ASOCIAŢIA GEOMORFOLOGILOR DIN ROMÂNIA

REVISTA DE GEOMORFOLOGIE

13

editura universităţii din bucureşti
2011

REVISTA DE GEOMORFOLOGIE / REVIEW OF GEOMORPHOLOGIE

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Şos. Panduri, 90-92, Bucureşti – 050663; Telefon/Fax: 021.410.23.84
E-mail: editura_unibuc@yahoo.com
Internet: www.editura.unibuc. ro

Tehnoredactare computerizată: Meri Pogonariu

ISSN 1453-5068

REVISTA DE GEOMORFOLOGIE

VOL. 13 2011

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Geomorphological impact of floods in the Bâsca Catchment (Romania)

Gabriel MINEA, Liliana ZAHARIA

Abstract. The purpose of the current study is to analyse the floods and their impact on the dynamics of river channels and slopes in the Bâsca Catchment. Floods analyses are based on processing statistical data on maximum monthly and annually discharge of the Bâsca River at the closing hydrometric station, Bâsca Roziliei (period 1960 – 2007). It underlines specific aspects regarding the variability of the maximum flow (at multiannual scale and during the year) and the flood potential. The frequency analysis of the maximum monthly discharge indicates that the month with the highest flood potential is June followed by July. The consequences of the floods on the Bâsca river channel, consist on fluvial processes amplification: river bank erosion (e.g. upstream auto-station Varlaam), and channel aggradation or degradation. Therefore floods, by actioning on the river banks, imbalance slopes, determining landslides and rockfalls.

Key words: floods, maximum discharge, geomorphological effects, Bâsca Catchment

Rezumat. Prezenta lucrare are drept scop analiza viiturilor şi a impactului acestora asupra dinamicii albiilor şi versanţilor în bazinul hidrografic al râului Bâsca. Analiza viiturilor se bazează pe prelucrarea statistică a datelor privind debitele maxime lunare şi anuale de la staţia hidrometrică de închidere Bâsca Roziliei, în perioada 1960 - 2007. Sunt relevate aspecte privind variabilitatea scurgerii maxime (la scară multianuală şi în timpul anului) şi potenţialul de viitură. Din analiza frecvenţei de producere a debitelor maxime lunare reiese că luna cu cel mai mare potenţial de viitură este iunie urmată de iulie. Consecinţele geomorfologice induse de viituri asupra albiei râului Bâsca constau în amplificarea proceselor fluviatile, prin accentuarea eroziunii laterale (de exemplu amonte staţia automată Varlaam) şi agradarea albiei. În acelaşi timp, viiturile, prin acţiunea asupra malurilor, afectează stabilitatea versanţilor, favorizând prăbuşirile şi alunecările de teren.

Introduction

Floods are natural risk phenomena with socio-economic and environmental consequences, multiple and complex, both direct and indirect. Through their erosive and transport power, floods act on the river bed, accelerating its vertical and horizontal dynamics. Floods action on the river banks determines imbalance slopes, generating landslides and rockfalls. Short or long term, geomorphological processes induced by floods can cause significant human and material damage. In order to minimize their impact, measures are necessary, and appropriate protection works against floods and geomorphological processes associated with them.

The present paper analyzes the floods and their impact on the dynamics of river channels and slopes, and identifies the engineering works necessary to mitigate the floods consequences in the Bâsca Catchment. Positioned in the external region of the Curvature Carpathians, the Bâsca Catchment (Fig. 1) has a surface of 785.1 sq km. It lies at a medium altitude of 1,081 m between the Lăcăuţi Peak (1,777 m a.s.l.) and the confluence whit Buzău River (385 m a.s.l.). The Bâsca River (length = 81 km) is one the main tributary of the Buzău River.

Zaharia (2004) showed the importance of knowing the characteristics of the maximum discharge for building and exploitation of hydrotechnical works, stream improvement, territorial planning, management of water resources, as well as for estimating the risk induced by floods.

The results of the present study complement and update specific information on some parameters like maximum discharge and floods from the Bâsca River Catchment, published in hydrologic papers and synthesis about Romania (*Râurile României. Monografie hidrologică*, 1971; Ujvári, 1972) and at regional scale (*Monografia hidrologică a bazinului hidrografic al râului Siret*, 1967; Diaconu, 2005; Zaharia, 2004, 2005; Chendeş, 2007, etc.).

Regarding the dynamics of geomorphological and hydromorphological processes in the Bâsca River Catchment, basic information on them are presented mainly in the papers written by Ielenicz (1984), Rădoane et *al.,* (1991).

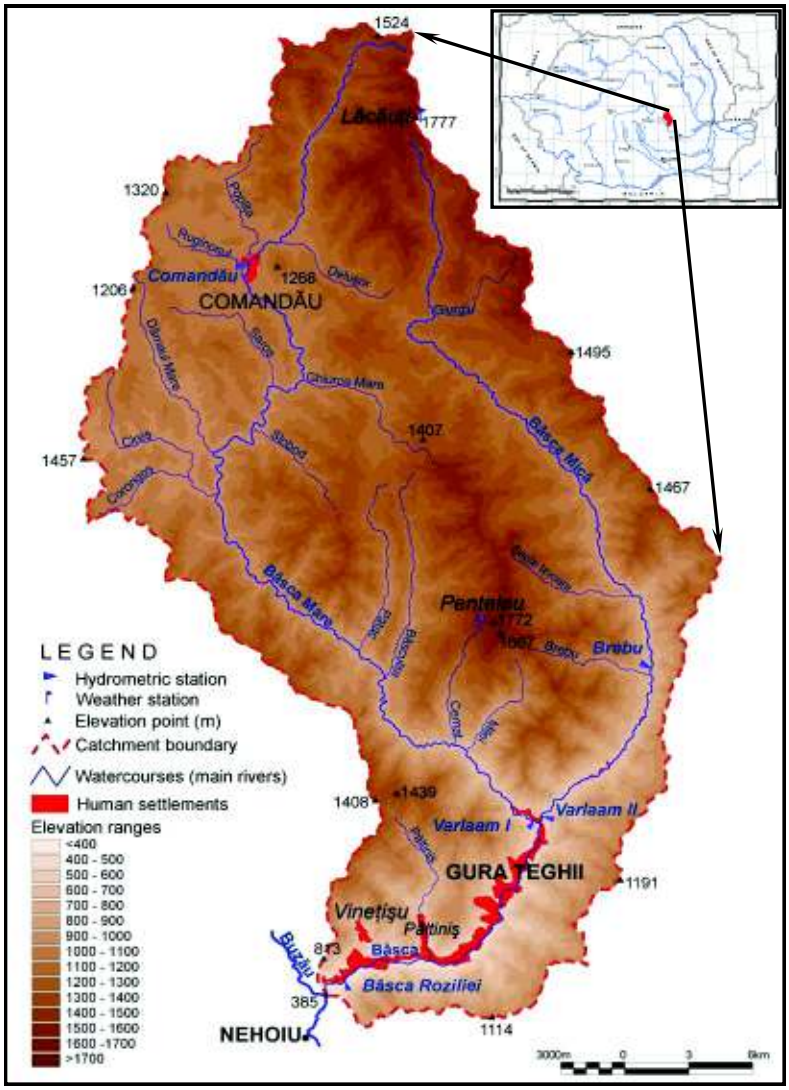

Fig. 1. **The Bâsca Catchment and its location in Romania**
Source: data processed from topographic maps, scale 1:25,000, MTD, 1982

1. Database and methodology

In the analysis we used following types of data: cartographic (topographic maps scale 1:25,000 by Military Topographic Department -MTD, 1982); climatic parameters: temperature and precipitation (average monthly & annual) at the Lăcăuţi (1960-2000) and Penteleu (1988-2007) weather stations (w.s), provided by the Regional Meteorological Center Muntenia (Buzău); hydrological data: maximum monthly and annual discharges of the Bâsca river at the Bâsca Roziliei hydrometric station (h.s.) (1960 - 2007); discharges during the main floods (the hydrological data were provided by the "Romanian Waters" National Administration, Buzău – Ialomiţa Water Basin Administration -BI BWA- and the National Institute of Hydrology and Water Management – NIHWM).

The main methods used are: spatial analysis using GIS techniques (ArcView Gis 3.3 and ArcGis 9.3) and statistical analysis of hydrological and climatic data.

2. Favourable factors of floods and hydrogeomorphological processes

Floods genesis is a highly non-linear process that depends on favourable factors such as the geological and morphometrical features (e.g. lithology, slopes, energy relief and drainage density), pluviometric regime, vegetation, soils and antecedent conditions of the catchment (e.g. land use).

From the geological point of view, the Bâsca Catchment overlaps the orogenic unit of the Eastern Carpathians, where the external Paleogene flysch is predominant, including: sandstones (Tarcău sandstones Facies), marls, conglomerates (Fig. 2.a).

This area is characterised by tectonic uplift and by severe seismicity related to the Vrancea Epicentral Area, being affected by deep-seated landslides (Ielenicz, 1984). Lithology is dominated by the presence of the hardest and hard rocks, covering 96.7% of the catchment surface (Table 1).

In the Bâsca Catchment slopes declivity is frequently between 10 and 20^0 (44.3%) followed by classes $20\text{-}30^0$ (23.8%), $0\text{-}3^0$ (14.5%), $3\text{-}10^0$ (7.52%), with the highest values exceeding locally 30^0 (9.77%) (Fig. 2.b).

The slopes significantly influence the concentration time of precipitation on slopes and therefore velocity in the genesis and transmission of floods.

The slopes have a very important role on the genesis and propagation of floods. The average slope of the Bâsca River is 13.3 m/km, but its main tributaries have slopes exceeding 90 – 100 m/km: Păltiniş = 94.4 m/km (where linear human settlements are presents), Cernat = 122.6 m/km, Brebu = 111.4 m/km (Table 2).

Drainage density shows values up to 5.21 km/km^2 (Table 2), being another favourable factor for the concentration and production of flows and floods. Confluence and convergence hydrographic areas have an increased flooding risk. Similar areas were identified in the human settlements perimeters: Comandău (where Bâsca receives main tributaries Deluşor, Popliţa Rivers), Varlaam (where Bâsca confluence with Bâsca Mică) and Păltiniş (at confluence of the Bâsca and Păltiniş River).

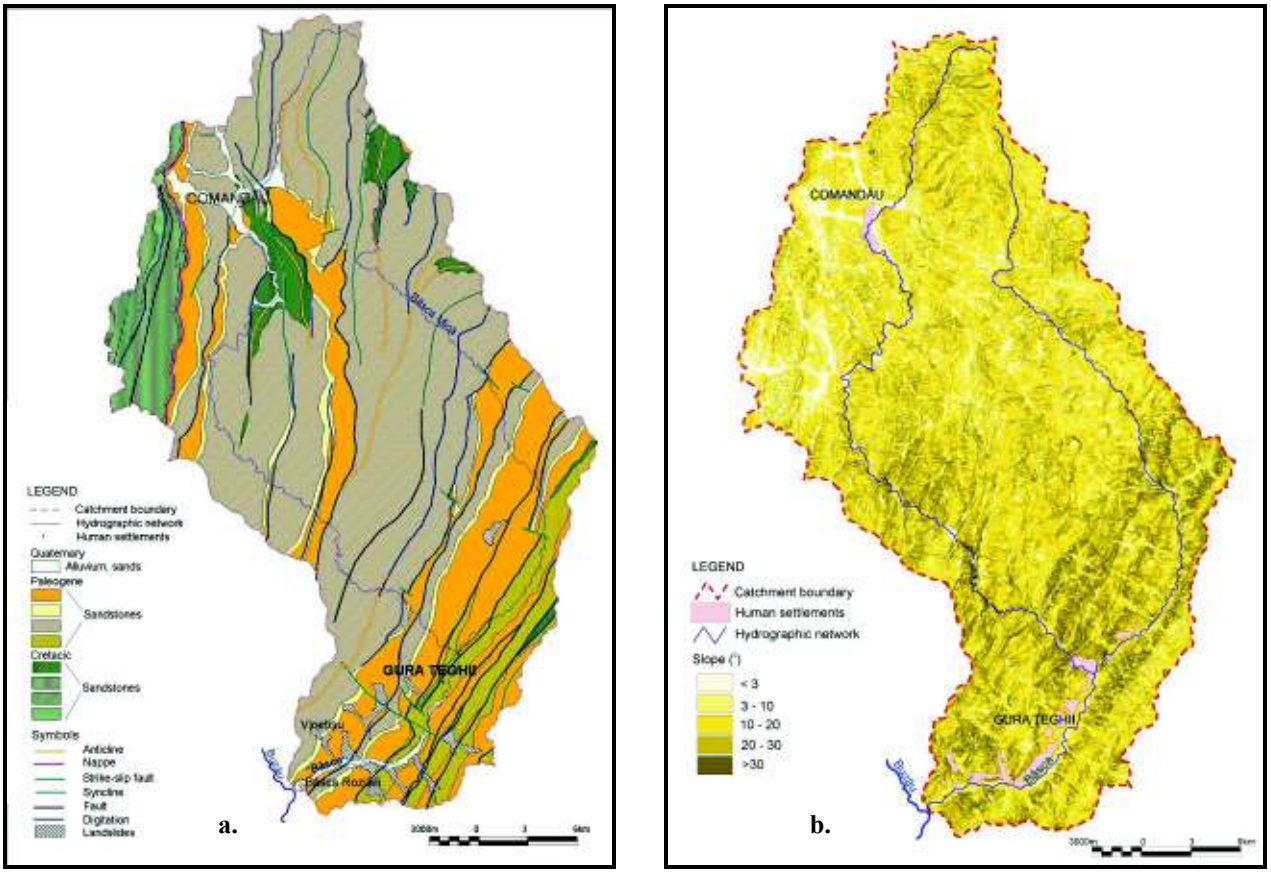

Fig. 2. **Geological** (a) **and slopes** (b) **maps of the Bâsca Catchment**
Sources: data processed from geological map (scale 1:200,000) and topographic maps (scale 1:25,000)

Table 1. **Rocks classification according to their perforation resistance* in the Bâsca Catchment**

Rocks hardness	Coefficient of resistance	Physical-mechanics characteristics	Geological formations	P (%)
Hardest	15 -17	consolidated rocks	Siliceous sandstone	96.77
	10-12		solid sandstone	
Hard	7-8	reduced alteration, well-cemented	sandstone, marls	
Soft	1-2	unconsolidated rocks	alluvial, sands	3.23

* According to Geological Committee of Romania (Zăvoianu, 1985)

Table 2. **A summary of the significant morphometrical features of the Bâsca Catchment**

River	*RIVER CHANNEL LENGTH (KM)*	Drainage area (km^2)	Drainage density (km/km^2)	Sub-basin Elevation (m)			Slope (m/km)	Channel slope (m/km)
				H*	H**	H***		
Bâsca Mare	**64.2**	**440**	3.65	1.148,5	**1.777**	520	*30.4*	*14.7*
Bâsca Mică	46.5	238	3.63	1.148,5	**1.777**	520	*30.4*	21.5
Bâsculiţa	11.5	40	4,01	1.278,5	1.772	785	124.6	46.3
Popliţa	9.29	22.4	3.37	1.198	1.387	1.009	112.5	22.2
Cireş	11.1	19.6	3.61	1.114	*1.193*	1.035	140.8	6.8
Păltiniş	9.69	25.1	4.61	*937*	1.439	*435*	112.5	94.4
Ghiurca Mare	9.59	23.3	3.76	1.283	1.601	965	162.2	58.8
Dârnăul Mare	10.6	21.5	4.20	1.081	1.219	943	115.1	16.7
Deluşor	6.88	20.9	3.65	1.323	1.618	1.028	231.1	32.3
Pătac	10.0	18.5	*2.90*	1.144	1.479	809	134.1	45.2
Giurgiu	6.48	16.2	3.98	**1.440**	1.720	**1.160**	**267.8**	57.9
Şapte Izvoare	6.62	15.6	4.72	1.271	1.772	770	247.3	95.2
Milei	6.43	15.8	**5.21**	1.119,5	1.604	635	176.3	95.6
Saroş	7.84	14.9	4.02	1.154,5	1.244	1.065	169.3	14.9
Corongoş	5.32	12.8	3.98	1.094	1.250	938	214.6	20.1
Brebu	6.55	11.1	5.15	1.100	1.520	680	178.7	111.5
Ruginosul	*5.14*	11.8	3.81	1.107,5	1.206	1.009	219.1	42.0
Cernat	6.69	11.1	4.50	1.213,5	1.772	655	193.0	**122.6**
Slobod	6.18	*9.22*	4.11	1.187	1.429	945	193.1	67.2
Bâsca	81	785.1	3.69	1.081	1.777	385	22.3	13.3

*- mean altitude, **- maximum altitude, *** - minimum altitude; bold values are maximum values of each variable while italics indicate the minimum values.
Data are obtained from processed GIS after topographic maps (scale 1:25,000)

The climate of the Bâsca Catchment is temperate-continental. Föhn phenomena moderate the characteristics parameters of climatic elements (e.g. amounts reduced of precipitations and moderate value of air temperature).

The average multiannual temperature in the study area ranges between 1.2^{0}C at Lăcăuţi w.s. (1961 – 2006) and 2.4^{0}C at Penteleu w.s. (1988-2007). In the mentioned periods, the average annual amount of precipitations recorded at Lăcăuţi w.s. were 827.3 mm and 664.3 mm at Penteleu.

During the considered periods, the annual precipitations varied between 308.9 mm (in 1990 at Penteleu w.s.), and 1,319.9 mm (in 1972 at Lăcăuţi w.s.). At both meteorological stations, summer is the wettest season, with 45% of the yearly amount of precipitation, followed by spring and autumn with comparable amounts (23%, and 18% respectively), whilst winter is the driest, with 14% of the total annual amount of precipitation (Minea, 2009).

The pluviometric regime has a summer torrential character, being favourable to flow genesis and evolution. The most humid month is July (117.4 mm to Penteleu and 127.2 mm to Lăcăuţi w.s.), followed by June (Fig. 3.a). Under these circumstances, these months have the highest flood potential. In floods genesis an important role is represented by the 24 hours rainfalls. At Lăcăuţi w.s., in summer months, they exceed 80 mm (Fig. 3.b), which favours flash-floods and explain the high frequency of floods in the summer period.

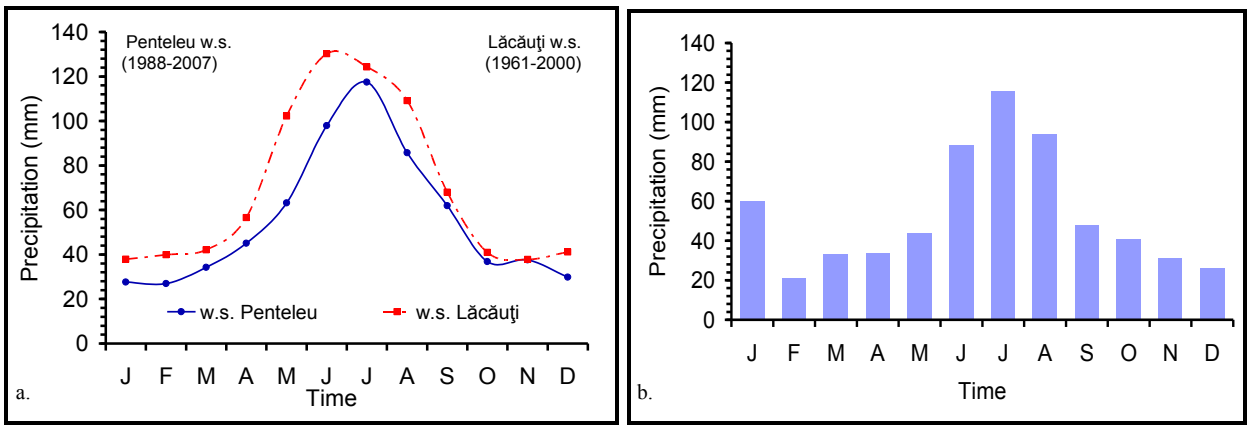

Fig. 3. **a. Pluviometric regime in the Bâsca Catchment. b. Maximum amounts of precipitation in 24h at Lăcăuţi w.s**. (1961–2000)
Source: data process from Regional Meteorological Center Muntenia (Buzău) and *Clima României,* 2008

Land cover. According to the Corine Land Cover 2006 classification, the main category of land use in the Bâsca River Catchment is category 3, represented by forests and semi-natural areas (92.6% from catchment area). The catchment, in general shows a high forestation degree (83.4%), which constitutes a moderator factor of superficial flow on slopes. The forests include the following subdivisions: beech forests (102 sq km), mixed forests (280 sq km) and coniferous forests (273 sq km) (Minea & Vişan, 2010). In some areas, is encountered concentrated cutting of forests (e.g. Cernat Catchment, where is private forestry management: *Ocolul Silvic Penteleu*), which led to escape favouring the runoff on slopes.

3. Floods: potential and features

Floods analyses are based on processing statistical data on maximum monthly and annually discharge of the Bâsca River at the closing hydrometric station Bâsca Roziliei (period 1960 – 2007). Discharges during the main floods were also used. In the considered period, the annual maximum flow of the Bâsca River varied between 39.4 m^3/s (year 1986) and 960 m^3/s (year 1975) (Fig. 4). Exceptionally floods were recorded in the years: 1975 (960 m^3/s), 1969 (697 m^3/s), 1991 (530 m^3/s) and 1985 (515 m^3/s). Multiannual average discharge at this station is about 12 m^3/s.

A particulary year for this catchment was 1975 when at Bâsca Roziliei, in 24 hours fell 135,2 mm of rainfall, resulting a flood with a peak discharge of 960 m^3/s (on July 2) (BI BWA, 2009). It was the historical maximum discharge recorded on the Bâsca River at Bâsca Roziliei h.s. The parameters of this flood were: time to peak - 24 hours, recession time - 99 hours, total time - 123 hours), volume - 75.8 mil.m^3. Socio - economical impact was dramatically and generated serious damages (Zăvoianu & Podani, 1977).

Most floods have pluvial causes, occurring mainly in the warm season. Monthly frequency analysis of production of the largest floods indicates that the greatest potential for flood is encountered in the months from May to July. Thus, from the total of 59 major floods identified (were considered cases in which maximum discharge monthly of values were above average annual maximum discharge), 13 (22.0%) occurred in June and each 10 (16.9%) in May and July (55.9%) (Fig. 5).

As a result of specific physico – geographical conditions from the catchment, some floods may be flash-floods. Heavy rainfall and deforestations have increased the incidence of flash-floods and landslide (Bălteanu *et al.,* 2010).

4. Geomorphological floods impact and its economic consequences

Associated with floods is a rich alluvial transport, due to high erosive force of water acting on the river bed and river banks. If the multiannual mean suspended sediment load of the Bâsca River at Bâsca Roziliei h.s. is 9.267 kg/s, during the major floods the suspended sediment load exceeded 10,000 kg/s: 19,800 kg/s (18.VII.1991), 16,400 kg/s (2.VII.1975), 10,045 kg/s (2.VII.1971), (according to the data from BI BWA, 2009).

An important geomorphological impact of floods is the growth of channel processes: lateral erosion (Fig. 6.a), degradation and aggradation (Fig. 6.b). As a consequence of the historical flood in 2nd July 1975, the channel and floodplain morphology of the Bâsca River have been strongly modified both by erosion and by aggradation. On the river bed, sand and rubble sediments were deposited with a thickness of 0.5-1.5 m, which generated stretched stairs of 50-100 m and wide of 10-25 m (Ielenicz, 1984).

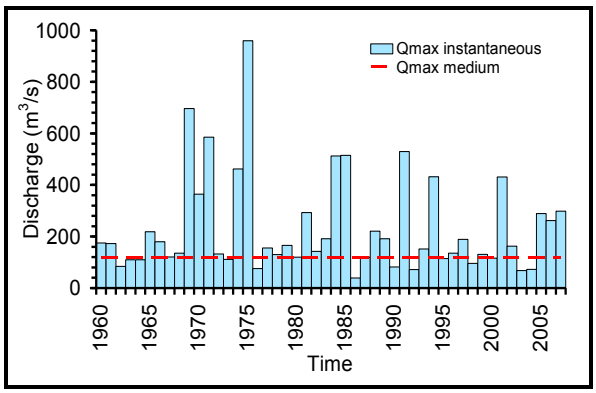

Fig. 4. **Multiannual variability of the maximum discharges of the Bâsca River at Bâsca Roziliei h.s.** (1960-2007)
Source: data process from BI BWA, 2009

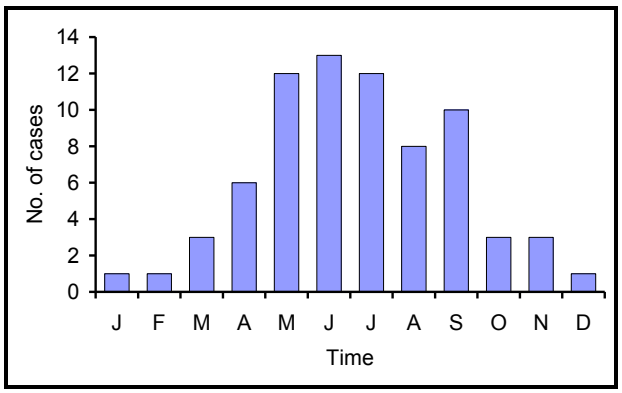

Fig. 5. **Monthly distribution of major floods at the Bâsca Roziliei h.s.** (1960-2007)
Source: data process from BI BWA, 2009

Fig. 6. **Geomorphological effects of floods on the Bâsca River channel: river bank erosion** (a) **and alluvial processes** (b) (Photo: Minea, November 2009).

The erosion action of the floods on the river banks favors slopes destabilization and mass wasting (falls, landslides) (Grecu, 2008). These are also caused by the infiltration and the down-slope flow, the geological features (alternation of different deposits and rocks, presence of faults) and the high slopes (76 sq km of the Bâsca Catchment has slopes exceeding 30^0).

Changes of the Bâsca River channel and its tributaries due to processes of erosion and accumulation have been identified in several locations. In some cases they have caused economic damages, such as:

- deterioration of the forest railway embankment (after 1969 it was out of service);
- undercutting and detachment of engineering techniques (for example along the Păltiniş River) (Fig. 7.a) and degradation of the county and departmental roads: DJ203K, DC178 at auto-station Varlaam (Fig. 7 b), DC173 and DC66.

5. Hydrotechnical works for reducing the geomorphological effects of floods

For prevention and mitigation of the floods effects and their geomorphological impact, engineering techniques were made in the Bâsca River Catchment. These include longitudinal and transversal in-stream structures for bank and bed protection: revetments (gabions, lining with concrete etc.), grade control structures (weirs, sills), re-sectioning and realignment (Aquaproiect, 2006). Engineering works for slope protection and consolidation were also made in areas vulnerable to falls and landslides, due to fluvial erosion on the slope base.

Fig. 7. **Economic damages caused by the fluvial dynamics processes: a – degradation of hydrotechnical works in the Păltiniş River channel; b - erosion and crumble of the departmental road DC178 near auto-station Varlaam)** (Photo: Minea, November and July 2009).

The destructive stream power during the floods associated with neotectonic process by uplift movements with rates of *+5 mm/year* Buzău Mountains (Polonic, 2006) and seismicity, affected in time the hydrotechnical works. In figure no. 8 we present the hydrotechnical works from the middle and lower parts of the Catchment (where are positioned the human settlements: Vadu Oii, Varlaam, Gura Teghii, Nemertea, Furtunești, Păltiniș, Vineţişu and Bâsca Roziliei), and their physical status.

After 2007, for reducing the destructive impact of the floods in the lower sector of the Bâsca River, Buzău – Ialomiţa Water Basin Administration started new hydrotechnical works (gabion baskets).

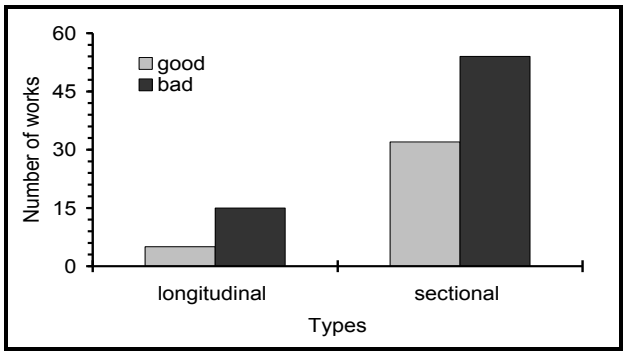

Fig. 8. **Physical status of hydrotechnical works in the middle and lower part of the Bâsca Catchment**
Source: data process from ICAS, 1996

Conclusions

Floods in the Bâsca River Catchment are common risks phenomena, favoured by physical and geographical conditions of the catchment: high proportion of impermeable rocks, high slopes and river slope, energy relief and the torrential regime of rainfalls.

The floods are characteristic in the warm period, especially between May and July, with a maximum flood potential in June. Floods cause quick changes to river bed, in vertical and horizontal profile, through enhanced erosion and accumulation processes. Also, trough erosion actions on river banks are favoured and slope processes amplified (rockfalls, landslides).

Such phenomena have been identified in several sectors along the main river and on its tributaries and cause economic damages (deterioration of roads and hydrotechnical works).

Although there are hydrotechnical works to protect against floods and geomorphological processes associated with them, these works are degraded at a rate of 65%, requiring rehabilitation, and development of new hydrotechnical works.

ACKNOWLEDGMENTS

The research was accomplished within the doctoral training programme and supported by a POSDRU grant, financed by the Social European Fund (SEF). Thanks to Professor Florina Grecu make-up editors of the *Revista de Geomorfologie,* for the final form of this scientific paper.

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