TYPOLOGY OF HAZARDS WITHIN THE DANUBE FLOODPLAIN, CALAFAT - TURNU MĂGURELE SECTOR

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Abstract. The present paper aims at correlating the national and international research and policy context in order to achieve a typology of the hazards that are relevant for Calafat - Turnu Măgurele sector of the Danube Floodplain. The topic is of great present importance, as both natural and man-induced hazards show a growing trend, while their exact assessment is still extremely difficult and the vulnerability of the elements at risk is more significant than before. In this broader context, the achievement of a hazard typology - emphasizing the interdependency and feed-back relations between environment and stressors, the submission of adequate structural and non-structural measures and the monitoring of their implementation represent key-factors in the management of the environmental components/processes and the sustainable development of the human communities that live near the Danube.

Keywords: the Danube Floodplain, natural hazards, technological hazards, structural measures, non-structural measures.

Rezumat. Tipologia hazardelor din Lunca Dunării, sectorul Calafat - Turnu Măgurele. Lucrarea de faţă îşi propune să coreleze contextul de cercetare şi legislativ la nivel naţional şi internaţional, pentru a crea o tipologie a hazardelor relevante pentru sectorul Calafat - Turnu Măgurele al Luncii Dunării. Subiectul este important şi actual, pentru că atât hazardele naturale, cât şi cele induse antropic, prezintă un trend ascendent, în vreme ce evaluarea lor corectă este încă extrem de dificilă, iar vulnerabilitatea elementelor la risc este tot mai pronunţată. În acest context mai larg, crearea unei tipologii a hazardelor, cu sublinierea relaţiilor de interdependenţă şi feed-back între mediu şi factorii de stres, propunerea de măsuri structurale şi non-structurale adecvate şi monitorizarea efectelor implementării acestora reprezintă elemente-cheie în managementul componentelor/proceselor mediului şi dezvoltarea durabilă a comunităţilor riverane Dunării.

Cuvinte cheie: Lunca Dunării, hazarde naturale, hazarde tehnologice, măsuri structurale, măsuri non-structurale.

INTRODUCTION

The consequences of natural and man-induced hazards are large, pervasive, expensive, and they show a growing trend and complexity. Consequently, they are on the agenda of most national and international institutions, but their assessment is still extremely challenging. At the same time, implementing public regulatory policy to reduce the consequences of hazard events is rarely straightforward or successful. Neither the consequences of those events, nor the continuing problems associated with implementing public policies to reduce those consequences is a trivial matter (ALESCH et al., 2012). Moreover, *freedom from hazard impacts* has been introduced among the manifold dimensions of human security concept, thus emphasizing the environmental dimension of human security and society's (in)security versus natural and human-induced hazards (BOGARDI & BRAUCH, 2005).

The difficulty is increased by the general confusion around the particular meaning of the word *hazard* and the related terminology. The approach of the hazard issue brings together researchers with different fields of work, sometimes from different countries and the data sources are even more diverse; therefore, a common approach in assessing hazards and a joint database are required. The frequent usage in the common activity attenuated or enriched the signification of certain hazard-related terms, while the simultaneous employment in various disciplines requires a complex and comprehensive definition of each term. Further ambiguities are induced by the presence of certain terms that are difficult to conceptualize (*vulnerability, coping capacity, resilience, adaptation*, etc.). A clear and concise research language is crucial for the correct multi-hazard analysis, as well as for the dissemination of the results, which involves local actors with different social-economic and demographic profiles.

Scheidegger defines *hazard* as being the probability that a stable state or condition within a system undergoes a sudden change (SCHEIDEGGER, 1994, quoted by VOICULESCU, 2002). As no consensus is reached in this matter, part of the international research community describe the term in question in relation with the occurrence possibility of a potentially devastating phenomenon, at a given time and on a given area, definition that is broadly accepted in the vulnerability and risk studies (ARMAŞ et al., 2003). In either situation, the hazard implies a certain degree of danger, and, often, extreme events. Moreover, it can also include latent conditions, as source of future disruptive events.

The UNISDR terminology has been adopted for the present paper. In this acceptation, the hazard represents a dangerous phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage (UNISDR, 2009). This choice is justified by the fact that the term is based on a broad consideration of different international sources and the definition has been improved following the feedback offered by specialists and other practitioners. Moreover, the definition is concise, comprehensive and largely agreed upon at international level. Lastly, the UNISDR's experience in acting as focal point in the United Nations system for the coordination of disaster reduction and to ensure synergies among disaster reduction activities (UNISDR, 2009) and our vision of the development of a *connect and convince strategy* to reduce disaster impacts at the level of all interested stakeholders in the area analysed in the present paper further supports the terminology option.

The general classification process and the particular achievement of a concise and comprehensive hazard typology supplies a solid theoretical fundament and represents reference system for further and detailed vulnerability and risk evaluations (GOȚIU & SURDEANU, 2007). Presently, there are in use various classifications of the hazards, which take into consideration the origin of the event, the type/subtype (depending on the triggering agents, occurrence pattern, frequency, amplitude, duration, magnitude), affected area, character (simple/complex), activation (sudden, moderate, slow), environmental sub/systems potentially affected etc.

The present paper aims at identifying the main hazards within the Romanian Danube Floodplain stretching from Calafat in the west to Turnu-Măgurele in the east, the particular hazard-prone areas, and at supplying some measures for mitigating their effects and increase resilience. For this, we adopted the most commonly used typology depending on the prevalent triggering agent; thus, it was possible to distinguish two main categories (natural hazards and technological hazards), which are further sub-categorized, detailed and localized at the level of the case-study area. Because these two classes of hazards sometimes act in complex combinations, a third category may be added (complex hazards), while, if we study the population as direct hazard agent, socio-natural hazards (such as thievery) might be also considered. A background objective of the paper is to supply some adequate measures that in the approach of mitigating the effects of hazards and of increasing individual/community resilience.

The sector under analysis is located in the south-western Romania (Fig. 1), on a distance of about 200 fluvial kilometres, between the town of Calafat and the town of Turnu-Măgurele, covering an area of ca. 200,000 hectares (of which 95,000 hectares represent the proper floodplain). From the administrative point of view, the 52 permanent settlements under study are located on the territories of Dolj, Olt and Teleorman Counties (NUTS III). The total population of the 25 territorial-administrative units (NUTS V) located along the Danube within the study-sector is ca. 140,000 persons (as recorded at the 2011 census), of which almost 50 percent are urban residents. Despite this latter value, the low number of urban centres (five), their main economic features and poor public infrastructure support the general rural character and main agricultural use of the space under study. From the natural viewpoint, only few of these settlements are situated in fact in the Danube Floodplain, but the extension of their farmlands/other estates and, thus, of the human footprint within this unit, as well as the importance that the great river with its adjacent wetlands hold in the general dynamics of the settlements determined their consideration for the present analysis (LICURICI, 2010; 2011).

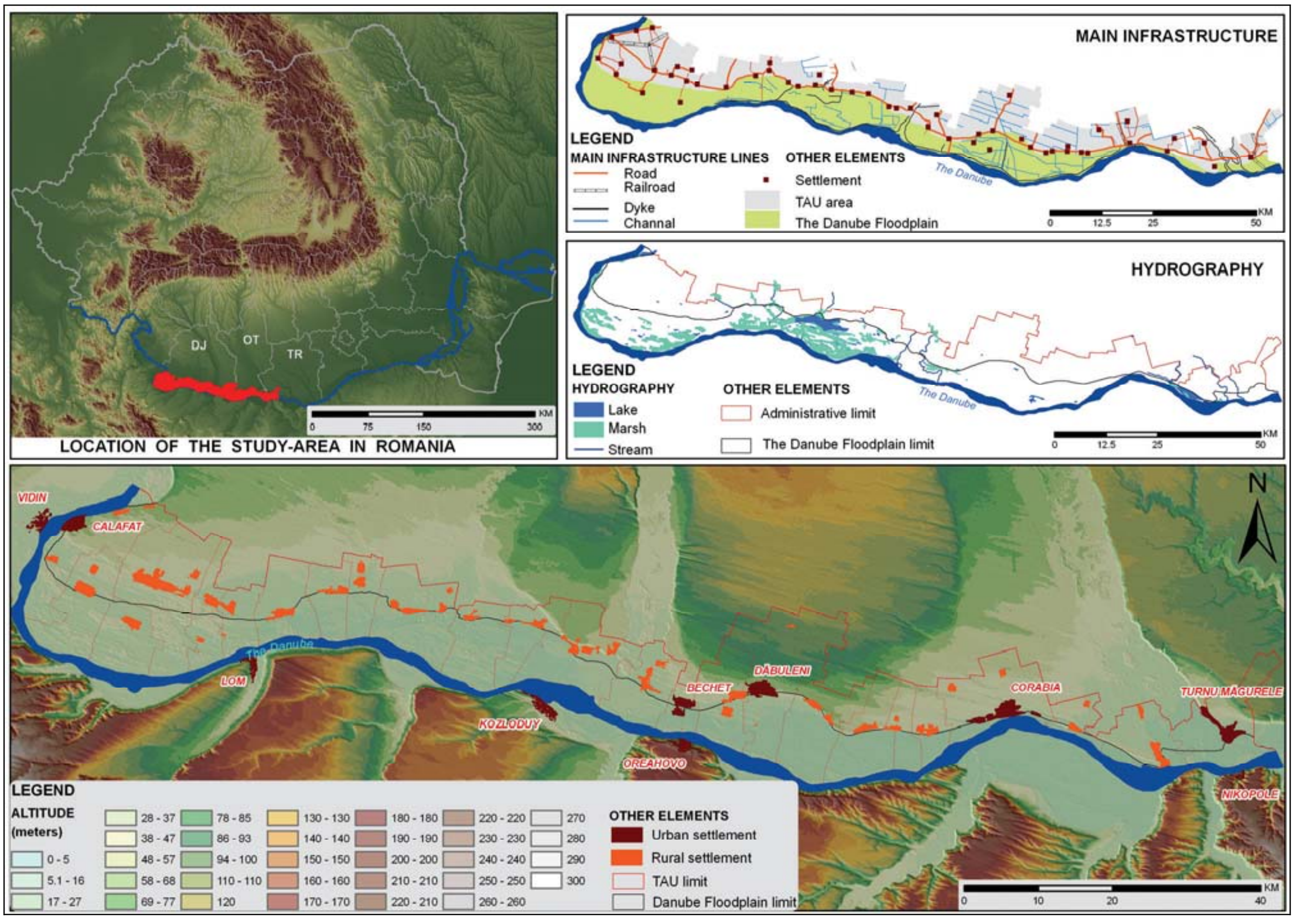

Figure 1. Location and main characteristics of the study-area (original).

Severely transformed by the human agent (extensive land use and land cover transformations in the socialist period, followed by abandonment and incertitude during the following period), the natural landscape of the study area displays a high degree of vulnerability towards natural and man-induced hazards, among which the hydro-meteorological phenomena and those related to soil degradation are prevalent. To accentuate the general vulnerability, the social and economic context of the local communities adds a serious ageing issue, low incomes, poor education, mediocre access to medical services and information possibilities.

Among all types of hazards, at the level of the Danube basin, extensive research has mainly concerned the mechanisms, pattern and effects of floods, as well as the related risk management. One of the important projects in this field, *Danube FloodRisk*, concluded in 2012, changed significantly the cross-border cooperation of all countries within this river basin, with respect to flood risk management. The project contributed significantly to the implementation of the *European Spatial Development Perspective*, the *Danube Strategy* and the EU flood policy.

MATERIAL AND METHODS

In establishing a coherent and adequate hazard typology for the Danube Floodplain, we analysed and synthesised the national and international hazard typology frameworks; the approach took into account the location of the study-area at the Romanian - Bulgarian border and its specific character, as well as the increasing importance attributed to the hazard framework of knowledge and to their mitigation.

The transformations and the dysfunctions induced by the human factor were analysed by means of a series of data representing quantitative values of the natural and technological hazards measurement. The assessment was conducted at the level of the territorial-administrative units (TAUs) that include surfaces of the Danube Floodplain, Calafat - Turnu Măgurele sector. The analysis of the natural hazards followed the recent events and their impact on the environment and on the exposed population.

A comprehensive database was created in GIS environment, on the basis of various generations of cartographic documents (topographical maps of different generations; thematic maps, such as that of the geomorphology, soils, vegetation; Landsat satellite images, etc.) and significant statistical data supplied by regional and national specialized authorities (information concerning the settlement and TAU level). Statistical analysis and field measurements and observations allowed for a better understanding of the dangerous potential within the area, in close connection with the human influence on the landscape transformation.

RESULTS AND DISCUSSIONS

The environmental degradation (i.e. the reduction of the environmental capacity of meeting social and ecological objectives and needs, according to UNISDR, 2009) of the floodplain environment became severe during the last fifty years, its most significant characteristics being: land misuse, soil erosion and loss, deforestation, loss of biodiversity, land, water and air pollution, topo- and microclimate changes, etc. With the change of ownership system after 1989, other degradation aspects appeared (increased deforestation, irrigation abandonment). Consequently, the frequency and magnitude of natural hazards (droughts, floods, mass movements, erosion, etc.) increased and so did the vulnerability of communities.

1. Natural hazards

This large category of hazards is represented by natural processes or phenomena that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage (*ibidem*). Natural hazard events can be characterized by their magnitude or intensity, speed of onset, duration, and area of extent. For example, droughts are slow to develop and fade away and often affect the entire Romanian floodplain under analysis, while rapid mass movements may affect small steep areas located especially at the geomorphologic contact.

1.1. Hydrometeorological hazards

Among the natural dangerous phenomena that characterize the Danube Floodplain, the hydrometeorological hazards are prevalent. For the study area, the main dangerous phenomena of atmospheric or hydrological nature include floods, drought, heat waves and, to a lesser extent, thunderstorms, hailstorms, blizzards, heavy snowfall, cold spells, etc. Hydrometeorological conditions can be a factor in other hazards such as the transport and dispersal of toxic substances.

1.1.1. Floods

This hazard includes floods from rivers (the Danube and tributaries), precipitation, underground sources and may exclude floods from sewerage systems (*Directive 2007/60/EC*); through its magnitude and duration, it could generate human victims and material damages, which, in their turn, disturb the social-economic activities in the affected area.

During the last hundred years, flood protection along the Danube river has been generally conducted by constructing dykes, thus leading to a feeling of safety and, therefore, a decrease of flood awareness (*Danube Atlas of hazard and risk map*, 2012). The 2006, 2010 and 2013 floods occurred on the lower reach of the Danube basin have again highlighted the limits of implemented protection measures since overtopping or dyke failure occurred, reminding that residual flood risk remains despite all efforts. Moreover, some human activities (such as increasing built-up space and economic assets in the floodplain and reducing the natural water retention by land use) and decisions, together with the changing precipitation pattern and other climate change features contribute to an increase in the likelihood and adverse impacts of flood events.

The floods that affected the Danube Floodplain during the last decade (2006 - Figs. 2, 3; 2010 and 2013) substantiate the national and international importance of the area under study concerning the amplitude and impact of this type of dangerous hydrological phenomena. During April, 2006, most of the hydrometrical stations along the Danube registered values that surpassed the defence levels; thus, at Calafat hydrometric station, the water level recorded in 2006 (861 cm) was 59 cm above the maximum projected level; at Bechet, the water level (845 cm) was 58 cm above the projected level, while at Corabia, the projected level was surpassed with 45 cm, the recorded water level being 801 cm (*Romanian Ministry of Environment*, 2006). During July, 2010, the Danube water level showed values above the danger projected levels at Bechet (recorded level: 735 cm, 35 cm above the danger level), Corabia (recorded level: 665 cm, 15 cm above the danger level), Turnu Măgurele (recorded level: 650 cm, 41 cm above the danger level) (*Press release, the Jiu and the Olt Regional Water Administrations*, 2013). On March 28th, 2013, at Bechet hydrometric station, the inundation level was surpassed by 20 cm, while at Calafat, the attention level was surpassed by 42 cm (*Press release, the Jiu Regional Water Administration*, 2013).

Figure 2. Cârna village, flooded during April 2006 (photo by Boengiu S.)

Figure 3. Bechet Harbour Building, with the marks of 1970 and 2006 floods (photo by Boengiu S.).

As *Danube Flood Risk* represents the latest and most detailed transnational, interdisciplinary, stakeholder oriented assessment of flood risk and of its components (hazard and vulnerability), we shall relate to its outcomes in the presentation of flood hazard within Calafat – Turnu Măgurele floodplain sector. An important result of the project was represented by high quality, stakeholder-oriented flood hazard and risk maps (with levels of 100-year flood and extreme floods), developed and produced for the Danube river floodplain in order to provide adequate risk information for spatial planning and economic requests. Comparably frequent events, such as floods with recurrence intervals of 30 and 100 years are indicated by their inundation boundaries (Fig. 4).

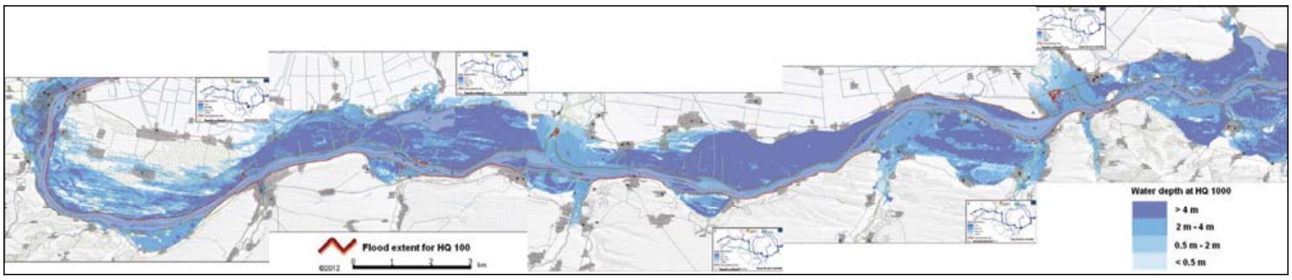

Figure 4. Flood hazard map of the Danube Floodplain, Calafat - Turnu Măgurele sector (original).
(Processed after the Danube Atlas of hazard and risk map, 2012; Sheet no. 47, 48, 49, 50, and 51).

Flood hazard is analysed for three levels of frequency and magnitude: frequent event (30 years return period), medium event (100 years return period), and extreme event (1,000 years return period). For Calafat - Turnu Măgurele sector, the very rare events (HQ1000) generate flood extents and depths that are distinctly larger/higher than what has been usually observed, but they broadly overlap the 2006-flooded area. Theoretically, in this case, the northern limit of the flooded areas connects Ciupercenii Vechi, Ciupercenii Noi, Desa, Pisculeţ settlements (mainly 2 to 4 m water depth), continuing eastwards on the line of Rast, Negoi, Bistreţul Nou, Bistreţ, Brânduşa, Goicea, Săpata, Măceşu de Jos settlements (mostly above 4 m water depth), including the settlements located at the Jiu - the Danube confluence, i.e. Gighera and Ostroveni (water depths between 2 and 4 m, and even 0.5 to 2 m), Bechet, Călăraşi, Dăbuleni, Ianca, Potelu, Gura Padinii, Orlea Nouă, Celei, Corabia (mostly above 4 m water depth) and ends in the Olt – the Danube confluence area, with Islaz and Turnu Măgurele settlements (water depths between 2 and 4 m and even below). For the areas between HQ100 and HQ1000 limits, no direct restrictions of land use arise, however preventive flood strategies and emergency planning should be accounted for, especially regarding vulnerable objects (*Danube Atlas of hazard and risk map*, 2012). The flood event with 100 years return period is widely accepted as the design level for flood protection measures along the Danube River. Normally, flood hazard in the areas between the limits HQ30 and HQ100 is known mainly to the residents having lived there for a long time. In the area under study, on the line of Corabia - Gârcov - Islaz settlements, only the HQ100 limit is present, which means that this sector does not represent a flood-prone area.

1.1.2. Climatic hazards

The climatologic research regarding the Oltenian Danube Floodplain, or a more extensive area that includes this unit making clear reference to it (BOGDAN, 1999; DUMITRAŞCU et al., 2001; VLĂDUŢ, 2004 - 2011; DUMITRAŞCU, 2006; MĂRINICĂ, 2006; BURADA et al., 2011; DRAGOTĂ et al., 2011) identified considerable changes of the precipitation quantities and distribution, as well as of the temperatures within the area, especially during the last decade of the 20th century. Whether this phenomenon represents a normal climatic variation or the effect of human activities is a matter of debate; what can be clearly stated is the fact that the dryness and drought phenomena impact heavily on the environmental sub-systems, this being amplified by the accentuation of local human intervention and by the degradation of the environmental processes.

Among the numerous and complex climatic dangerous phenomena with increasing frequency and magnitude within the area, drought and dryness have the most severe effects upon the local communities and environment. Droughts are complex phenomena induced in time and triggered by meteorological factors (the precipitation level represents a key-factor), which harm all biotic and abiotic environmental components and the intensity of which may depend upon the characteristics of these environmental elements (for example, the effects of drought are intensified by the partial loss of the precipitation water in the soils with low retention capacity, as the sandy or compacted soils in the case-study area) (*Strategia naţională privind reducerea efectelor secetei*, 2008). Furthermore, some authors consider that aridity characterises a given area where two categories of factors acted in synergy. i.e. the climatic elements and the human activities (MĂRINICĂ, 2006).

Dryness and drought (Fig. 5) are not new occurrences within the analysed sector of the Danube Floodplain; although the great river represents a constant source of water vapours, such dangerous phenomena as those mentioned above are often registered in the adjacent area and their frequency was presented by using different methods. Thus, the correlation of the monthly mean temperature and precipitation values in the Peguy and Walter-Lieth climograms, BOGDAN & NICULESCU (1995) identify dryness phenomena (June - September) and drought (mostly August) extended at the level of the entire sector and beyond (broadly between Gura Văii and Giurgiu settlements). Using the same parameters correlated in the Gaussen climatic diagrams system, DUMITRAŞCU (2006) concludes that the dryness period stretches over more than three months, while the drought span is comprised between 1 to 1.5 months (meteorological stations within the Oltenian Plain).

The past thermal excesses and the pluvial deficit did not have on the environmental components an impact as severe as that observed during the last decades. One explanation lays in the transformation of the environmental response under the increasing stress of the human impact (change of the active surface, use/abandonment of irrigation etc.), while another is connected to the significant transformation of the pluvial regime (rare and short downpours that sometimes lead to flooding, which alternate with long drought periods (Fig. 6) and which replaced the past slow and long rains, as well as a thin and discontinuous snow layer, which replaced the past heavy snows). At the same time, there has been recorder an significant increase of the evapotranspiration, a consequence of natural processes and human actions, which can generate important moisture deficits, especially in dryness conditions, but also within a normal pluvial regime (DUMITRAŞCU, 2006).

Along with the temperature, precipitation, wind speed and direction, insolation, vegetation type, water reserves, and ground water depth (ŞERBAN, 2010, quoted by DRAGOTĂ et al., 2011), the potential evapotranspiration stands as a key-factor in the computation of aridity indices and the further analysis of the moisture deficit. The annual values of the potential evapotranspiration (Thornthwaite computation method - ET0 - TH, mm), which characterise the floodplain sector under analysis are above 720 mm, sometimes even above 740 mm (the area located south of Calafat) (PĂLTINEANU et al., 2007), and their correlation with the mean multi-annual precipitation values (1961 - 2000: Calafat - 518 mm; Bechet - 508.3 mm) indicate the necessity of irrigation during summer. The aridity index (Thornthwaite method - Iar – TH) displays values above 50 percent for the entire area under analysis, which, according to Thornthwaite, are characteristic to a climate with marked aridity (PĂLTINEANU et al., 2007). The values of the annual climatic water deficit (DEF, negative), i.e. the difference between the annual precipitation and the potential evapotranspiration underline the fact that the Danube Floodplain is the most representative area for the development of this phenomenon in the entire south-Oltenian region. Thus, extensive surfaces within Ciuperceni - Desa - Pisculeţ, Bistreţ - Bechet - Corabia, and Turnu-Măgurele sub-sectors of the floodplain are crossed by the - 200 mm isoline, while the rest of the area is characterised by a water deficit that ranges between - 150 and - 200 mm.

It is enough evidence that the Calafat - Turnu-Măgurele sector of the Danube Floodplain is included in a broader area, located in southern Romania, which is more frequently and strongly affected by accentuated aridity, the consequences of this phenomenon being severe both at the economic and environmental level. This hazard cannot be totally justified by the climatic factors, but it is rather the result of the complex interaction between natural elements and human activities at different spatial and temporal scales: global climatic changes, human impact, misuse of land and water resources, etc. The values of the indicators above include the sector under study among the areas that are most affected by restrictive climatic phenomena, especially drought and dryness (on the second place at national level, after eastern Dobrudja) (DRAGOTĂ et al., 2011). In this framework, the revaluation of certain key-components of the human activity in the area (especially of those connected to agriculture and forestry) is mandatory.

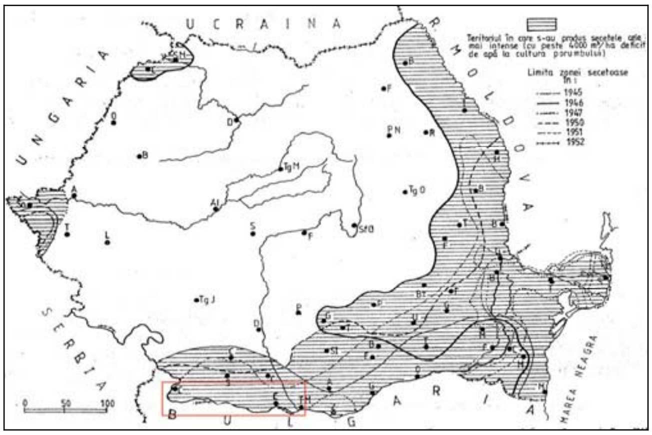

Figure 5. Areas affected by drought in Romania. (Source: RĂDULESCU et al., 1968)

Figure 6. Landscape generated by hydro-climatic variations and soil conditions, south of Bistreţ (photo by Licurici M.).

1.2. Geomorphologic hazards and those related to soil degradation

A threat or a succession of threats for human communities or environmental factors resulted from the instability characteristics of the terrestrial surface, even if the causes of this instability have a different nature (endogenous: earthquakes; exogenous: climatic, man-induced, etc.) (GARES et al., 1994).

Within the study area, the geomorphologic hazards are mostly present at the steep contact of the proper floodplain with the neighbouring units, along the banks, on the sandy surfaces, etc. They are mostly regarded as related to landscape changes that affect human systems. The processes that produce the changes are rarely geomorphologic in nature, but are better regarded as atmospheric or hydrologic or man-induced (*ibidem*).

Being a complex result of the fluvial and Aeolian processes with high frequency within the sector, the geomorphologic landscape of the Danube Floodplain undergone the severe transformation exerted by the human agent. This type of significant influence was materialised especially through the building of dams, flood-control dykes, a complex network of irrigation and drainage channels and, finally, through an extensive and severe land use and land cover change that had subsequent effects at the level of all environmental components, including the geomorphologic elements. Thus, humans have become active geomorphologic agents and some of the geomorphologic hazards within the area are triggered or accelerated in close connection with the human activity or with the lack of human involvement.

Geomorphologic hazards constitute a subgroup of natural hazards and include events and processes, which cause a change in the characteristics of the floodplain or terrace surface detrimental to human society and its activities. Natural processes may induce such changes in the Danube Floodplain but, for quite a number of them, human intervention is - directly or indirectly - responsible (SZABÓ et al., 2010).

The unfolding of the study area along the Danube floodplain, with human ecosystems located at the contact of landforms with different characteristics, makes these areas vulnerable to various types of geomorphologic hazards, the differences increasing when the features of the Romanian and of the Bulgarian floodplains are considered. The geomorphologic hazards concern the floodplain proper, in certain cases the slope and flat of the neighbouring terrace (and, thus, the floodplain - terrace contact, where numerous settlements are located), and the banks of the Danube or of its tributaries. Judging by the amplitude of the damages (impact on the economic and social components, change of the geo-components, visible effects on the landscape, etc.), frequency and intensity, the most important geomorphologic hazards within the reference area include the erosion processes (more active at the geomorphologic contact or along the riverbanks), the land degradation processes, associated with the landslides that are more characteristic on the Bulgarian side. The precipitation, through its distribution along the year and especially the frequency of downpours, correlated with the new vegetation type and with the deficient agricultural practices, represents an essential factor connected with the activation of degradation processes and with their annual rhythm.

Among the aims of the research is the achievement of the typology of geomorphologic and soil-related hazards, which are triggered or accelerated by human intervention and act back upon the local communities, in the complex framework of environmental degradation. The present study of the geomorphologic hazards is done in five fields: geomorphologic hazards primarily related to gravity, geomorphologic hazards primarily related to (rain) water erosion, geomorphologic hazards primarily related to wind erosion, geomorphologic hazards related to anthropogenic landforms, and geomorphologic hazards related to soil degradation.

Geomorphologic hazards identified and evaluated in terms of source type, occurrence and impact have been correlated with the human interventions and activities such as deforestation, overgrazing, appearance of inappropriate waste dumps, exploitation of sand/gravel, deficient agricultural practices, expansion of artificial surfaces, channels, dykes, reservoirs and dams are the most numerous. All these human-induced structures have been exposed to the geomorphologic hazards (especially, by the sediment movement from the source to delivery), so many human interventions have had hazardous tendencies by their response.

1.2.1. Geomorphologic hazards primarily related to gravity mainly concern mass movements, landslides, surface compaction, and debris or mud flows. This type of hazards develops in three different cases, depending on the terrain morphology, human impact and fluvial erosion. Primarily, this is the case of the Danube banks and of its tributaries, which are subject to lateral erosion. The illegal or improper deforestations and the lack of riverbank consolidation measures (Fig. 7), along with the fluvial traffic contributed to an accelerated erosion modelling of the high riverbanks. Secondly, this type of hazard is characteristic to the floodplain - terrace contact; from this viewpoint, two situations are to be noticed: the geomorphologic contact areas with the low terrace, generally masked by the presence of Aeolian sand and the areas where the floodplain comes in contact with the high terrace (the 2nd terrace of the Danube, 20 meters – at Corabia, the 3rd terrace, 28 meters - at Calafat, etc.), the significant altitudinal difference thus appeared favouring the geomorphologic hazards. The exposed areas are located along the contact line marked by the presence of settlements: Calafat – Basarabi - Golenţi, Măceşu de Jos – Nedeia, Potelu – Grojdibod – Corabia, etc. On the unconsolidated slopes or riverbanks, the gravitational or water-triggered geomorphologic processes (mainly collapses or the torrentially phenomena) were accelerated by the inadequate land use (overgrazing, deforestation, removal of construction material, heavy buildings on the terrace flat, near the edge, road construction, etc.) and by the lack of erosion-control measures. Lastly, the extension of the sandy areas, as well as the man-induced changes on the floodplain and in the near vicinity of this unit favours the surface compaction.

1.2.2. Geomorphologic hazards primarily related to (rain) water erosion concern any slope area within the floodplain and the geomorphologic contact. An assessment of this type of hazard can be done in the field of splash erosion, sheet erosion, concentrated (rill/gully/torrent) erosion and suffosion. Erosion is a natural process, but it has been increased dramatically by human land use (especially by deforestation, agriculture, cutting down of orchards/vineyards and overgrazing) in the framework of climate changes. While any declivous surface is exposed to splash/sheet erosion, the suffusion is a hazard that endangers the surfaces characterized by the presence of the loess and the concentrated erosion develops at the contact of the floodplain with the high terrace.

1.2.3. Geomorphologic hazards primarily related to wind erosion concern deflation, abrasion and deposition of the sand. Large surfaces of the floodplain (Calafat - Ciupercenii Noi - Desa - Piscu Vechi - Ghidici, Bechet - Dăbuleni, etc.) are vulnerable to this type of hazard, which is to be assessed in the context of the land use/land cover changes (cutting down of forest shelter-belts, deforestation, removal of the natural vegetation, usage of pesticides, which leaves the soil naked between crops, etc.) and climatic changes (long dry/drought periods, increased occurrence of storms, high-speed winds, etc.).

1.2.4. Geomorphologic hazards related to anthropogenic landforms are more difficult to categorize, but they are triggered by the direct human impact on the relief. This category of hazards is to be put in connection with the construction of great dams that modified the liquid and solid flow of the river (and the slope modelling or the sedimentation type/rate), or to the activities and the forms resulting from the extraction of construction materials (rock plants, borrow pits/areas, etc.) (Fig. 8). The Danube and its floodplain traditionally represented a source of raw materials for the construction works but sometimes this activity accelerated certain geomorphologic hazards. Starting from the borrow pits realised for the collection of sand, gravel or clay, in certain situation the dangerous geomorphologic process became uncontrolled and rapidly extended through lateral and regressive erosion.

Figure 7. Accelerated erosion on the high Danube banks, south of Desa settlement (photo by Licurici M.).

Figure 8. Rapid erosion modelling on sands with clay intercalations (south of Zăval settlement) (photo by Licurici M.).

1.2.5. Geomorphologic hazards related to soil degradation include a significant variety of surface and underground processes, such as gleization, salinization, vertical migration of soil elements, removal/covering of the fertile soil cover by wind, etc. The causes are also to be put in connection with the inadequate agricultural techniques, deforestation, overgrazing, interruption of the lateral connection between floodplain and the Danube, etc.

After the fall of the socialist system and with the rise of the private ownership, along with the quasi-generalised destruction or abandonment of the agricultural equipments in the floodplain, the new complex social-economic situation influenced the occurrence of certain types of geomorphologic hazards. A simple example shows that in certain instances the deforestations (overlapping serious drought phenomena that influenced the vegetation) generated the reactivation of sand dunes. In the framework of the lateral connectivity interruption between the Danube and its floodplain, the lack of irrigations has consequences at the level of soil degradation, etc.

The aims of the anthropogenic geomorphologic research in the framework of the integrated environmental management must include the assessment of the purpose, type and extension of the human impact on the relief, certain predictions regarding the geomorphologic dynamics subsequent to the human intervention, the identification of the areas worth protecting (with the estimation of the conservative value and of the vulnerability of the minor landforms) (SZABÓ et al., 2010), as well as the achievement of correlations between the hazards induced within the new geomorphologic landscape and the dimensions of the environmental components vulnerability.

2. Technological hazards

Technological hazards, as defined by the UNISDR, originate from the technological or industrial conditions, including accidents, dangerous procedures, infrastructure failures or specific human activities, which may cause loss of life, injury, illness or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage (UNISDR, 2009). The emission from a technological hazard may leak out of a production facility, a deposit, a stockpile, a transport corridor, etc. through specific transmission media (water, air, soil) (SCHMIDT-THOME, 2005). One of the most important technological hazards, industrial pollution has decreased in recent years. Within the Danube floodplain, this class of hazards is also represented by nuclear radiation (Kozloduy), toxic wastes, dam failures (Iron Gates II, located upstream of the study area), transport accidents, fires, chemical spills, etc. Technological hazards also may arise directly as a result of the impacts of a natural hazard event.

Unlike natural hazards, technological hazards offer the possibility for controlling and coping with their effects. Due to numerous severe technological accidents, international organizations and governments have continuously tried to improve the legislation in order to prevent such events. At European level, there are worth mentioning: the International Strategy for Disaster Reduction, Convention for the Prevention of Major Industrial Accidents, The SEVESO Directive, and Stability Pact for South-Eastern Europe, subsequently Regional Co-operation Council, as well as regional and national strategies and programmes. In Romania, there is quite an extensive legislation for preventing major industrial accidents, the policy mainly concerning the manipulation and control of dangerous substances, the emergency plans in case of accidents involving such substances, the distribution of support functions in case of emergency situations, etc.

2.1 Industrial hazards

The area under study is a historically agricultural one, the most important industrial units being concentrated in Turnu Măgurele (Teleorman County) and Corabia (Olt County). Thus, potential sources of technological industrial hazards were identified only in Turnu Măgurele, where there is one SEVESO industrial site, upper pile, S.C. Donau Chem SRL, which manufactures four chemical substances (ammonium nitrate, carbamide, ammonia and nitrate acid) and has four deposits for industrial waste. One of them is destined for dangerous waste – pyrites ash, covering an area of approximately 52.9 ha. In 2011, the National Agency for Environment Protection, Teleorman, carried out several soil sampling and analysis to evaluate the soil quality from the point of view of chemical pollution within the activity area of Donau Chem company, which indicated that the soil quality is below the alert threshold.

In or near the settlements from Dolj and Olt counties, bordering the Danube, there are no deposits or reservoirs of substances with major chemical and explosion risk, as stipulated by *G.D. 804/2007*. Still, in Olt and Teleorman counties, there is a gas pipe connecting Turnu Măgurele and Corabia, 27 km long, north of Islaz, Giuvărăşti and Gârcov, near three NATURA 2000 sites.

Considering the potential 'hazard path' represented by the Danube, the chemical plants and mining industries located in the middle Danube basin, along the Danube or its tributaries, may also be relevant for the target area.

2.2 Transport related hazards

Road transportation of oil and other hazardous fuels is generally related to the towns in the area – Calafat, Bechet, Dăbuleni, Corabia and Turnu Măgurele, on the national road along the Danube. According to the National Strategy for preventing emergency situations, in order to prevent accidents during the transportation of dangerous substances, there exists a monitoring system of such transports (the county Inspectorates for Emergency Situations) in order to ensure an opportune and operative intervention in case an accident should occur.

The harbours at Calafat and Corabia, with quite large moorings, have few activities due to the decay of harbour installations and platforms.

2.3 Radioactivity contamination

On the Romanian side of the Danube floodplain, there is no nuclear power plant in the target area, but just across the border, in Bulgaria, at Kozloduy, there is such a plant, which would severely affect the settlements bordering the Danube in case of accident. Air and water would be contaminated, including the aquifer, which would compromise

Sadova-Corabia irrigation system (Ianca, Dăbuleni, Călăraşi settlements, where it still functions) for a longer period of time. Within 30 km range, 10 administrative units from Dolj County and two communes from Olt county (Ianca, Grojdibodu) would be affected. This scenario is taken into consideration by the authorities, the County Inspectorates for Emergency Situations developing evacuation routes. There is also the risk of severe accidents during the occasional shipment of new or used fuel for Kozloduy nuclear power plant on the Danube.

The nuclear hazard would have an extensive area of manifestation, but, theoretically, the occurrence probability is extremely low (FORTUM, 1999, quoted by DUMITRAŞCU, 2008). The settlements located in the Bistreţ – Bechet sub-sector are placed in the eviction area in case of nuclear accident, the rest of Calafat – Corabia sector stretching within the planned emergency area in case of exposure to the radioactive cloud, while the easternmost sub-sector overlaps the planned emergency area in case of exposure through ingestion (Fig. 9). The nuclear hazard complexity is enhanced by the project proposal concerning the depositing of low and average radioactive waste with short life span, generated during the functioning and closing of the NC Kozloduy, the functioning of the future NC Belene, as well as those originating in other conventional activities - medicine, scientific research, technical applications, etc. (*Romanian Ministry of Environment and Forests*, 2012).

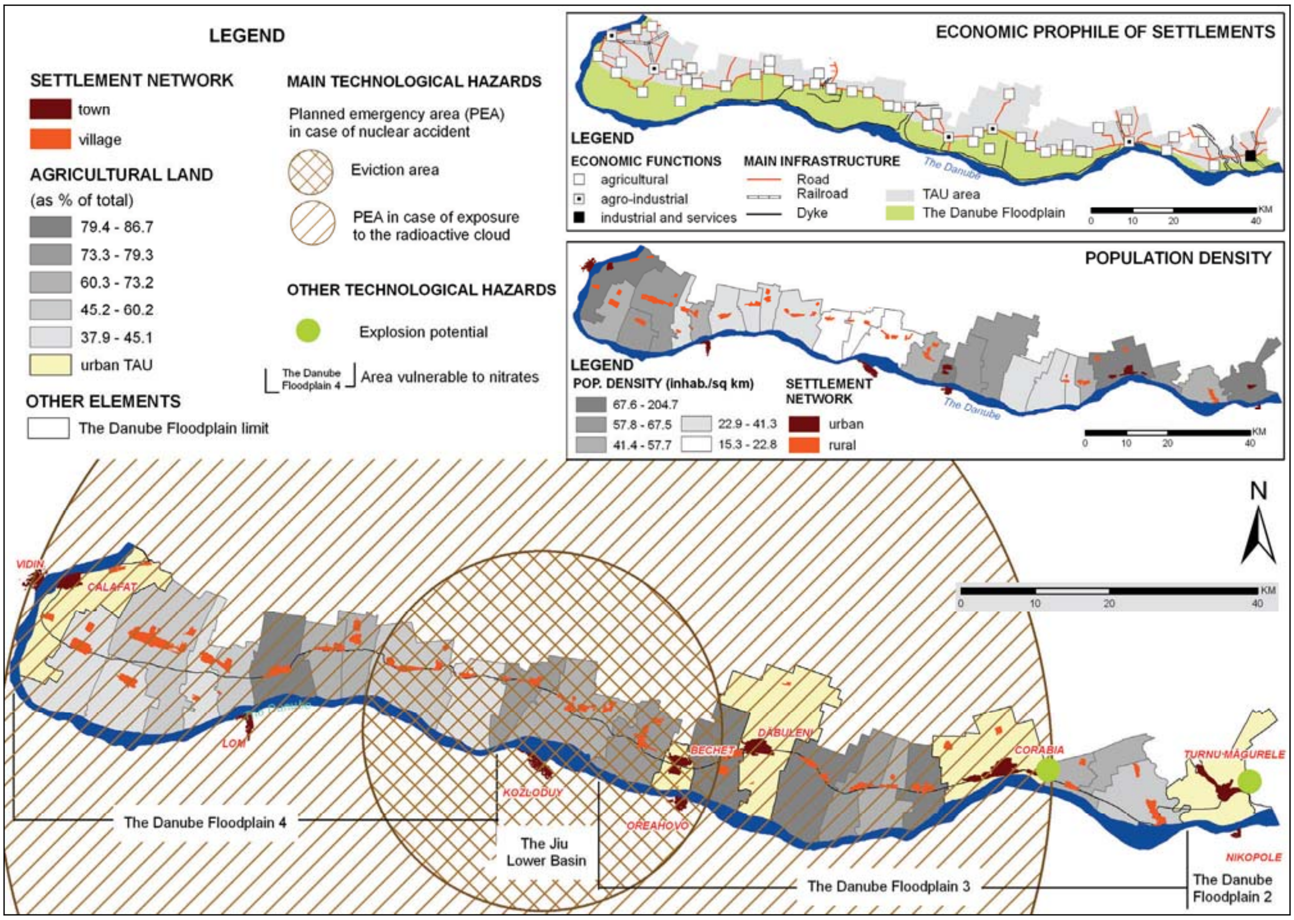

Figure 9. Main types of technological hazards within the study-area.
(Processing after National Statistics Institute, 2013; Management Plans – the Jiu, the Olt, the Argeş – the Vedea catchments, 2010; DUMITRAŞCU, 2008)

The area mostly at risk, located around Bechet town (i.e. near Kozloduy Plant), is endowed with an environmental radioactivity surveillance station/*Rom. SSRM* (included in the National Network for the Environmental Radioactivity Surveillance). Other global beta measurements, dosimetric observations and gamma spectrometric analyses are conducted by SSRM Craiova. During 2010, this latter station participated in the Programme for Monitoring the Radioactivity of Environmental Factors within the Area under the Influence of Kozloduy Plant. Periodically, there were drawn and analysed environmental samples from the area at risk, along the Danube, as well as from the area near Craiova city, for analogy. The results derived from uncultivated soil, spontaneous vegetation, and the Danube water showed the presence of just one artificial radionuclide, Cs-137, of Chernobyl origin (low concentration). The analyses of atmospheric sedimentation and aerosols pointed out that the only radioisotopes above the detection level were the natural radionuclides Be-7 and Pb-210 (no artificial elements of the sort above the minimum detection threshold of the measuring equipment) (*Raportul anual privind starea mediului în judeţul Dolj*, 2010).

2.4 Soil and groundwater contamination

Besides scarce industrial activities in the area, domestic waste that is deposited in several unauthorised places or before treatment leads to water and soil contamination. For most of the area under study, an important hazardous element is represented by industrial, construction or domestic waste. Besides rare cases (mostly represented by urban centres), the field public infrastructure is poor or inadequate. The area is poorly endowed with drinking water and sewerage installations (projects for the connection to potable network and, subsidiarily, to sewerage, are ongoing in numerous rural TAUs, but in certain cases the governmental funds linger or are suspended. The waste issue (regardless their nature, from domestic waste and those collected from public spaces to the ones resulted from demolition or sludge following purification of sewage) falls in the same context, but with an even severer state. Old waste deposits represent environmental pollution sources, as they lack the necessary endowments, but also biologic hazard sources, mostly through the action exerted by pathogen agents (*Raportul anual privind starea mediului în județul Mehedinți*, 2010). The inadequate waste management and the abandonment of residues (correlated with the lack of collection systems and with the severe economic, social and demographic issues of the area under study) induce large environmental problems and serious social-natural hazards.

The floodplain sector under analysis is included in the general context of the Romanian territory, which has been identified as area sensible to nutrients pollution (total nitrogen and phosphorus), based on the criteria listed in the *Annex II of the Directive 91/271/CEE* regarding the purification of urban wastewater. The more extended field European policy is represented by the *Nitrates Directive (91/676/CEE)*, which aims at reducing water pollution with nitrates from agricultural sources and at preventing future pollution, and which has been transposed in the Romanian legislation through *G.D. No. 964/2000* (ratifies the *Action Plan for the Protection of Water against Nitrates Pollution derived from Agricultural Sources*).

The identification of vulnerable areas was conducted by the *National Institute for Research and Development in Pedology, Agrochemistry and Environmental Protection*, along with the *"Romanian Waters" National Administration*, based on the assessment of the natural conditions (soil, terrain, climate, hydrology, hydrogeology) of the areas that have important potential of transmitting nitrates from the agricultural system to surface and underground water bodies. Thus, the areas vulnerable to nitrate pollution are represented by agricultural fields through which diffuse discharges, contributing to the pollution of soils and water. The qualitative assessment of the surface and underground waters within the vulnerable areas is conducted mainly on the basis of nitrate concentrations, which should not surpass the threshold of 50 mg/l, in accordance with the *G.D. No. 964/2000*. In 2010, most of the surface water monitoring sections located in vulnerable areas within the Jiu, the Olt and the Argeş – the Vedea catchments did not record values surpassing the threshold, while in the case of the underground waters, more than half of the monitoring sections situated in the same conditions registered values above 50 mg/l NO3.

The floodplain sector under study partially overlaps four areas designated as vulnerable to nitrate pollution: *Jiu Inferior - the Lower Jiu* (Gighera settlement), *Lunca Dunarii 4 - the Danube Floodplain 4* (Ciupercenii Noi, Desa, Poiana Mare, Piscu Vechi, Ghidici, Rast, Negoi, Catane, Bistreţ, Cârna, Măceşu de Jos and Ostroveni settlements), *Lunca Dunării 3 - the Danube Floodplain 3* (Călăraşi, Ianca, Grojdibodu, Gura Padinii, Orlea, Gârcov, Giuvareşti settlements), and *Lunca Dunării 2 - the Danube Floodplain 2* (Izlaz) (*Management Plans* - the Jiu, the Olt and the Argeş - the Vedea catchments, 2010). The agricultural land corresponding to the TAUs within the case-study area confirms their potential for nitrate pollution (Fig. 9). Thus, the agricultural surface (1065.47 sq. km within the administrative boundaries of the study-area) represents 48.09 percent of the total surface. Most of the TAUs account for values above 50 percent of the agricultural surface, the maximum being registered at the level of Orlea settlement (Olt County), with 86.70 percent.

2.5 Dam failures

Damages at dams along the Danube floodplains may have serious negative consequences on the rural settlements lying along the river. The most severe event took place during the floods of 2006. On April, 14^{th}, 2006, the liquid discharge of the Danube exceeded 14,800 cm^3/s (the highest discharge after the damming works), causing a break of about 20 metres in the dam near Catane, which later on broadened to almost 1 km. Water flooded all the precincts that had been drained, increasing the pressure on the partitioning dams and on those protecting the settlements. As a result of Ghidici-Rast-Bistreţ precincts flooding, three settlements in Dolj county- Rast, Catane and Negoi, and more than 11,000 ha of agricultural terrains were entirely damaged, as well as Plosca, Carna and Macesu de Jos settlements for the Ghidici-Rast-Bistreţ and Bistreţ-Nedeia-Jiu precincts (PLENICEANU et al., 2006).

2.6 Buried ammunition remained from the first and second world wars can still be found in Olt county, according to the county Inspectorate for Emergency Situation, in the Corabia, Islaz and Ianca neighbourhoods.

3. Increasing resilience and mitigating hazard effects

The economic and social impact of natural and technological hazards is significant most of the time, these hazards having both direct and indirect costs, triggered by the immediate loss of physical and human capital and crops, disruption of economic activities and their consequences (LAFRAMBOISE & LOKO, 2012). That is why, great importance is attached to community resilience to hazards. According to UNISDR, *resilience* is defined as *the ability of a community or a society that is exposed to hazards to resist, absorb, accommodate and recover from hazards quickly and efficiently*. Extensive research has been carried on adaptive governance, co-management and resilience (DJALANTE, 2012; BAKER, 2009; PLUMMER & ARMITAGE, 2006; ADGER et al., 2005), community resilience to natural hazards and disasters (JHA et al., 2013, NORRIS et al. 2008), social vulnerability to hazards, (GAILLARD, 2007; CUTTER et al., 2003).

Enhancing resilience of local communities is all the more necessary as during the last years the climatic hazards have intensified in the area under study. This can be done following a proper identification and prioritization of the most important needs of the area and ways to meet these needs (JHA et al., 2013). Communities in hazard-prone areas must be trained to develop their own preparedness strategies, while local authorities must integrate disaster risk management into development plans (WORLD BANK, 2013).

Community resilience is the result of four primary sets of adaptive capacities, i.e. economic development, social capital, information and communication and community competence (NORRIS et al., 2008). Since the economy of most of the area under study relies primarily on agriculture and the demographic profile testifies for a high proportion of population at risk (numerous elderly population and poor people that lack access to resources such as information, knowledge and technology (CUTTER et al., 2003), building collective resilience is quite a challenging task. The diversification of income sources is very important (ZHOU et al., 2010), as community resilience relies heavily on the diversity of economic resources, as well as their volume (NORRIS et al., 2008).

The effects of hazards must be lessened as much as possible and this may be done through mitigation measures encompassing structural and non-structural measures.

Considering that drought and floods are the main natural hazards in the Danube floodplain, structural measures may include engineering techniques, such as river embankment, construction of dams, reforestation and restoration of forest shelter-belts, setting up a building code. Great construction works within the study area were carried on during the 60's and the 70's, including flood-control dykes along the Danube and its main tributaries, partitioning levees, complex channel networks. The dimensions of the flood-control dykes (length - L, in meters and height– H, in meters) vary according to the local morphometrical features. The flood-control dykes along the Danube are built in the precincts of the following settlements: Calafat (Dyke 1: L=0.615 m, H=3.5 m; Dyke 2: L=1 km, H=4 m), Ciupercenii Noi (Dyke 1: L=240 m, h=1; Dyke 2: L=140 m, h=0.8 m; Dyke 3: L=150 m, h=0.8 m), Desa (Dyke 1: L=50 m, h=2.5 m; Dyke 2: L=150 m, h=1 m), Ianca (L= 12.8 km), Grojdibodu (L = 8 km), Gura Padinii (L = 6 km), Orlea (L=4 Km) and Corabia (L= 6.4 km; h= 4 m). The levees along the two main tributaries that the Danube receives in the area are built in the precincts of Gighera (along the Jiu: L=11 km, h=2.5 m) and of Islaz settlement (along the Olt: L=20.4 km). The following flood-protected precincts (with the corresponding included TAUs) are located within the floodplain sector under analysis: Ghidici - Rast - Bistreţ (L=18.8 km, h=6 m) - Ghidici, Rast, Negoi, Catane and Bistreţ; Bistreţ - Nedeia -Jiu (L=39.2 km, h=6 m) - Bistreţ, Cârna, Maceşu de Jos and Gighera; Jiu - Bechet - Dăbuleni (L=19.4 km, h=3 m) - Ostroveni, Bechet, Călăraşi and Dăbuleni; Lita - Seaca (L=9 km), Turnu Măgurele.

The drastic transformation of the natural flood-prone area significantly contributed to the important increase of the water flows and of the flood risk in the downstream area. Even if these negative consequences were foreseen, they were considered as an acceptable risk, taken into account the economic benefits brought by agriculture at that time. The flood occurrences during the last decade, as well as the general flood hazard supply solid grounds to question the above-mentioned decision. In case of extreme hydrological phenomena, as it was the case in 2006, certain dams were broken and catastrophic floods took place on the Romanian territory. It is highly necessary that these dams be reinforced with clay core (PLENICEANU et al., 2008). Furthermore, since the settlements located on the lower terrace were not flooded frontally, but the water advanced laterally, arriving at the rear of the settlements, surrounding, isolating and then entirely flooding them, it is highly necessary to have minute surveys along NR 67 (national road), in order to identify the natural areas which are below the maximum level of the flood from 2006 and take proper measures (PLENICEANU et al., 2006).

Apart from engineering techniques, improved environmental policies and public awareness are key factors for hazard mitigation (UNISRD, 2009). Non-structural measures, designed to keep people away from hazards and reduce the impact, are less costly and quicker to implement. They may include four categories of measures: increased preparedness, avoidance, emergency planning and management, speeding up recovery and using recovery to increase resilience (JHA et al., 2012). Soft or non-structural measures also refer to a proper early warning system. Such a system is of utmost importance in case of the floods or technological accidents at the Kozloduy plant. County Inspectorates for Emergency Situations are aware of this possibility and have developed evacuation routes for the settlements located within a 30 km range.

Raising awareness and pre-disaster education is the cornerstone for reducing risks within the natural and technological hazard-prone areas. This may be achieved by public dissemination of information on measures to mitigate the flood, drought and technological risks, targeted at authorities, builders and community leaders, through TV, radio or printed means. Open meetings at schools and community centres are also quite important for raising awareness. Messages should be targeted at the appropriate level for each interest group (JHA et al., 2012), since there are many local, rural communities, with a high share of old persons. This is the main target of the transboundary project *Natural and Technological Hazards Assessment in the Danube Floodplain. The Calafat - Vidin - Turnu Măgurele - Nikopole Sector.*

Health awareness and hygiene promotion campaigns must not be neglected. People must be educated about the necessity of potable water and how they may purify water whenever there is doubt about it being fit to drink. Plans must be drawn for potable water purification and distribution for each commune. This is of utmost importance not only in case of severe floods or other natural or technological disasters, but also on a regular basis, considering the fact that the case-study sector generally overlaps a designated area vulnerable to nitrates. In this respect, the *EU Directive 91/976/EEC*, transposed into the national legislation, states as important objectives the decrease of pollution induced by nitrates from agricultural sources (structural measures), as well as the prevention of this type of pollution (non-structural measures). The actions required in order to reduce the nitrate pollution potential in the vulnerable areas located within the floodplain sector in study must take into account the periods during which fertilizers are used, the terrain characteristics (declivity, water-saturated land, surfaces covered by water, snow or frozen, the proximity of water bodies), adequate techniques (fertilization rate and uniformity), the capacity and construction characteristics of the systems where manure is deposited. Furthermore, there are to be followed supplementary stipulations of the *Code of Good Agricultural Practice*: land use (convertible husbandry, proportion of permanent crops versus annual ones), minimum degree of vegetation coverage during certain periods, fertilization plans and records at farm level, prevention of nitrate pollution from surface discharges and percolation.

CONCLUSIONS

The hazard analysis, focusing on hydrometeorological and technological potentially catastrophic events had not only an informative character, but they were mainly conducted with the purpose of understanding the occurrence mechanism, the effects and the systemic intromissions of these natural phenomena, as well as for the improvement of the response to the dangerous phenomena.

The fight against the natural and man-induced risk phenomena implies the reduction of vulnerability (of population, infrastructure, crops, etc.). This can be realised through the reconstruction and the appropriate maintenance of the existent infrastructure and through the diversification of the economic activities.

The ecological and economic restoration of the Danube floodplain, as well as the achievement of structural and non-structural measures play a major role in this broad context represented by the environmental management and by the sustainable development of the human communities that live near the Danube.

The effects of structural measures implemented in hazard mitigation are easier to monitor, but there must be stated that this type of measures incurs great financial costs and cannot entirely eliminate the hazard risk. Moreover, they have potentially increased impact when such structures fail, as it happened in the spring of 2006.

Hazard avoidance must also be taken into consideration by any management plans, including land use planning (which must control the land use and constructions within the floodable areas), waste management and insurances of the households against the floods. Rural people need assistance for enhancing resilience to drought, heat and erosion, with particular emphasis on cropping patterns and water management in order to save their crops and improve productivity. Moreover, the results of scientific research must be adapted to each type of stakeholder and it must be integrated into their own social, economic, cultural, and environmental context. Individuals' skills and institutional knowledge and expertise are the principal resources for adapting to natural and technological hazards.

The communities living in close connection with the Danube Floodplain need, among others, information resources and could benefit from public awareness programmes or skill-building programmes, as tool to decrease their vulnerability to hazards. Dissemination of the results obtained through research and assessment and of good practices are also common non-structural measures that would help the exposed population. A serious problem to be solved in the area of interest concerns the land use planning and environmental laws and especially their enforcement, as well as the clarification of the ownership situation of the floodplain terrains, water bodies, certain constructions and equipments, etc. Public awareness is considered a key factor in effective disaster risk reduction. The population within the area of interest receives most of its information through media (generally television) and educational institutions (generally schools, where they exist). Other means to increase the public awareness are rather scarce, as there are almost no specialised information networks or centres in the rural space of the floodplain and the participation actions and the advocacy by senior public officials/community leaders is very limited or does not exist. The above-mentioned context underlines the importance of research and information projects on the hazard issue, particularly in international collaboration, as it is the case of *Romanian-Bulgarian Cross-Border Joint Natural and Technological Hazards Assessment in the Danube Floodplain. The Calafat-Vidi -Turnu Măgurele-Nikopole Sector* (*ROBUHAZ-DUN*).

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