

# THE EFFECTS INDUCED BY THE APPEARANCE OF PERIODS WITH MAXIMUM FLOW ON RIVERS IN THE SUCEAVA HYDROGRAPHIC BASIN

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**Abstract.** The effects induced by the appearance of periods with maximum flow on rivers in the Suceava hydrographic basin. Floods represent the hydrological hazard that occurs most often around the world and along the human and Earth's history. Floods affect the natural and anthropic environment, and have positive (nutrients transport, regeneration of underground water resources and ecosystems, etc.) and negative effects. Suceava River basin is an area belonging to the Eastern Romanian Carpathians and Moldavian Plateau that is not that often affected by the negative effects of the maximum water flow, which are the floods. This article tries to present the periods when the floods had negative effects of the studied area. In the interval 1950-2010 where periods when floods were not recorded, but also periods when the negative effects were so evident, that it generated loses of human lives, damages to households and infrastructure, etc.. The most important period with floods was 2005-2010, when the effects were disastrous to the natural and human environment, summing thousands of lei in monetary value.

**Keyword:** social, economic, environmental effects, damages, floods

## 1. INTRODUCTION

The Suceava, the first important tributary of the Siret, has an asymmetric watershed on the right with an area of 98 km<sup>2</sup>, of which 13% is developed on the territory of Ukraine. In the this hydrographic basin there are three relief steps, of which the mountain one includes the eastern part of the northern part of the Eastern Carpathians represented by the Obcinele Bucovinei. It holds the largest part of the basin, followed by the step corresponding to the Suceava Plateau, which includes hilly units (the Dragomirna and Fălticeni) and depression. The transition from Obcinele Bucovinei to the Suceava Plateau is made through a transitional step similar to the Subcarpathians of Moldavia.

Floods and high waters represent important phases in the flow regime of the rivers in the Suceava hydrographic basin, which occur frequently in spring and summer and less often in autumn, being absent in winter. The negative effects on the natural and anthropogenic environment are caused by the floods generated by the periods with maximum discharge. Floods occur when the beds and water levels exceed the storage capacity of the bed. In addition to the negative effects,

periods with maximum runoff also have positive effects consisting of: the transport of nutrients and sediments, helping to form fertile soils; restoring water reserves from the aquifer layers; refreshing wetlands, balancing their ecological health, by increasing the oxygen level in the water; refreshing ecosystems and maintaining the biodiversity of rivers and floodplains (Diaconu, 1988).

The damages caused by floods appear when the degree of demographic and economic loading of the lands near the rivers exceeds a certain critical limit unprepared against this extreme process. The damages caused by floods have been included in two large categories: direct, which can be measured and quantified immediately after their production and indirect whose effects are maintained even after the end of the flood. Direct damages are divided into tangible (material losses) and intangible (loss of human lives) (Zăvoianu, 1981, Romanescu, 2006, Arghiuș, 2007).

The demographic and economic loading of the territories near the rivers, a very frequent and intense phenomenon in the contemporary period, is facilitated by a series of favourable factors to the mentioned territories (water resources, cheap transport routes, the topography of the land favourable for various constructions, the presence of fertile soils favourable for agricultural crops).

## 2. DATA AND METHODS USED

The data related to the effects caused by floods came from the Suceava and Siret basin agencies. Several methods were used in the study: analysis, observation, comparison. For the calculation of the different indicators, statistical methods were used, and for the spatial representation of the results obtained, the mapping and geospatial analysis method (GIS) was used.

The period studied was 2005 – 2010 (Anghel, 2010), because in this interval the most representative and numerous historical floods took place. From the analysis of all the floods produced in the period 1970-2010 in the Siret watershed carried out by ABAS - Bacău (2016), the fact emerged that in the Suceava river watershed the most important historical floods (22) occurred in the period 2006-2010 (Table 1).

**Tabel 1.** Historical floods in the Suceava river basin (source ABAS Bacău)

No. crt.	Name of event	Source	Characteristics	Flood Mechanism	Date of generation
1	Flood Solca River - sector loc.	A12, A15	A21, A24	A31, A36	June 2006
2	Flood Suceava R. - av. loc. Ulma	A11	A21, A22	A38	July 2008
3	Flood Putna R. - loc. Putna	A11	A21	A38	July 2008
4	Flood Voitinel R. - av. loc.	A11, A13	A21	A31	July 2008

5	Flood Pozen R. - av. loc.	A11	A21	A38	July 2008
6	Flood Sucevița R. - av. loc.	A11, A15	A21, A22	A38	July 2008
7	Flood Solca R. - sector loc Solca	A12	A21	A31	July 2008
8	Flood Horaiț R. - loc. Grănicești	A11	A21	A31	July 2008
9	Flood Horaiț - loc. Bălcăuți	A11	A21	A31	July 2008
10	Flood Soloneț R. - av. loc.	A11	A21	A31	July 2008
11	Flood Pătrăuțeanca R. - loc.	A11	A21	A31	July 2008
12	Flood Hănțești R. - loc. Hănțești	A11	A21	A31	June 2010
13	Flood Suceava R. - av. loc. Ulma	A11	A21	A38	June 2010
14	Flood Pozen R. - av. loc.	A11	A21	A31	June 2010
15	Flood Sucevița R. - av. loc.	A11	A21	A38	June 2010
16	Flood Solca R. - sector loc Solca	A12	A21	A31	June 2010
17	Flood Iaslovăț R. - loc. Iaslovăț	A12	A21	A31	June 2010
18	Flood Horaiț R. - loc. Grănicești	A12	A21	A31	June 2010
19	Flood Soloneț R. - av. loc.	A11	A21	A31	June 2010
20	Flood Hătrnuța R. – tributary of	A11	A21	A31	June 2010
21	Flood Pătrăuțeanca R. - loc.	A11	A21	A31	June 2010
22	Flood Dragomirna R. - loc. Mitocu Dragomirnei	A11	A21	A31	June 2010

Source: A11 = Fluvial; A12 = Rainfall; A13 = From ground water; A15=Artificial barrage  
 Defence infrastructure: A21 = Exceeding the transport capacity of the bed; A22 = Exceeding the assurance of defence works; A24 = Block / Restrict  
 Production mechanism: A31 = Flash Flood; A36 = Flood with high alluvium transport; A38 = Flood with remarkable levels.

### 3. RESULTS AND DISCUSSIONS

The effects induced by floods are felt on several levels: social and psychological, economic and ecological.

Social effects refer to several aspects. The most dramatic are the loss of human lives, followed by the sanitary effects, the destruction and damage to homes and households, the damage and interruption of activities, the damage and destruction of cultural, sports, socio-cultural institutions, psychological effects, etc.

In the period 2005-2010, floods in the Suceava hydrographic basin caused 22 deaths. Most were caused by the spontaneous flood of 2006, which affected the town of Arbore, where 11 people died. Deceased persons were also registered in the localities of Liteni (3 in 2005), Cacica (1 in 2006), Satu Mare (1 in 2008), Brodina (1 in 2010). Marginea (1 in 2010), Țerăuți (3 in 2010), Todirești (1 in 2010). Among the sanitary effects, the reduction of drinking water resources, their contamination, etc. can be noted.

During the floods in the period under study, cultural-religious edifices were affected (Sucevița and Dragomirna monasteries), town halls and religious homes in several communes (Frătăuții Noi, Mușenița, Vicovu de Sus, Sucevița) and in the towns of Liteni and Suceava.

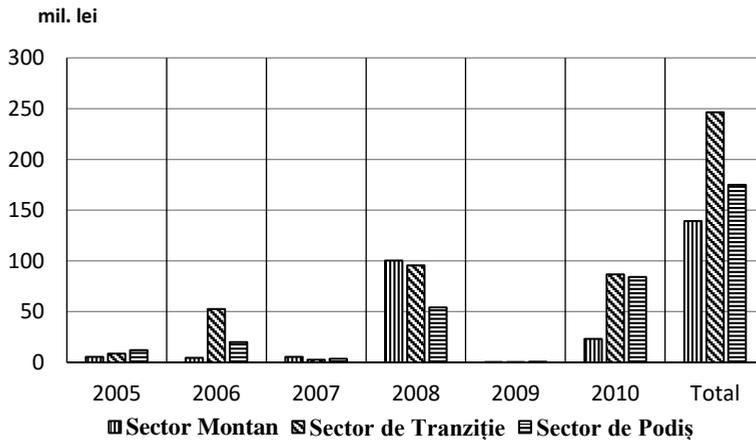
The economic effects include different types of damage:

- direct - which involve affecting several economic components (households and household annexes, transport infrastructures, constructions corresponding to some industrial units, agricultural lands and crops, public utility networks, hydro-technical works);

- indirect, which consist in the losses due to the dysfunction of public institutions and economic units due to the reduction or temporary interruption of the activity generated by the lack of labour force, raw materials, the interruption of the electricity supply, etc.

The floods produced in the interval 2005-2010 produced damage whose total value was estimated at 562 mil. LEI.

Following the distribution of damages at the locality level, it is noted that the highest values were recorded in settlements located in all relief steps: mountain (Brodina, Ulma), transitional (Marginea, Arbore, Cacica), and plateau (Verești, Liteni) (Table 2).



**Fig. 1.** The distribution of total damages (in mil. lei) produced by the floods from 2005-2010 on the three relief steps in the Suceava watershed (source ABAS Bacău)

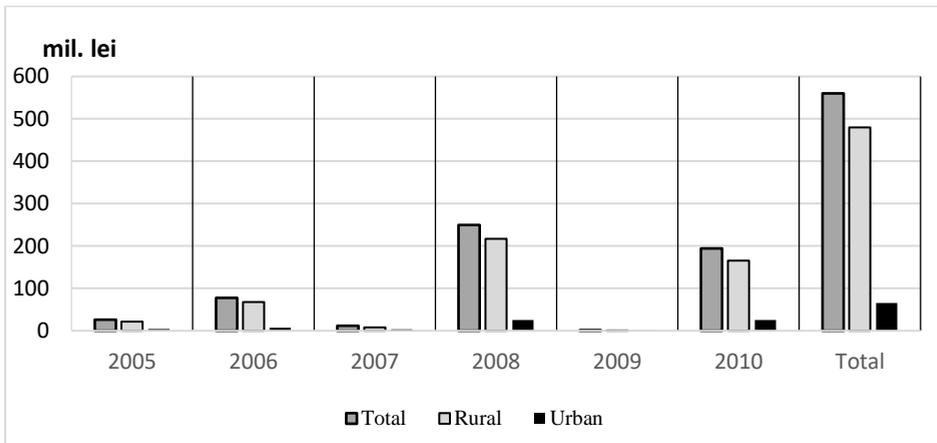
The most affected localities by floods are concentrated in the following hydrographic basins: Brodina, Ulma, Solca, Sucevița, Cacica, Soloneț.

The damage values caused by floods varied from year to year on the three relief levels. The floods of 2008 produced large damages in the three stages, especially in the mountain and transition, while the floods of 2010 produced

damages with similar values in the transition and plateau sectors (Fig. 1). The supply from 2006 was concentrated on the Pozen, Sucevița, Solca and Solonet basins developed mostly in the transition sector.

From the analysis carried out on the distribution of damages caused by floods in rural and urban environments, it follows that 85.7% of the total damages occurred in rural areas. The explanation lies in the fact that protection and defence measures against floods are better in the urban environment. At the same time, the hearth of the cities is located at some distance from the watercourses. The only city more affected by floods was Liteni.

In both environments, the greatest damage occurred following the floods that occurred in 2008 and 2010 (Fig. 2).



**Fig.2.** Distribution of total damages in rural and urban environments.

Following the distribution of the damages caused by floods on the relief steps, it is noted that the greatest damages occurred in the transition sector, which has the smallest area, but has the highest population density. In this sector, total payments were 250.9 mil. lei, while in the plateau sector they were 171.8 mil. lei, and in the mountain sector 139.1 mil. lei (Table 2).

**Table 2.** Total damages (mil. lei) recorded (per commune) in the period 2005-2010 (Source: ABA Suceava)

Town/ Commune	Sector	Mil. lei	No. case	Mil. lei/case	Town/ Commune	Sector	Mil. lei	No. case	Mil. lei/case
Cajvana	Transition	2,546	5	0,509	Iaslovăț	Transition	6,446	7	0,921
Liteni	Plateau	<b>12,789</b>	10	1,279	Ilișești	Transition	1,455	8	0,182
Milișăuți	Transition	<b>11,299</b>	9	1,255	Ipotești	Plateau	4,391	5	0,878

## ADRIANA MIHAELA PORCUȚAN

Rădăuți	Plateau	5,939	5	1,186	Izvoarele Sucevei	Mountain	<b>7,755</b>	5	1,551
Salcea	Plateau	2,864	5	0,573	Marginea	Transition	<b>43,347</b>	7	<b>6,192</b>
Solca	Transition	<b>13,415</b>	5	2,683	Mitoc Dragomirna	Plateau	1,930	2	0,965
Suceava	Plateau	<b>16,948</b>	3	<b>5,649</b>	Mușenița	Plateau	4,132	7	0,590
Vicovu de Sus	Transition	<b>14,401</b>	7	2,057	Părtești de Jos	Transition	8,838	6	1,473
Arbore	Transition	<b>20,236</b>	8	2,530	Pătrăuți	Plateau	3,591	4	0,898
Bălăceana	Transition	8,423	10	0,842	Poieni-Solca	Transition	1,175	3	0,392
Bălcăuți	Plateau	2,424	5	0,485	Putna	Mountain	<b>11,267</b>	2	<b>5,634</b>
Bilca	Plateau	9,564	3	<b>3,188</b>	Satu Mare	Transition	4,838	4	1,209
Bosanci	Plateau	2,112	6	0,352	Scheia	Plateau	4,027	5	0,805
Botoșana	Transition	8,047	5	1,609	Șerbăuți	Plateau	5,902	4	1,475
Brodina	Mountain	<b>37,697</b>	7	<b>5,385</b>	Straja	Mountain	<b>13,313</b>	5	2,662
Cacica	Transition	<b>33,521</b>	7	<b>4,789</b>	Stroiești	Plateau	<b>1,724</b>	3	0,591
Calafindești	Plateau	2,939	4	0,735	Sucevița	Mountain	<b>33,802</b>	9	<b>3,756</b>
Comănești	Transition	7,004	4	1,751	Todirești	Transition	<b>30,432</b>	8	3,804
Dărmănești	Plateau	9,392	4	2,348	Udești	Plateau	<b>11,365</b>	6	1,894
Dornești	Plateau	10,739	4	2,685	Ulma	Mountain	<b>35,315</b>	8	<b>4,414</b>
Fantanele	Plateau	2,710	5	0,542	Vicovu de Jos	Transition	<b>16,224</b>	7	2,318
Frătăuții Noi	Plateau	4,367	4	1,092	Volovăț	Transition	<b>10,132</b>	10	1,013
Frătăuții Vechi	Plateau	3,002	4	0,750	Voitinel	Transition	5,883	8	0,735
Gălănești	Plateau	7,712	5	1,542	Veresti	Plateau	<b>23,708</b>	5	<b>4,742</b>
Grănicești	Plateau	17,606	10	1,760		<b>Mountain</b>	<b>139,1</b>		
Horodnicu de Jos	Transition	1,700	5	0,340		<b>Transition</b>	<b>250,9</b>		
Horodnicu de Sus	Transition	1,619	4	0,404		<b>Plateau</b>	<b>171,8</b>		

Following the distribution of damages by objective categories, it was found that the most affected was the transport infrastructure (roads, bridges, railways). Thus, of the total budget of 562.1 mil. lei, the transport infrastructure holds 55.4% (311.6 mil. lei). Lower values belong to hydro-technical works, agricultural lands and family households.

From the transport infrastructure, the roads, railways and bridges (bridges, pedestrian bridges) were the most affected. The total amount of road damage was estimated at 184 mil. lei (33% of the total amount). The total amount also included the damage caused to the railways, heavily affected by the floods of 2008 and 2010 on the Dornești – Rădăuți – Putna – Brodina - Nisipitu route (Fig. 3).

The roads in the mountain area were more strongly affected by the floods in 2008, while in 2006 and 2010 the roads in the transition sector were affected. The highest values of damage to transport routes were recorded in the localities of Brodina, Marginea, Sucevița and Ulma. The evaluated values exceeded 10 mil. lei. The amount of the fees depends a lot on the affected road category. The value of the damage is greater on county roads than on communal and forest roads. For example, the destruction of 0.5 km of county road 209 G in the town of Ulma cost 10 mil. lei, while 5,445 km of communal road destroyed in the town of Brodina cost 5 mil. lei.



**Fig. 3.** The Rădăuți - Brodina railway after the 2008 floods (photo: Porcuțan, A.)

The bridges, footbridges and pedestrian bridges in the researched region were also heavily affected by the floods produced in the period 2006-2010. The value recorded following the destruction of this type of infrastructure amounted to 12.7 mil. lei. The damages caused by the floods of 2008 were distributed approximately equally in the three relief steps. Following the floods of 2010, the greatest damage was recorded in the plateau sector, where the bridge over the Suceava river that connects the towns of Verești and Udești was heavily damaged, causing damages in the amount of 20 mil. lei.

The floods during the studied period affected several engineering works (bank defenses, gabions, reservoirs, spillways) causing payments in the amount of 127.5 mil. lei. The biggest damages were caused by the floods of 2008 and 2010. The most affected were the hydro-technical works in the transition and mountain sectors. The damages caused to family households amounted to 16.5 mil. lei (Table 3). More than 80% of these damages were recorded in 2010 and 2008.

**Table 3.** Distribution of damage to households (in lei) in the period 2005-2010 in the Suceava river basin (source ABAS Bacău)

Sector	2005	2006	2007	2008	2009	2010	Total
Mountainn	2.100	600	0	1.476.000	0	306.870	1.785.570
Transition	50.050	3.201.123	14.300	2.212.000	26.890	1.693.677	7.198.040
Plateau	50.820	90.880	0	2.876.820	605.846	4.429.848	8.054.214
Rural	68.670	3.249.553	14.300	5.519.020	26.650	6.269.488	15.147.681
Urban	34.300	43.050	0	1.055.800	606.086	189.907	1.929.143
<b>Total</b>	<b>102.970</b>	<b>3.292.603</b>	<b>14.300</b>	<b>6.079.820</b>	<b>632.736</b>	<b>6.432.800</b>	<b>16.555.229</b>

A special fact is that the damage was greater in the plateau sector, where the number and size of households is greater than in the other sectors. The value of the damages varied from one year to another. In 2006, they were mainly recorded in the transition sector. Instead, in 2008, the damages caused to households and household annexes appeared in all sectors, affecting 576 households in the mountain sector (1,476 mil. lei), 874 households in the transition sector (2,212 mil. lei) 1,111 households in the plateau sector (2,817 thousand lei).

Damages caused to agricultural crops, arable land, hay and pastures were much smaller than those caused by the other economic components, representing only 3.7% of the total amount of damages, i.e. 21.029 mil. lei. The most affected was the plateau sector, where the extent of agricultural land is higher in the other sectors.

The ecological effects produced by floods consist of: changes in river beds and banks (erosion of banks, deposition of sediments, overflows, changes in course); clogging of reservoirs; reducing the stability of slopes (landslides, collapses); bio/building effects; changes in the physico-chemical and bacteriological properties, etc. Among the lakes most affected were the Călinești and Șerbăuți reservoir and the Dragomirna reservoir, which, following successive blockages in 2010 and the following ones, had to be drained and prepared for a total cleaning..

In the period 2005-2010, they were produced on almost the entire area of the Suceava hydrographic basin. The landslides were caused by the over-wetting and undermining of the lands at the base of the water courses affected by the floods. The most affected locality by landslides was the municipality of Suceava, where in 2006 a landslide occurred on the slope in the Zamca area, and in 2010 a slide affected the Sports High School, causing damages of 3.6 mil. lei. Also in 2010, landslides occurred on the perimeter of the localities of Bălăceau, Straja, Ulma, etc., affecting portions of the county and municipal roads that cross the mentioned localities.

#### 4. CONCLUSIONS

The floods from the Suceava River basin represent the most important risk factor in this area. They present different characteristics in each of its sectors - the mountains, transition and plateau.

The effects are especially dangerous in the transition area from mountain to plateau, the water exiting the mountains creating great damages to the river plain and to the households situated next to the river bed, but also to the vegetation and to the human population. This is why the rural areas are more affected than the urban ones, and the transition sector, where more than 13 of the population lives.

The greatest floods (historical floods) in the recent years were recorded in 2005, 2006 and 2010, affecting especially the area of the Suceava municipality, and the localities Brodina, Sucevita, Marginea, etc..

For a better response and management of the floods in this area it is necessary to improve the urban and rural structural and non-structural defences against flood effects, and to maintain in the memory of the population the risks that floods bring, through drills and community exercises that keep in the memory these effects. This thing is necessary because after 2010, the floods became less present, with an increase of drought periods that make people less mindful to the effects that a big sudden rain can bring.

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