A DATABASE DESIGN OF MAJOR PAST FLOOD EVENTS IN ROMANIA FROM NATIONAL AND INTERNATIONAL INVENTORIES

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ABSTRACT. – A database design of major past flood events in Romania from national and international inventories. Floods are one of the most significant natural hazards in Romania, causing losses of human lives and important damages to buildings and infrastructure. Romania is recognized among the most flood prone European countries. This work was conducted in the framework of the VULMIN project, aiming to extract the available key indicators of major and historical flood events in Romania, as a basis for better understanding the patterns of socio-economic vulnerability to floods at regional and national scales and of the adaptive capacity of living areas along the main rivers of this country. The existing databases on flood records at global (e.g. EM-DAT International Disaster Database, Dartmouth Flood Observatory, GLIDE database) and national level (the preliminary flood risk assessment conducted within the framework of the EU Flood Directive), research projects (e.g. Hydrate, Danube Flood Risk) and the available literature have been explored to collect indicators of intensity, magnitude, extent and impacts associated to past major flood events recorded in Romania. Starting from the scientific and reporting needs, taking into account the reliable information found in the documented databases, the main attributes of floods and flash-floods events has been embedded into a proposed database to be developed in the project, which may be useful for further analyses related to hydrological changes associated to climate change.

Key words: floods, flash-floods, vulnerability, disaster databases, Romania**.**

1. INTRODUCTION

Floods are among the most important weather-related loss events in Europe due to their large economic consequences, producing total losses of over 50 billion over the past decade (EEA, 2010). Extreme precipitation events and floods are frequent, and projected to increase, in many European countries, with a great concern in Eastern Europe - one of the existing flood hot spots (Vautard et al., 2014). Romania is considered recognized by World Health Organization (WHO, 2013) and the Romanian Catastrophe Insurance Scheme (PRAC) as highly exposed to natural disasters including earthquakes, floods and landslides. Among these threats, floods are dominant, in terms of frequency (e.g. the severe floods have in some areas, like plain landforms, low return periods of up to 10 years) and

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economic damage losses, having a great impact on human communities. According to the Natural Disaster Insurance Pool (PAID), the recent severe floods of 2005-2010 produced a total (direct) loss of more than 3 billion Euros in Romania, including 62,000 affected and 15,600 destroyed houses (www.paidromania.ro).

The paper aims to explore, collect and review the existing national and international inventories referring to major Romanian floods, in order to create a framework to support regional and local evaluation of floods exposure. This work will provide the baseline to better understand the patterns of socio-economic vulnerability to floods at various scales and of the adaptive capacity of living areas along the main rivers of this country. In this respect, 9 international databases were explored, documenting over 100 major flood events occurred in the last 50 years, aiming to extract the available key impact indicators of major historical flood events in Romania (e.g. losses, casualties, extend of affected area). This work is also in line with the joint initiative of the European Environment Agency (EEA) and Joint Research Centre (JRC), in collaboration with the Centre for Research on the Epidemiology of Disasters (CRED) and the European Topic Centre on Climate Change Impacts, Vulnerability and Adaptation (ETC-CCA), aimed to built an European Flood Impact Database.

2. ROMANIA IN INTERNATIONAL DATABASES ON PAST FLOOD EVENTS

The existing **international databases** on flood records make inventories mostly at global scale (e.g. EM-DAT International Disaster Database, Dartmouth Flood Observatory, GLIDE database, Global Disaster Alert and Coordination System), with various temporal coverage and include both spatial and statistical data. There are no common criteria in these databases in defining a major flood event, but the most typical entry criteria are related to the number of casualties and losses at national level. However, the EM-DAT International Disaster Database is the only dataset that uses a particular set of quantitative criteria for defining major floods, such events being considered only when fulfilling at least one of the minimum "disaster-threshold": $\geq$10 casualties, >100 affected persons; declaration of a state of humanitarian emergency, the need for international assistance.

The *EM-DAT* is one of the most comprehensive and detailed global disaster database covering 1900-to date period, with an extensive inventory of major flood recorded in Romania. The data related to consequences are provided from sources as United Nations agencies, NGOs, government communications, research institutions, earth observation data, etc. The natural disaster statistics for Romania rank the floods of June 2010 in Romania as the costliest from all past flood events, through a total economic damage cost of over 1 million US$x1,000 at national scale, followed by the floods of June 2005 (800,000 US$x1,000). The number of about 1,000 fatalities recorded during the floods of 1926, places these events as the deadliest disasters in Romania from all EM-DAT entries. However, this event was not found among the national records.

After 1950, the events producing the greatest number of casualties has been registered in May 1970, affecting the northern and central parts of Romania (215 victims), and in July 1991, in Siret River Basin, affecting especially Trotuş sub-basin, where the dam failure of the Belci reservoir caused most of the 108 recorded deaths. The effects of the exceptional floods of July 1975 are also well captured in the natural disaster country profile of EM-DAT, the event ranking the first in terms of the total number of affected people (about 1 million).

Detailed analysis of this database leads to the conclusion that after 1990, the information on the consequences of flooding is more transparent and complete, even the total loss associated to certain major events (e.g. 2006, 2008) is still missing (Fig. 1). The lack of such data explains the significantly lower total damage reported for Romania compared with other European countries with similar phenomena and exposure (Poland, Czech Republic, Slovakia, etc.). Also, the analysis of the floods consequences in Romania, but also in other EU Member States, highlights that, after 1990, there is a decreasing trend of events generating victims (especially those with more than 100 victims, typical for the 1970-1985 period).

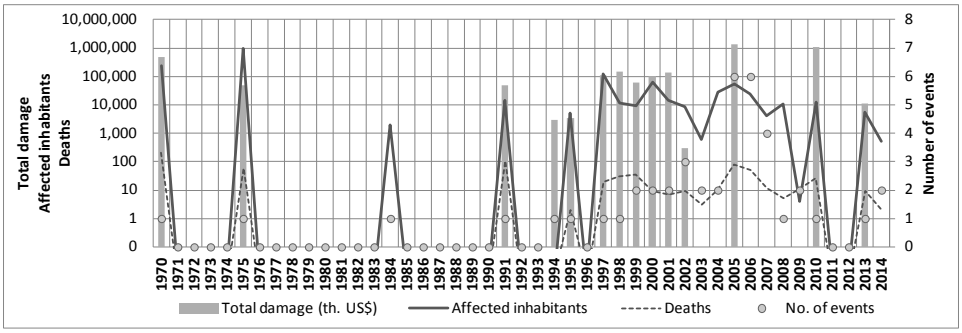

Fig. 1. ***Number of flood events in Romania and main consequences included in EM-DAT database***

The *Dartmouth Flood Observatory (DFO)* contains information about 40 flood events in Romania, derived from remote sensing sources, in-situ instrumental measurements, governmental communications, covering a 24-year period (1991-to date). According to DFO, the floods of 2005 rank the first in terms of economic losses and spatial extension of flooded areas.

Other disaster databases, with relevant floods data for Romania, mainly integrate core information from EM-DAT, CRED (Centre for Research on the Epidemiology of Disasters) and DFO, combined with other quantitative data from various sources: *Center for Refugee and Disaster Response* (CRDR); *Global Disaster Alert and Coordination System* (GDACS); *GLobal unique disaster IDEntifier Number* (GLIDE); *Global Risk Data Platform* (GRDP); *International Disaster Charter* (IDC); *Floods Portal of the Joint Research Center* (FP-JRC); *European Flood Alert System* (EFAS).

The list of past flood records in Romania as derived from the existing international inventories is large, totalling over 100 major events and comprehensive, comprising a great number of key-impact indicators. Table 1 synthesizes the main

characteristics of the analyzed datasets (type, temporal coverage, available key impact indicators), as well as of the most important flood events affecting this country (e.g. human losses, economic damage, extent of flooded areas).

Table 1. ***Main characteristics of global disaster databases relevant for floods in Romania.***

Databases	Type*	Temporal coverage	Available key impact indicators and flood information
EM-DAT (www.emdat.be)	St	1900-to date	Number of killed and affected people, economic damage costs
DFO (www.dartmouth.edu/ ~floods/Archives/)	St-Sp	1985-to date	Flooded area location, flood duration, flood triggering factors, surface of flooded area, flood severity and magnitude, number of causalities and evacuees, damage costs, animations of flood events
CRDR (www.jhsph.edu/research/ centers-and-institutes/center-for-refugee-and-disaster-response/ natural_disasters/_Event_Floods.html)	St	1984-2009	Flooded area location, flood duration, surface of flooded area, number of causalities and displaced people, socio-economical characteristics of flooded areas
GDACS (www.gdacs.org/)	St	Real-time	Flooded area location, date and time of flood occurrence, surface of flooded area, number of affected people, warning thresholds of precipitation intensity
GLIDE (www.glidenumber.net/ glide/public/about.jsp)	St	1997-2010	Location of flood event, date and time of flood occurrence, surface of flooded area, number of affected people, flood event identification code
IDC (www.disasterscharter.org)	St-Sp	2000-to date	Location of flooded area, date of flood occurrence, the main land use type in the flooded areas, spatial distribution of pounding and flooding areas
GRDP (www.preview.grid.unep.ch/)	St-Sp	1999-to date	Assessment of mortality and economic risk from flooding, maps of flood frequency, population exposure to floods
FP-JRC (floods.jrc.ec.europa.eu/)	St-Sp	2010-to date	Daily warnings of critical hydrological levels and flood alerts for the main European rivers
EFAS (www.efas.eu)	St-Sp	2009-to date	Flood probability, hydrological (1-5 days and over 5 days) and meteorological (24-48 hours) forecasts for the main European rivers

*Type: St-statistical, Sp-spatial.

Besides the existing global multi-peril databases, several **database research projects** funded by the EU complement the existing flood inventories (e.g. PREEMPT, MEDIS, EMBRACE, CONHAZ, ENHANCE). Some of the main relevant examples, useful for flood research and mapping in Romania are FP6 HYDRATE project (2005-2008), which provides an archive of detailed data for a number of flash flood events recorded in Europe since 1994 and SEE Danube Floodrisk project, that developed a system of flood hazard and risk maps for the Danube River floodplains for different return period (10, 100 and 100 years).

Database created within the HYDRATE project *(Hydrometeorological data resources and technologies for effective flash floods forecasting)* is focused especially on triggering factors, hydrological features (Borga et al., 2011) and watershed characteristics. The main criteria for defining a flash-flood were duration of the storm event and maximum area of the catchment (Gaume et al., 2009).

A number of 150 events occurred in Romania are included in this database (http://www.hydrate.tesaf.unipd.it/). In order to define a more relevant database for

VULMIN project in terms of events with significant consequences, some hydrological and geomorphic thresholds have been modified after a detailed analysis. Thus, only the floods characterized by a runoff more than 900 l/s/km^2 and a peak flow over the 10-year return period flow ($Q_{max} > Q_{10\%}$) were selected. With this filter, only 40 events have been maintained as proper flash-floods. Other significant events registered in recent years, after the project end, were added in order to be used for developing of the flood assessment methodology under the VULMIN project (Fig. 2).

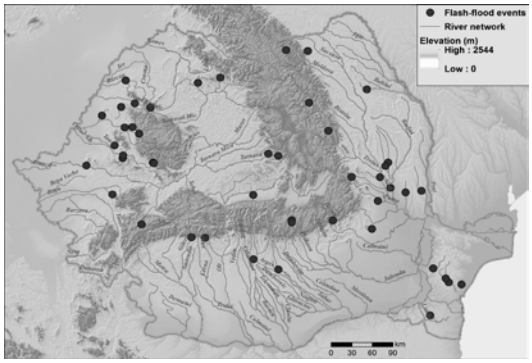

Fig. 2. ***The location of significant flash-floods***

3. NATIONAL INVENTORY OF PAST FLOOD EVENTS IN THE FRAMEWORK OF EU FLOOD DIRECTIVE

Under EU Directive 2007/60/EC on the Assessment and Management of Flood Risks (known as "Floods Directive"), the first stage, prior to hazard and risk mapping, consisted of a preliminary flood risk assessment, which involved the identification of significant historical events (both in terms of the phenomenon severity and the caused damage) and delimitation of areas with significant potential flood risk. The specific requirements refer to the mapping of the areas or river sectors affected by historical floods and their consequences on human health, environment, cultural heritage and economic activity.

The selection of significant historical floods in Romania was performed by applying the own country's criteria, established by specialists from NIHWM. Hydrological criteria focused on the selection of historical events, with an occurrence probability of less than 10%, or with streamflow over the one corresponding to the flood level affecting large areas. In terms of consequences, a number of thresholds have been established (Rădulescu et al., 2014), referring to: the number of fatalities, affected social, infrastructure and economic objectives (e.g. schools, hospitals, roads, factories), damaged or destroyed houses, units under the EU Directive on Integrated Pollution Prevention and Control (IPPC), etc.

A number of 36 significant historical floods at national, basin or local level, have been identified for the inland water courses, and other 3 events for the Danube. The largest events were those of May 1970 (Someş-Tisa, Mureş and Siret), July 1975 (Mureş, Olt and Argeş-Vedea), July 2005 (Olt, Argeş-Vedea, Buzău-Ialomiţa and Siret) and June 2010 (Fig. 3). Also, certain local severe floods that occurred on small areas have been added to the reporting. Their low occurrence probability and high magnitude of damage implied their classification as local significant historical floods (e.g. flash-floods or hydraulic structures failure) (Table 2).

The structure of Flood Directive Database imposed the segmentation of major events at the level of watercourses (rivers and main tributaries), resulting 380 different events (http://www.rowater.ro/EPRI/EPRI.aspx).

Someş-Tisa	Crişuri	Mureş	Banat	Jiu	Olt	Argeş-Vedea	Buzău-Ialomiţa	Siret	Prut-Bârlad	Dobrogea-Litoral	Danube
1970 / 05		1970 / 05						1970 / 05			
						1970 / 07					
		1975 /07			1975 /07	1975 /07					
	1980 / 07										
									1985 / 06		
								1991 / 07*			
	1995 / 12										
	1997 / 06										
											1998 / 01
		1998 / 06									
				1999 / 07			1999 / 06				
	2000 / 04		2000 / 04								
2001 / 03											
			2005 / 04								
					2005 / 07	2005 / 07	2005 / 07	2005 / 07			
		2005 / 08									
						2005 / 09.	2005 / 09			2005 / 09.	
2006 / 06								2006 / 06			2006 / 04
									2007 / 09.		
2008 / 07								2008 / 07	2008 / 07		
								2010 / 06	2010 / 06		2010 / 06

National or basin level Local level * both national and one local flood

Fig. 3. ***Significant historical floods in Romania (year and month of occurrence) selected for each River Basin Administration***

Table 2. ***Local floods reported in the framework of Flood Directive***

River Basin Administration	River/Event	Date	Frequency
Someş-Tisa	Ilişua	June 2006	3%
Mureş	Feernic	August 2005	1%
Crişuri	Barcau	June 1997	10%
Buzău-Ialomiţa	Comisoaia - loc. Cuculeasa	June 1999	1%
Siret	Tazlău –Belci dam failure	July 1991	0.1%
	Arbore	June 2006	0.1%
Prut Bârlad	Tecucel	September 2007	0.5%
Dobrogea Litoral	Costineşti	September 2005	0.2%

4. THE DESIGN OF FLOOD DATABASE DEVELOPED IN THE VULMIN PROJECT

Development of a database regarding the inventory of floods and of a spatial data portal should be an optimal combination between scientific content, practical utility and data collection possibilities. Also, a well defined connection should be between the attribute and GIS (geospatial) data in terms of the level of database structure and encodings relevance (Fig. 4).

Analysis of the previously mentioned databases, especially those available from Floods Directive (Maidens and Wolstrup, 2013),

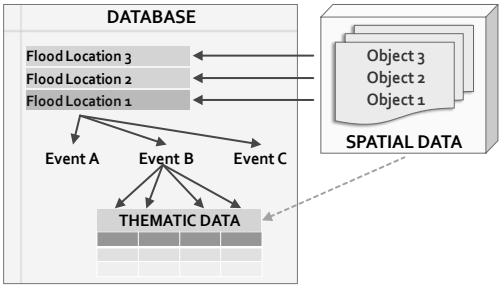

Fig. 4. ***The link between database and GIS data.***

HYDRATE project and EM-DAT, has led to the proposal of a database structure for historical events, mainly for future events that might become historical at a given moment (e.g. for the next reporting of the Flood Directive).

This structure is comprehensive, being usable primarily at national level, which could provide also the requested information at European level (Fig. 5).

Most of the data included in the proposed database are common to both types of phenomena, floods and flash-floods. Only those related to the physical-geographical indicators of watershed are specific to flash-floods, deriving from their particular characteristics and mechanisms of flooding.

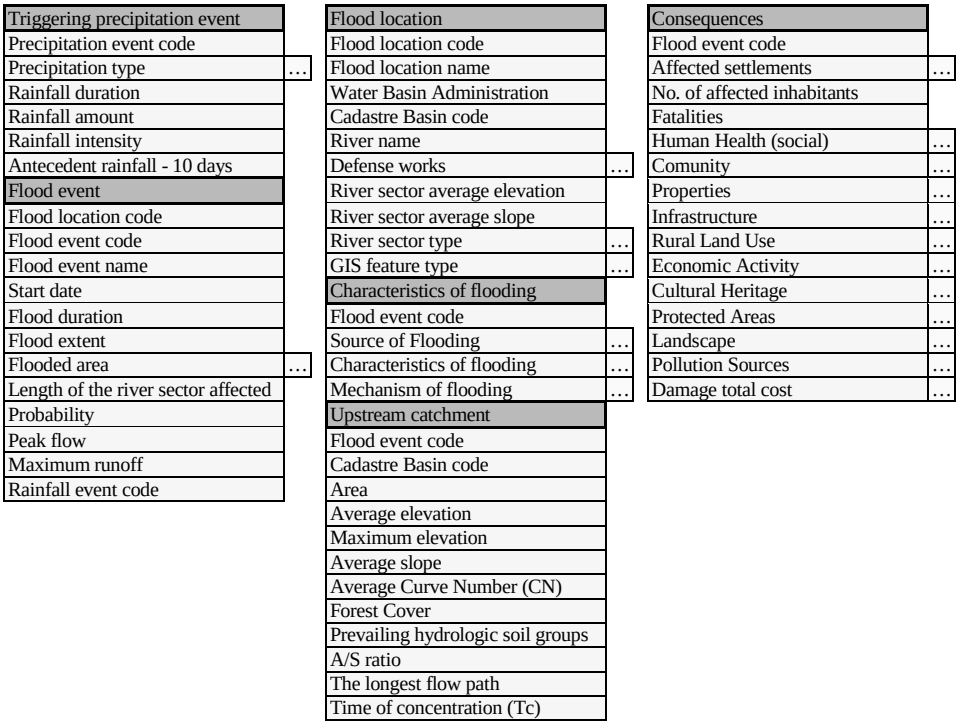

Fig. 5. ***Data and information types included in the floods database of the VULMIN project***

5. CONCLUSIONS

Romania is a flood hotspot in Europe, which experienced significant human and economic losses in the last decade (e.g. 2005, 2010). The global multi-peril databases surveyed, provided a relatively large amount of information about some of the exceptional past flood events in Romania, making the effects of these events public, and representing a valuable interdisciplinary tool in assessing the population exposure as a step towards the assessment of socio-economic vulnerability to floods. However, the available quantitative data must be handled with caution and prudence, when considering the primary flood information sources, both official and unofficial. In a few cases, the flood monetary damage could be considered reliable. The damage

amount is still missing for some major past flood events (e.g. 2006, 2008). The total damage produced by past major flood events occurred during the communist period (e.g. 1970, 1975) is rather underestimated, while for some events registered after 1990 (e.g. 2010), overestimated. In the available databases, there is not an easy distinction between the two types of floods, certain differences existing in terms of triggering factors, flood location features, etc. This aspect leads to some difficulties in the designation of a homogeneous database.

Considering the scientific and flood reporting needs, but also the availability of reliable information about floods (including slow floods and flash-floods), the main attributes of these events have been included into the database of the VULMIN project. The database could be a useful tool for more detailed analyses, including future hydrological changes connected to climate change. The historical flood and flash-flood database will be available at www.igar-vulmin.ro by the end of the project.

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