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THE FREQUENCY OF OCCURRENCE OF FLASH FLOODS ON THE RIVERS IN THE LAND OF DORNA

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Abstract: Flash floods are extreme natural phenomena that determine numerous property damage and loss of human life on both global and local level. In order to highlight not only the frequency of occurrence of floods on the rivers in the Land of Dorna but also their effects on the community, we set ourselves to perform a secondary analysis of data provided by Siret River Basin Administration. As a result, one can observe that the highest frequency of occurrence of flash floods in the region of Dorna is in the spring. During the same period of time (from 1993 to 2003) there were recorded only significant property damages after the flash floods. At the end of this paper we suggested a series of coherent measures in order to combat the negative effects of flash floods.

Keywords: The Land of Dorna, flash flood, frequency, damages

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INTRODUCTION

Flash floods, in terms of extreme natural phenomena, represent peaks in the evolution of river discharge and are considered *„the most dramatic episodes in hydrology"* (Pardé, 1955, p. 142). They are characterized by a rapid development (in just a few hours) and sometimes extraordinary, of water level and increase of flow, to reach a maximum, followed by a decrease of waters that drain back to normal in a relatively short period of time.

In many cases, the immediate and sudden nature of flash floods, is the flooding of surrounding areas. Viewed in a European and global context, floods have been considered among the most common and aggressive natural phenomena, causing annual damage and numerous

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casualties. Average annual economic losses due to natural hazards was estimated at € 40 billion all over the world (Gaume et al., 2009, p.70).

Most frequently, flash floods and floods are a direct consequence of climate conditions, which represent the main factor in the occurrence of these phenomena. In the last few decades the increase of frequency and intensity of such phenomena has been attributed to recent climate changes (Lehner et al., 2006; Dankers & Feyen, 2008; Hirabayashi et al., 2008; Lasda et al., 2010; Klijn et al., 2012 etc.).

In Europe, between 1946 – 2007, there were inventoried 578 major floods (Gaume et al., 2009, p.73) that appeared in seven important regions and overlapped the Mediterranean (Spain - Catalonia, Italy, France, Greece) and continental areas (Austria, Slovakia, Romania). With an amount of 152 cases, Romania lies between the most affected European countries in terms of such hydrological-risk phenomena.

As for the territory of Romania, the issue of flash flood and floods is found both in large studies covering the continent (Barredo, 2007; Gaume et al., 2009; Marchi et al., 2010; Kundzewicz et al., 2013) and in some synthesis papers concerning extended territorial units or even the whole country (Arghiuş, 2008; Mustăţea, 2005). Also, there exist many research studies about the hydrographic basins, which capture in detail the determinant factors and the manifestation of phenomena (Şerban et al., 2010; Romanescu et al., 2011; Romanescu & Nistor, 2011; Toma, 2011; Minea 2013 etc.).

In general, in the Land of Dorna, the hydrological studies on rivers are relatively limited and capture the appearance of flash floods and floods during winter, as a result of the formation of ice gorges (Surdeanu et al., 2005; Romanescu, 2005; Rădoane et al., 2009). According to Mihalca (2014, p. 135), in the Land of Dorna the main natural risks observed by analyzing four watershades (The Bistriţa Aurie river, Dorna, Bistriţa and Neagra river) are the flash floods and floods. These are caused by a series of interrelated factors such as: position of the region and the morphogenetic and morphometric features of the relief; the morphogenetic, morphometric and hydraulic characteristics of watercourses; climate characteristics of the region; anthropic activity and lack of protection measures along the main rivers.

Thus, the morphogenetic and morphometric characteristics of the relief (relative altitude between 747 - 2100 m, values of fragmentation density between 0.5 - 4.8 km / km²; relief fragmentation depth between 20 - 520 km/km²; declivity between 2 - 40º etc. - Mihalca, 2014, p. 88-90), the position of the main units and climate changes in the region have influenced the appearance of some peculiar features of the hydrograpic network and the formation of ice structures, causing rivers to flood.

Over 90 % of the rivers in the analyzed region have their origin here, being included in the cathegory of eastern Carpathians system with high water levels during spring and summer and low levels in autumn and winter. This situation has been confirmed by the average runoff - over 45 % of total annual runoff recorded in spring (from March to May) due to snowmelt in the peripheral mountainous areas and abundant rainfall (average annual precipitation amounts are uneven, lowlands registering 650-700 mm, and in the heights recording over 1000 mm). The high density of the river system (1.34 km / km²) is determined by the nivo-pluvial regime in the mountain areas, pluvial regime in piedmont and depression areas, superficial and underground runoff, which influences the torrential regime of the four basins (Mihalca, 2014, p. 107-108, 128-129).

The Land of Dorna comes under the regions characterized by a type of climate specific to intra-mountainous depressions and mountain areas. Due to the multi-annual average monthly temperatures ranging between -5º – -7º in the lowest areas (data collected from Cârlibaba, Poiana Stampei, Vatra Dornei weather stations) and -9,2º in the heights (Călimani station (Reţitiş)), to which we can add high values of altitude differences, one can observe that in the low-elevation areas there are frequent *thermal inversions*. These processes occur as a result of the interaction among general atmospheric flows, nocturnal radiation and adjacent surface characteristics causing accumulation and stagnation of cold air masses in the depression areas in winter (Mihalca, 2014, p. 103, 105).

Also, in winter, under the influence of low temperatures, there can be observed different types of ice formations developed on the rivers in this region. The most frequent formations are recorded along the Dorna River and its tributaries, as a result of morpho-hydrographic characteristics of the basin and the fact that they are located in the Bârgău – Vatra Dornei - Broşteni Corridor. Thereby, the Land of Dorna is affected not only by the influences of continental climate (central - European) causing snowmelt a few weeks earlier but also by thermal inversions. At the same time weather has a major repercussion over the drainage system of rivers. Thus, eastern air masses are behind up-river thawing and because of thermal inversions ice bridges still remain, causing river ice jam and flooding in the Dorna Depression (Mihalca, 2014, p. 138).

Seeing all these above mentioned features, our objective was to analyze *the frequency of occurrence of flash floods* in the Land of Dorna and *the impact* on the community in this part of the country.

METHODOLOGY

Study area

The Land of Dorna lies in the north-western part of Romania (precisely in the western side of the Suceava county), being surrounded by the Maramureş, Bârgău, Suhard, Giumalău, Obcina Mestecăniş, Bistriţa and Călimani Mountains, in the centre having the Dorna Depression and in the south-east bordering the Drăgoiasa-Glod Depression. Therefore, the position of the region mainly covering mountain areas (91.36%) has a certain influence regarding *the frequency of occurrence of flash floods*. These phenomena often affect the ten constituent administrative-territorial units in the analyzed region (figure 1).

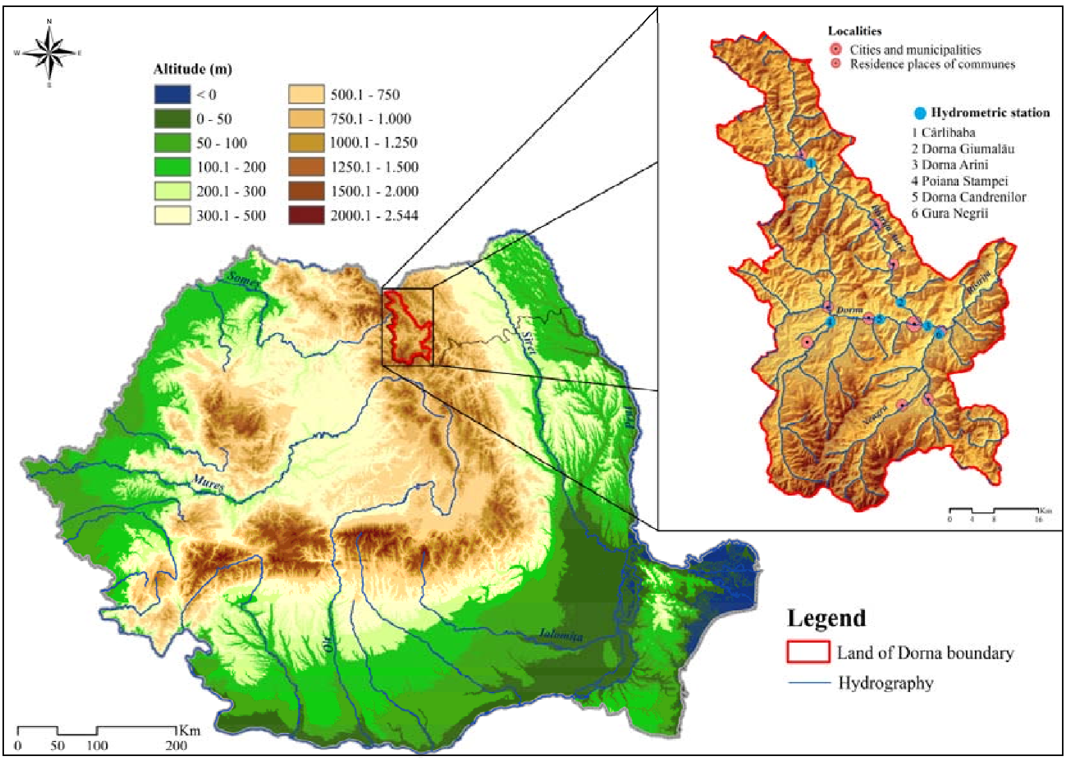

Figure 1. Framing Land of Dorna nationwide
(Source: Topographic map 1:50 000; processing according to NASA (n.d.), SRTM 45 m)

Method

In order to point out the frequency of occurrence of flash floods on the main rivers and their effects on the community in the Land of Dorna, there has been used a *secondary analysis* of data gathered from *„Siret River Basin Administration"*. Hence, for the period covering the years 1993-2003, we calculated the total amount of flash floods recorded on the six rivers with gauging stations in the region (Figure 1) and we finally analyzed all the characteristics of the quantitative and qualitative parameters and the interrelation of certain parameters (maximum discharge - Qmax (m^3 / s), rise time – T (h), volume growth - V (mil. m^3), decrease time – T (h), volume decrease – V dec. (mil. m^3), total time - T t (h), total volume - V t (mil. m^3), shape coefficient - γ, the layer of water drained - q (mm), the ratio of the volume increase and decrease volume (VCR / VSC), volume growth and total volume (VCR / Vt) and of the rise time and the total time (Tcr / Tt)).

Next step of the research was to choose from all flash floods generated during 11 years, several *case studies* to emphasize the most important aspects regarding intensity and all types of damage.

The main programmes that were used in this research were CAVIS, ArcGIS 10.1. and Excel 2007. The first one was used to analyze the parameters of flash flood hydrographs (Figure 2), the second to represent the exact position of the six gauging stations in the Land of Dorna and the third one was used to figure the Gantt chart (Table 1).

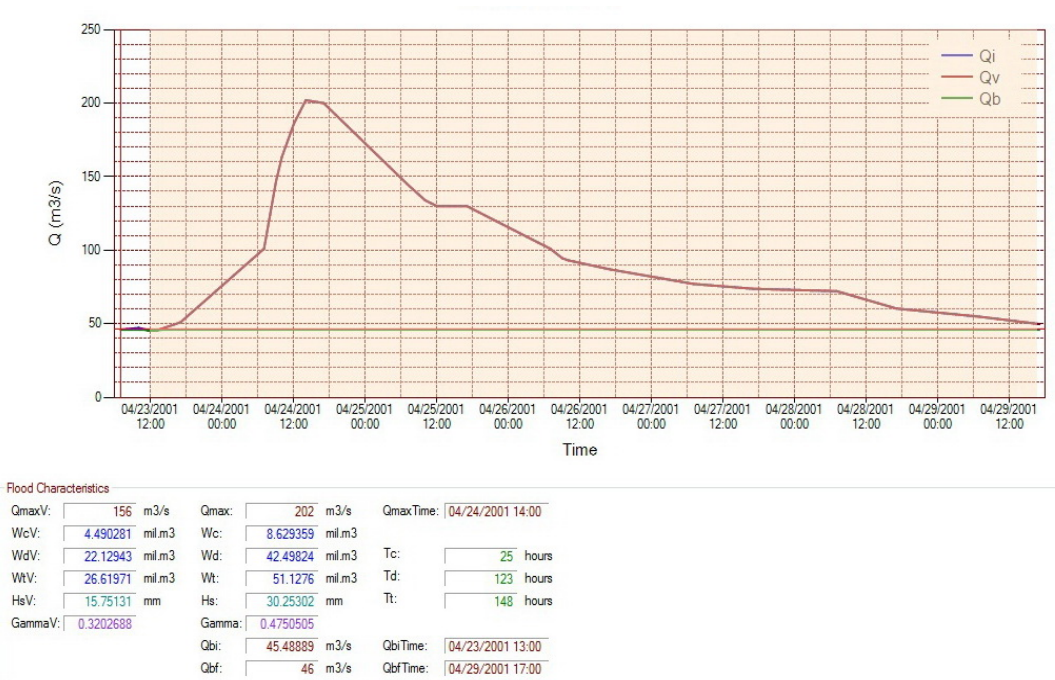

Figure 2. Example of calculating flash flood parameters using CAVIS

RESULTS

With the data provided by the *„Siret River Basin Administration"* we managed to analyze the characteristics of the quantitative and qualitative parameters and the relations among certain high flash flood parameters on the rivers in the Land of Dorna for the period 1993-2003.

As a result of data processing we have managed to draw the Gantt chart (table 1), which can give us information about the *frequency of flash floods* in the four hydrographic basins (Bistriţa Aurie, Dorna, Bistriţa and Neagra basins) from this territory. Taking into consideration the flash floods of different intensities recorded at the existing stations, one can observe that most of them took place in spring (from March to May) because of the mix between snowmelt processes in mountain areas and high amounts of accumulated rain. Then follow those recorded late summer - early autumn (from August to October) when flash floods superpose on secondary pluviometric maxima with a torrential character. Thus, in the Land of Dorna, flash floods and floods are generated mainly by the depth of rainfall recorded in a relatively short period of time in the peripheral mountain areas (in the proximity of Dorna and Drăgoiasa-Glod Basins[1]) and the melting of ice formations on water-courses (e.g. the Dorna river and its tributaries Dornişoare, Teşna etc. where ice thickness varies from 60 cm to 1 m - Honciung, 2010, p. 15). These events coincide with warm time span.

Table 1. Gantt chart of all the flash floods produced between 1993-2003
(data gathered from Siret River Basin Administration)

No.	River name/station	Period of time											
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
1.	Bistriţa/Cârlibaba		1-5	1-5	11-15	11-15	11-15	11-15	6-10	11-15	1-5		
2.	Bistriţa/Dorna Giumalău			1-5	6-10	6-10	6-10	6-10	6-10	11-15	1-5		
3.	Bistriţa/Dorna Arini		1-5	6-10	11-15	11-15	6-10	6-10	6-10	6-10	1-5		
4.	Dorna/Dorna Candreni		1-5	1-5	11-15	11-15	6-10	1-5	6-10	6-10	6-10		
5.	Dorna/Poiana Stampei		1-5	1-5	6-10	1-5	1-5	6-10	6-10	6-10	1-5		
6.	Neagra/Gura Negrii		1-5	1-5	6-10	1-5	1-5	1-5	1-5	11-15	6-10		

Legend: 1-5 flash floods 6-10 flash floods 11-15 flash floods

Among the most important flash floods that were seen on the rivers in the Land of Dorna during 11 years of survey, one can mention some events recorded in 1995 (150 m³/s – the Bistriţa River, Dorna Giumalău hydrometric station), 1998 (116 m³/s – the Dorna River, Dorna Candreni hydrometric station), 2001 (202 m³/s – the Bistriţa River, Dorna Arini hydrometric station) with high flow rates and some flash floods characterized by high degrees of torrentiality [2] in 1993 (0.32 γ – the Dorna River, Poiana Stampa hydrometric station), 1995 (0.29 γ – the Bistrita River, Giumalău Dorna hydrometric station) and 1999 (0.18 γ – the Dorna River, Dorna Candreni hydrometric station).

Analyzing the flash flood registered on the Bistriţa River (figure 3) at the *Dorna Arini hydrometric station* between 23 – 29 April 2001, one can notice that the main factor of development of this phenomenon was torrential rainfall, which caused floods and significant damage on all watercourses in this region (the Bistriţa River - at Cârlibaba hydrometric station - 23-27 April, the Dorna River – at Dorna Candreni hydrometric station - 23-28 April, the Dorna River – at Poiana Stampei hydrometric station 2-27 April etc.). At the hydrometric station there was measured a water level around 313 cm, exceeding the danger level of only 300 cm. Thus, on 24 April 2001 at 2 P.M., the values of water flow were 10 times higher (202 m³/s) than the mean annual discharge of 22.3 m³/s on the Bistriţa River at the Dorna Arini hydrometric station.

Unlike the previous analyzed situation, between 29 June 1995 and 6 July 1995, the flash flood that occurred on the same river (Bistriţa) but with data collected from another station (the Dorna Giumalău hydrometric station) (Figure 4) produced more property damage because of high degrees of torrentiality (0.29 γ). Also, the maximum recorded discharge (150 m³/s) was 10 times higher than the mean annual flow of 11.5 m³/s. At the hydrometric station there was recorded a water level of 325 cm, thus exceeding the flood level of 300 cm.

[1] In May 1970, flash flood occured because of heavy rainfall in the Suhard, Călimani, Giumalău Mountains etc., recording values between 50-60 l/m² (Honciung, 2010, p. 4).

[2] There is known the fact that the lower the values of shape coefficient (γ), the higher the degree of flash flood torrentiality is.

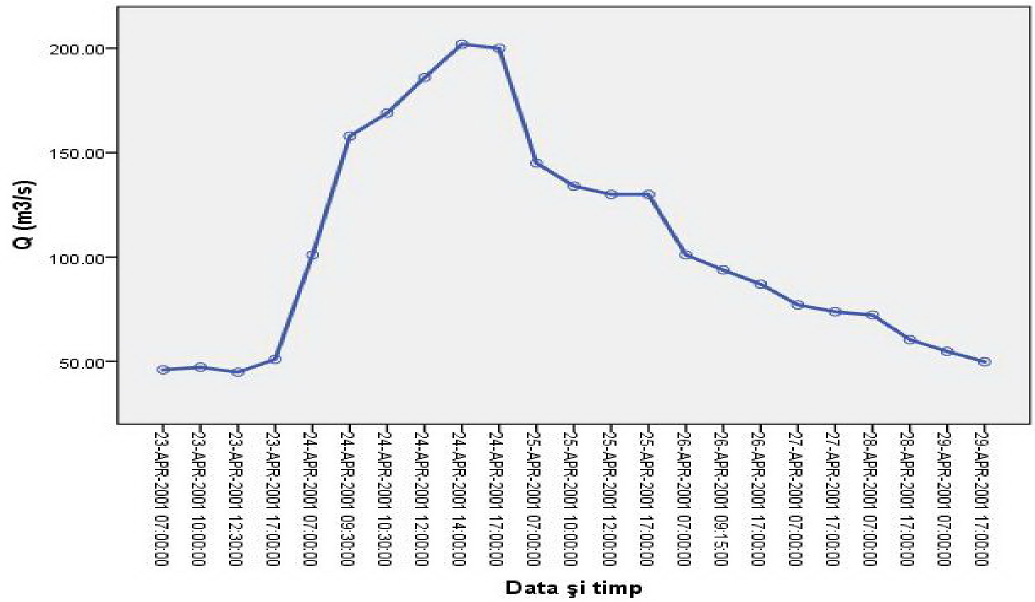

Figure 3. Flash flood hydrograph at the Dorna Arini gauging station (23-29 April 2001)
(data processed after raw data obtained from Siret River Basin Administration)

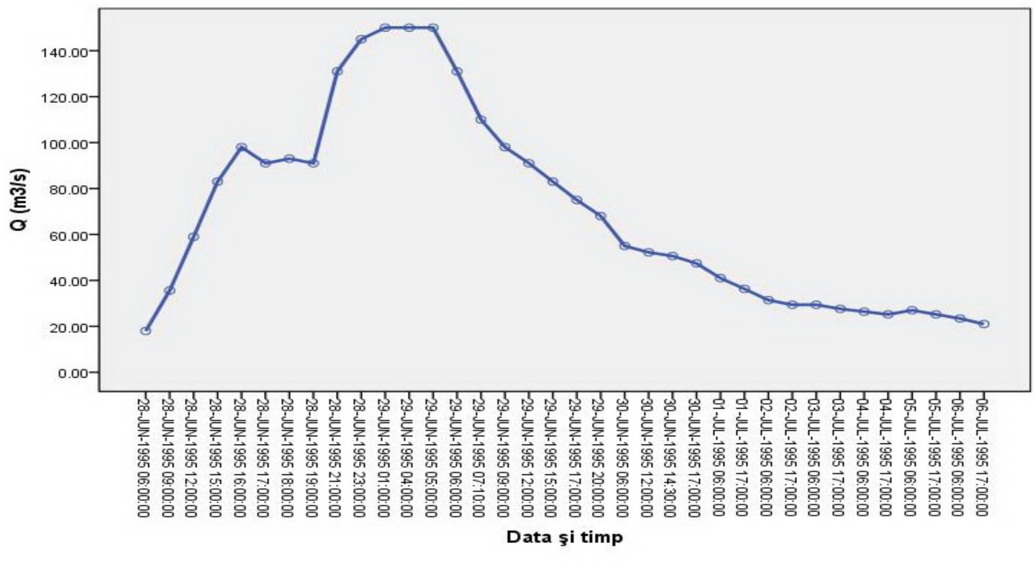

Figure 4. Flash flood hydrograph at the Dorna Giumalău gauging station (29 June-6 July 1995)
(data processed after raw data obtained from Siret River Basin Administration)

Besides the above mentioned elements, the torrential aspect of the two analyzed flash floods was influenced both by several morphohydrographic characteristics of the drainage basin and the morphometric features of the landscape (*high density of the hydrographic basin* of the Bistriţa River – cross-section downstream the city of Vatra Dorna (1.69 km/km²) and *high slope* of the mountain flanks (15.1-35°). In the Land of Dorna, on 13 May 1970 (Table 2) the most important flash flood occured and affected 59 km of roads, 187 km of forest roads and a number of several properties and households.

Table 2. Maximum flow values gathered from the gauging stations situated in the hydrographic basin of Bistriţa River on 13 May 1970
(Source: Honciung, 2010, p. 5, modified and adapted, cited by Mihalca, 2014, p. 137)

No.	River	Hydrometric station	Q a med (m^3/s)	Q max. (m^3/s)
1.	Bistriţa	Cârlibaba	7.5	170
2.		Dorna Giumalău	11.5	310
3.		Dorna Arini	22.3	580
4.	Dorna	Dorna Candreni	7.37	180
5.	Neagra	Poiana Negrii	2.32	98
6.	Neagra	Gura Haitii	4.22	50,4

***Note: Q a med – mean annual discharge; Q max – peak maximum discharge

CONCLUSION

All in all, the results of the research are satisfactory, observing that *the highest frequency* of *occurrence of flash floods* on the rivers in the Land of Dorna was in the months of spring and *damages* were of material ones, without human losses during the same period (1993-2003).

As a result, because of the frequent *occurrence of flash floods* on the rivers from this region (table 1) and based on a methodological framework consisting of Law No. 575/2001 concerning the approval of the National Territory Arrangement Plan - Section V, Natural Risk Areas, we identified the main areas affected by *hydrological risks* (the communes of Cârlibaba, Dorna Candrenilor, Iacobeni and Şaru Dornei). Below (table 3) we tried to suggest some coherent measures in order to combat the side effects caused by flash floods.

Table 3. Flash flood prevention measures against their destructive effects on the rivers in the Land of Dorna
(Source: Mihalca, 2014, p. 138-139)

Measures	
ecological restoration (see Societatea pentru Restaurare Ecologică[3]) and proper management of the drainage basins, focusing on the upper sections of the Bistriţa Aurie, Dorna, Neagra, Bistriţa Rivers and taking into account both the ecological restoration practices and the active laws	performing maintenance works, soil consolidation, reinforcing and constructing new dykes in the affected areas, taking into account the principles of ecological restoration[4]
to increase the capacity of storing high stream flows the existing sewage systems should be modified and enlarged in the localities affected by continuous floods	in order to facilitate the transition of the ice formations developed on the rivers during winter there should be reconsidered resizing bridges and footbridges
maintaining clean river banks involve land clearing and cleaning of shrub vegetation that blocks ice formations etc.)	reafforestation of lands affected by stubbings and wind damage
matching national emergency plans with the regional ones	local people's information and their reactions in handling emergency situations when flooding occurs
improvement of the main water-courses	maintanace works on the existing flood defence infrastructure

[3] Original: Society for Ecological Restoration.

[4] Among them we can mention: correction of watercourses by recreating a sinuous course to facilitate the mobility and functionality of the river; re-establishment of the riparian vegetation; recalibration of the watercourses by creating silt deposits; narrowing the width of the minor riverbed; shore protection against flooding by removing the existing infrastructure and the return to a natural riparian ecotone, which would provide clean flow etc. (The National Institute of Hidrology and Water Management, 2011 cited by Mihalca, 2014, p. 139).

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