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FLOODS THAT APPEARED IN THE UPPER JIJIA BASIN

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Summary. Floods that appeared in the upper Jijia basin. Over the years, in the upper Jijia Basin, there have been short and medium period floods and floodings generated by them, causing both material damage and human life losses, as well as environmental degradation. In this regard, the historical flood from 2010 on the Buhai River at the Pădureni hydrometric station, and on the Jijia River at the Dorohoi hydrometric station was analyzed. The average and short duration floods take place during the summer period and last a total of 2 - 6 days. These are caused by: heavy rainfall over 200-300 mm, of high intensity (due to atmospheric instability, thermal convection and formation of the retrograde cyclone above the Black Sea). They are produced on small and medium-sized water courses with areas up to 1000 km^2.

Key words: flooding, flood, retrograde cyclone, rainfall, flood risk management.

1. INTRODUCTION

Jijia, a tributary to the right of the Prut River, has developed its hydrographic basin in northeastern Romania, overlapping the Suceava Plain and Jijia Plain, geographic subunits in the northern Moldavian Plateau. The Upper Jijia Basin holds 5.26% of an area of 5757 km^2 for the entire basin.

Of the total length of the Jijia River (275 km), the analyzed sector reaches 9.82%, ie 27 km. The first tributaries on the left side of the Jijia River are the Tăietura, Tinca and Pârâul Pietros with its affluent the Pârâul lui Martin. On the right, the main tributary of Jijia is the Buhai River, which flows into Iezer Lake (located on the Jijia River upstream of the city of Dorohoi). As a result of the influence of the excessive temperate - continental climate, the low altitude of the relief (the average altitude of the basin is 240 m) and the substrate formed predominantly of clays and marl, Jijia and its tributaries are generally characterized by low discharges. In the years when torrential rain occurred, there were small and medium duration floods with significant consequences on social life, economic activity and the environment. The upper Jijia basin has an elongated shape which influences the water concentration time in the drainage channel and the shape of the floods. Due to the lower relief energy, the floods usually present more waves and a low intensity. Morphometric relief parameters influence the elements of the

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flood wave and the characteristic elements of the flood wave propagation process. The areas with high values of the relief fragmentation density (over 4 km / km²) influence the flood risk through the presence of discharge concentration areas. The slopes, although relatively low in value, play an important role in the production of floods and flooding.

2. DATA AND METHODS

The data used in the paper came from three meteorological stations, two of which are in the studied area (Dorohoi and Botoşani) and one in the Western neighborhood (Suceava), and two hydrometric stations (Pădureni and Dorohoi).

Statistical methods were used to process data from meteorological and hydrometric stations analyzed during their operation.

3. RESULTS AND DISCUTIONS

3.1. The determining factors in the formation and evolution of floods

The particularities of the atmospheric circulation affecting this part of the Moldavian Plateau contribute to the greatest extent to the occurrence and evolution of the floods.

Dominant is the northern movement through which it trains air masses of ocean origin from the polar latitudes, which in their way lose a large amount of precipitation (Musteţea, 2005). These air masses cause temperature drops, increased nebulosity and rainfall, especially in the period from June to July. An important role in the formation of the floods is the retrograde cyclonse from the Black Sea and the thermal convection. Of the climatic elements an important role is played by the precipitation in which distribution during the year there is a maximum during summer in June and a winter minimum in February (Fig. 1).

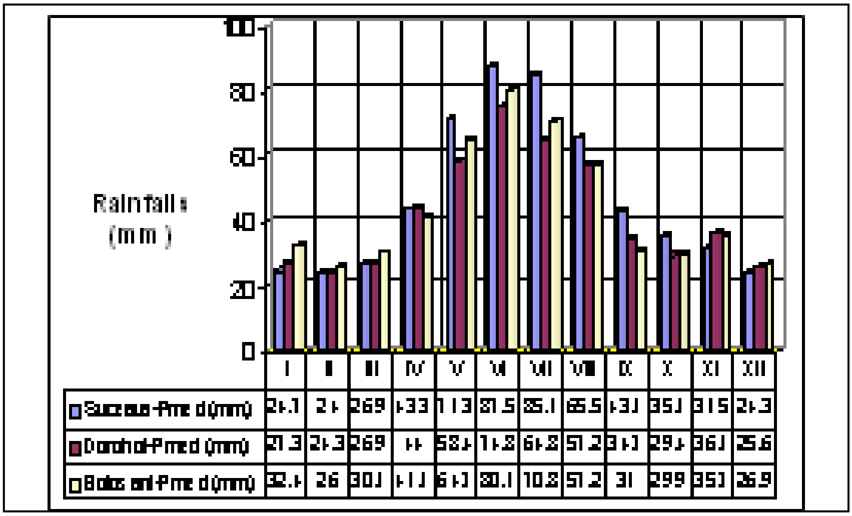


Fig. 1. Monthly multi-annual average rainfall distribution (mm) (1886-2006) at the meteorological stations: Suceava, Dorohoi, Botoșani

The maximum monthly precipitations in 24 hours have a temporal distribution very close to that of monthly average values (Fig. 2).

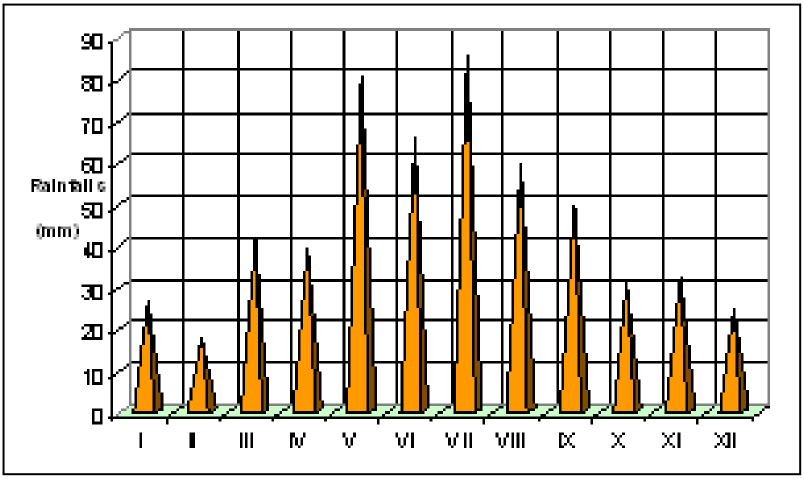


Fig. 2. Distribution of maximum monthly rainfall quantities in 24 hours (1961-2000), at Suceava meteorological station

In order to highlight the role of maximum rainfalls produced in 24 hours, the years with the large amounts of rainfall recorded at the Pădureni hydrometric station were analyzed. For this purpose were analysed the dates: June 17, 1998 (90 mm), August 19, 2005 (101.2 mm), August 27, 2006 (104.9 mm), July 1, 1991 (76 mm), July 26, 2008 (72.2 mm), and June 28, 2010, when were recorded 205,2 mm of rainwater at the Pădureni pluviometric station, being a historical value.

The air temperature influences the formation and the evolution of the floods, diminishing indirectly, the amount of water drained during the summer when the highest thermal values are recorded (Fig. 3).

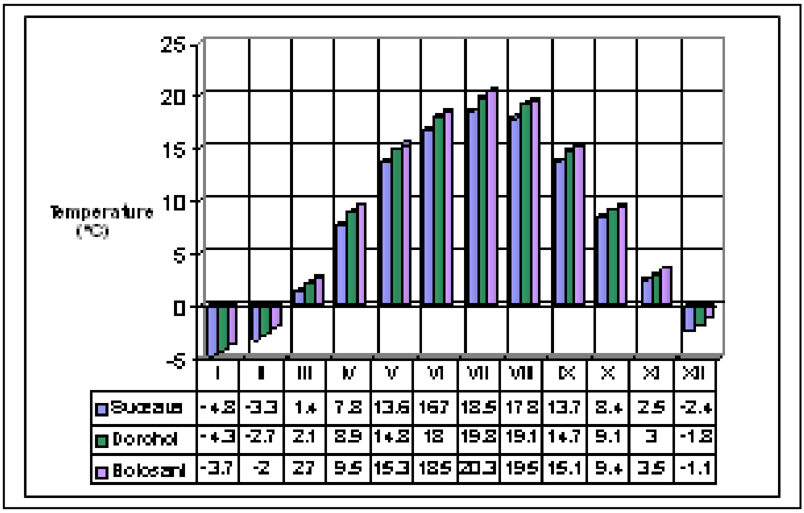


Fig. 3. The air temperature regime (1886-2006) at the Suceava, Dorohoi and Botoșani meteorological stations

3.2. Floods in the upper Jijia basin from 2010

From the floods analysis in the upper Jijia basin, it was found that the largest floods through discharges and effects occurred in the years 1991, 1998, 2005, 2008 and 2010.

Causes of the floods from 2010. The main cause of the historical floods in June-July 2010 was the high rainfalls during the period of instability from June 18 - July 9, 2010, when in almost the entire studied area they accumulated over 300 mm, exceeding 2-3 times the normal climatological values. Another cause was the torrential rain from June 28-29, 2010, during which in the upper Jijia basin fell over 200 mm in 24 hours (Fig. 4). These torrential rainfalls were generated by the thermal convection that developed after midday on June 28, 2010, which triggered rapid flash floods that caused massive material damage and loss of life. The most affected flood area was Dorohoi, where six people died (Sălăjan L. and others, 2013).

The atmospheric instability was due to the contrast between the very warm tropical mass in eastern Romania over the entire tropospheric column and the cold altitude air mass above our country, as well as the advection of humidity and the retrograde cyclone formed in the Black Sea (M. Huştiu, 2011, NMA).

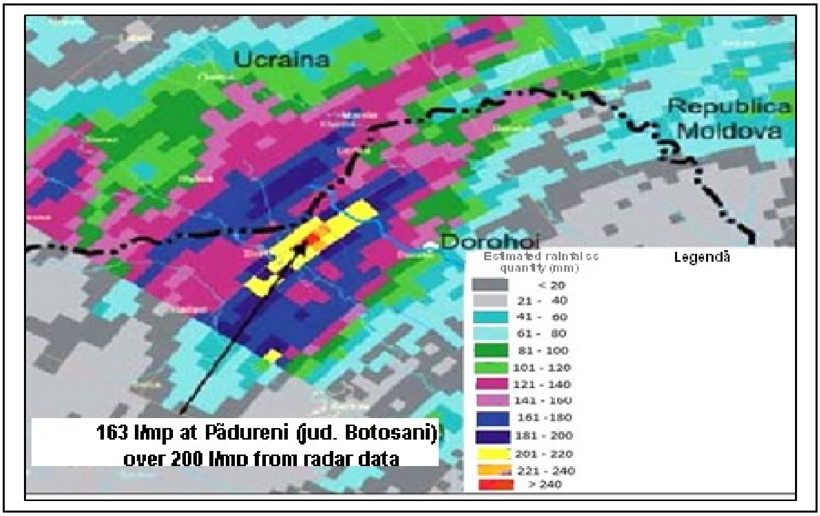
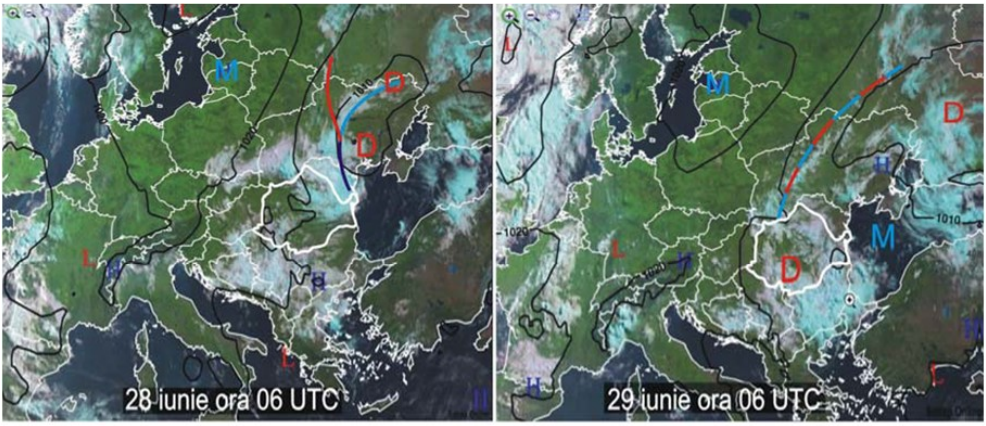


Fig. 4. Amounts of rainfalls estimated by Bârnova radar in the period 00^{01} - 23^{59} on 28.06.2010 (source: Huştiu M., 2011, NMA)

From a synoptic point of view, between 28-29 June 2010, there existed two barric systems: a high pressure one formed above Central Europe and a retrograde depression system at north of the Black Sea (Fig. 5a). The first was associated with a mobile anticyclone detached from the Azoric Anticyclone, and the retrograde depression system was of Mediterranean origin. As dynamic, the formed anticyclone had weakened, as it advanced to the interior of the continent, thus producing the heating process near the soil, while the cyclone, well delimited in the northern part of the Odessa Bay, partially broke out on the morning of June 28, and in 24 hours it appeared in the form of a prolonged thalweg over the Republic of Moldova (Fig. 5b). Thus, on the 28th of June, the dorsal of the anticyclone from the north-eastern basin of the North Atlantic Ocean advances towards the center of Europe, causing extreme phenomena such as the exceptional rainfalls, hail and two tornadoes formed near Ibănești and Dorohoi.

The depression thalweg formed to the north of the Black Sea, slightly moved towards the north, oriented almost on latitude over Ukraine, northern Moldova and half of the Republic of Moldova, giving rise to a zone of moisture convergence, while the anticyclone formed with the center in the Baltic Sea area, quasi-stationary for this range, showed some changes due to heating at the base and to its weakening.



a) **b)**

Fig. 5a. and 5b. Sea level pressure field and frontal analysis from the period 28-29.06.2010 (after Huştiu, 2011)

It is also worth mentioning the increase of the baric gradient in northern Moldavia, caused by local conditions, which favored the formation of a mass front on the eastern part of the Carpathian Mountains. As a consequence of the orography, the development of an anticyclone, which was intensified by the downward trend of a thunderstorm that developed northeast of the Wooded Carpathians. Thus, the proximity of the two masses of air (a dry and warm one from the Baltic Sea and another wet and warm from the East), accompanied by an increase of baric and thermal gradients (M. Huştiu, 2011, NMA) took place. The precipitations that occurred at the end of June and the beginning of July 2010 in the upper Jijia basin in the form of high intensity downpours were distributed in three episodes: 21-24 June 2010, over 100 mm; June 26-27, 2010, with values between 50-100 mm, and June 28-July 1, 2010, over 100 mm. These have led to: increased soil moisture, significant slope discharges, forming of torrents, streams and repeated floods at short intervals.

The characteristics of the floods from June - July 2010. The flood produced on the Buhai River at the Pădureni hydrometric station between 28 and 29 June 2010 had two peaks of 64 m^3/s and 85 m^3/s, respectively (Fig. 6).

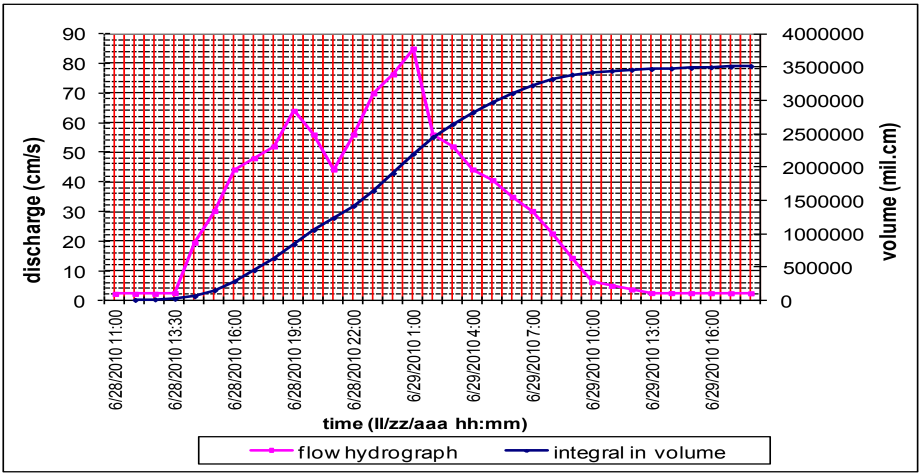


Fig. 6. The flood from 28-29 June 2010 on the Buhai River, at the Pădureni hydrometric station and the volume integral (data source: INHGA)

The maximum discharge was of 85 m³/s, 467 times higher than the multi-annual average flow from 1978-2010 and had an exceeding probability of 6%.

The characteristic elements of the 2 waves are shown in Table 1. The flood was determined by a precipitation of 164 mm, the increasing time was 13 hours and the flood duration was 33 hours. The total flood volume was 3.52 million m^3 and the equivalent surface runoff was 64.9 mm for the two waves.

Table 1. Flood wave elements from June 28 - 29, 2010 at the Pădureni hydrometric station, (data source: INHGA)

Elements	First wave	Second wave	
tcr 1 (increase time)	9	4	hours
tdcr1 (decrease time)	2	17	hours
T1 (duration)	11	21	hours
Qmax1 (maximum discharge)	64.0	85.0	m^3/s
γ (shape coefficient)	0.489	0.354	
α (surface runoff coefficient)	0.248	0.582	
Wcr1 (increase volume)	0.842	0.960	mil.m^3
Wdcr1(decrease volume)	0.396	1.32	mil.m^3
Wtot1 (total volume)	1.239	2.28	mil.m^3
h1 (rainfall layer)	92.2	72.2	mm
q1 (specific discharge)	1180.8	1568.3	l/s.km^2
hs1 (surface runoff)	22.9	42.0	mm

In the computation section, downstream the confluence between the Pârâul Întors with the Buhai River, there had been calculated a hydraulic flow of 190 m³/s, with the exceeding probability of 1%.

Upstream of the Dorohoi hydrometric station, there has been a backwater phenomenon that has led to the mitigation of the flood wave and the diminution of its effects in the downstream section. At the **Dorohoi** hydrometric station, located on the Jijia River, the peak flow discharge during the period 28.06 - 03.07.2010 was 190 m^3/s, being 274 times higher than the multiannual average discharge of 0.694 m^3/s, with the exceeding probability of 2 %. The flow had three peaks with flow rates of 190 m³/s, 106 m³/s and 76 m³/s respectively (Fig. 7).

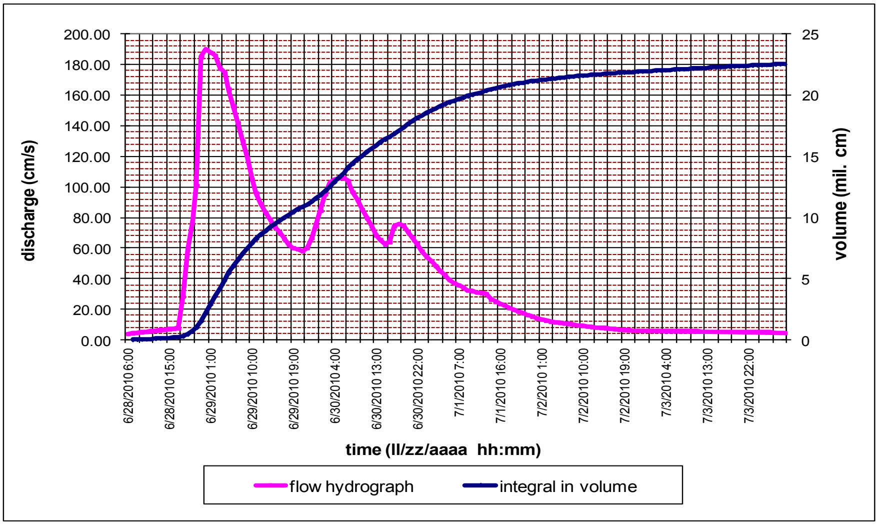


Fig. 7. The flood from June 28 - July 3, 2010, on Jijia River, at the Dorohoi hydrometric station and the volume integral (data source: INHGA)

The characteristic elements of the first two waves are shown in Table 2. The flood at the Dorohoi hydrometric station on the Jijia River was determined by a rainfall quatity of 250 mm, the invreasing time was 17 hours for the first wave and 9 hours for the second, and the total flood time was 144 hours. The total flood volume was 22.5 * 10^6 m^3 and the equivalent surface runoff was 94.4 mm.

The rainfalls in the upper Jijia basin at the two analyzed hydrometric stations, due to their rapid character and the friable substrate, led to large amounts of alluviums. Thus, between June and July 2010, 1200 kg of alluviums were recorded at the Dorohoi hydrometric station, the highest value in the statistical series for suspensions.

Tabel. 2. Elements of flood waves from June - July 2010 at s.h. Dorohoi

Elements	**First wave**	**Second wave**	
tcr 1 (increase time)	17	9	hours
tdcr1 (decrease time)	22	96	hours
T1 (duration)	39	105	hours
Qmax1 (maximum discharge)	190	106	m^3/s
γ (shape coefficient)	0.41	0.29	
α (surface runoff coefficient)	0.27	0.61	
Wcr1 (increase volume)	2.20	2.80	$mil.m^3$
Wdcr1(decrease volume)	8.60	8.90	$mil.m^3$
Wtot1 (total volume)	10.80	11.7	$mil.m^3$
h1 (rainfall layer)	170	80	mm
q1 (specific discharge)	795	444	$l/s.km^2$
hs1 (surface runoff)	45.5	48.9	mm

3.3. Consequences of floods from 2010

The June-July 2010 floods and the floodings they have generated had disastrous consequences for settlements in the upper Jijia river basin.

The floodings caused by the floods produced in June-July 2010 had negative social and economic effects (Fig. 8).

Fig. 8. Effects caused by the floodings produced by the floods from June-July 2010 (source: SGA Botoșani)

The floods affected 836 homes (of which 45 were completely destroyed and 369 in danger of collapse) (Table 3); 1031 ha of agricultural land and 1521 ha of pastures and meadows; 1806 fountains. In the Buhai River Basin, on the Dersca - Pădureni - Dorohoi direction, the flooded area was 4.07 km², the length of the affected area being 18 km. There were affected: 63 footbridges and a bridge, and 25 km of communal road, houses, agricultural land, fountains. On the direction Hilişeu - Horia - Dorohoi - Broscăuți, the flooded area was 16.25 km², the affected area having a length of 17 km.

Table 3. Situation of houses affected by the floods from June - July 2010, (source: S.G.A. Botoșani)

No. crt.	Locality name	Affected houses	Distroyed houses	Houses in danger of collapsing
1.	Broscăuți	14	1	10
2.	Dersca	0	0	1
3.	Dorohoi	347	32	274
4.	Hilişeu-Horia	47	8	60
5.	Lozna	0	0	1
6.	Pomârla	0	1	4
7.	Şendriceni	14	3	17
8.	Văculeşti	0	0	2
9.	**Total houses**	**422**	**45**	**369**

As a result of these floodings, 6 people lost their lives. There were affected: agricultural lands, meadows and pastures, 11 km of roads, 11 bridges and footbridges, the Dorohoi railway station (1 km of railway), 10 km of sewerage networks, fountains, 200 m national road (DN29A), 1 km of county road (DJ291 km), 8 km of communal road (DC 78 and 79). There were also affected public commercial units, industrial activities, water supply of localities.

4. CONCLUSIONS

The causes and characteristics of the floods produced in 2010 during June-July were: the atmospheric instability between 18 June - 9 July 2010, the torrential rain from June 28-29, 2010, the thermal convection and the retrograde cyclone formed in the Black Sea.

The floods from July / July 2010 caused floodings that killed six people and affected houses, infrastructure, agricultural land, pastures and hayfields, etc. Also during the floods, emergency measures were taken to protect the population and the flood was very well monotorized by the SGA, the town hall and emergency situations authorities.

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