA	CI	CP	Hmax (cm)		Qmax (m^3/s)		Qmed. Multi. June (m^3/s)	Qmed. Multi. July (m^3/s)
				July 2008	June 2010	July 2008	June 2010		
Brodina 2	250	300	350	341	224	426	151.2	7.552	7.170
Țibeni	250	300	350	432	376	1118	973.2	22.152	19.018
Ițcani	600	700	750	1127	619	1710	1017	30.126	26.31
Brodina 1	150	180	210	362	210	235	75	3.200	2.880
Horodnic	350	400	450	556	530	168	192	0.859	1.726
Părhăuți	200	250	300	740	500	382	346	2.098	0.775
Putna	150	250	300	410	136	145	36.6	1.136	1.046

* Source: A.B.A. Siret, Bacău, Hydrologic Service

Maximum specific discharge (q max) recorded at the stations from Suceava River Basin during these periods ranged between 372 l/s*km^2 at Brodina 2 station and 1696 l/s*km^2 at Părhăuți station and 2866 l/s*km^2 at Horodnic station, as demonstrated by the appearence in the Suceava River middle basin of the strongest flooding in the entire basin.

5. Floods effects

The floods caused by the strong rainfall during June-July 2010 period caused very high and large flash floods inside the Suceava River Basin, exceeded only by those of 2008. These effects were caused by the pouring water on the main water courses, but also by the water torrents that formed on the hills, destroying everything in their path. The effects of these floods can be divided into: environmental, social and economic.

Environmental effects

The environmental effects affected especially Suceava River middle basin (Pozen and Suceava rivers), where there have been changes in watercourses, which had rectified by correcting beds and by building new bridges in the formed beds.

Social effects

A total of 501 people were temporarily isolated, of which 134 in the Arbore, 4 in Todireşti, 65 in Bilca 24 in Burla, 21 in Dolhasca, one in Mitocu Dragomirnei and Zamostea, 30 in Stulpicani and 168 in Voitinel.

Economical effects

These floods have blocked traffic on roads DJ 209K Horodnicu de Sus - Bădeuți, DN 2K in Arbore, the relation Solca – Arbore, DN 2E in Cacica – the traffic evolved on a single band, and on DN 2H the circulation was interrupted, destroying kilometres of roads (damage of 110.324 million lei). In 19 of the 72 flood affected villages were evacuated about 2,390 people, with most - 500 - in Frătăuții Vechi, 368 in Grăniceşti and 300 in Zvoristea and Grămești.

Dragomirna was isolated by the rupture of the access road in the village around the Dragomirna Monastery by the rough waters of Dragomirna Stream.

The floods have destroyed 47 houses in Mănăstirea Humorului, Todireşti, Zvoristea, Zamostea, Şerbăuți, Pătrăuți, Milişăuți, Granicesti, Grămeşti, Dorneşti, Dolhasca, Dărmăneşti and Comăneşti. Were affected also 23 schools, two kindergartens, a dispensary, and seven monasteries or churches. However, due to floods, a total of 4,228 houses were damaged and 1,045 houses were insulated.

There were also destroyed 119 bridges and 658 culverts, 86 bridges and 803 culverts were damaged, 33.68 kilometres of river bank were destroyed and more than 11.775 km damaged; 17,571 hectares of farmland and pasture were flooded, being recorded 30 landslides, and the Arbore village was destroyed the electric network on a length of 1.7 km.

The flooding led to the clogging of 16,125 wells, damage of 42 economic objectives and to the destroying of one, being affected endangered cultural and national heritage.

6. Conclusions

The high precipitation fallen during the first half of 2010, the flooding and large floods from Europe and Asia, highly publicized in the media, which preceded the flood should have been a warning sign for both national and local residents as well as Romania and the study area. But the instant nature of the floods, with large frontal precipitation that fell at the same time in most of the basin, made the expected flood to have higher values than expected.

Therefore it would be desirable for the authorities to achieve a warning and response scheme adapted to the particularities of this basin (basin shape, power supplies, water regime), which can reduce the negative effects of flooding that would occur.

It would also be necessary to educate local population in the spirit of "living with the flood" which means an acceptance of the flood, requiring training and rapid response in case of such a flood, including simulations of action in case of such floods (creating a mentality of response to the floods) (including purchase of housing and life insurance), and physical measures of displacement from vulnerable areas, with most affected houses in these villages being located in the river's flood plain, two steps away from it.

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