RISK FROM NATURAL HAZARDS FOR THE ARCHAEOLOGICAL SITES ALONG BULGARIAN DANUBE BANK

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ABSTRACT
The research goal of this paper is to assess from a geospatial perspective the risk from natural hazards for the archaeological sites along Bulgarian Danube bank. On the basis of the contemporary geo-informational technologies and the related spatial-analytical methods are investigated and analyzed the main types of geo-hazards which threaten some of the most essential archaeological monuments in the investigated territory. A catalog of the existing essential archaeological monuments in North Bulgaria was created and the essential archaeological sites were categorized according the type and level of threat and from a spatial point of view. A GIS - based spatial models for assessment of the risk for specifically-chosen sites with high level of vulnerability were implemented. The results show that there are fife essential archaeological monuments along the Danube bank which are under high risk from floods, river bank erosion, landslides and other gravitation processes. Some recommendations about protection and prevention measures are proposed.

Keywords: *natural hazards, cultural heritage, risk, GIS based modeling*

INTRODUKTION

Natural hazards are between the main reasons for the damages suffered by archaeological monuments. There are direct, indirect, and secondary effects from the natural disasters which are relatively better investigated in respect of theirs influence on the social and economic infrastructure and the losses of people, capital, and materials. Very important, but still almost entirely unfamiliar aspect of the effects of the natural hazards in Bulgaria is their impact on the cultural and historic heritage as a whole and, particularly, on archaeological monuments. The larger part of these monuments is of exceptional importance to our national identity, science and education, and represents a prerequisite for the development of specialized, cultural, and education tourism in Bulgaria. The Bulgarian state holds a special responsibility for the protection of these monuments, some of which are a UNESCO-listed part of the world cultural heritage. The problem is even of greater importance heaving in mind the global climate change which is expected to cause continuous increase in the number and strength of the extreme phenomena.

STUDY AREA

The area of this investigation includes the Bulgarian bank of the Lower Danube (930-0 rkm) with lend of 472 km. The territory adjacent to the river bank includes the whole range of the Danube lowlands with an altitude up to 200 m above sea level. The archaeological sites in this area used to be exposed to the impact from different fluvial and geomorphic processes for a long time and theirs current state relates to both human and environmental history. In this particular part of the Danube River Basin these changes were significant over the time. During the Holstein Interglacial was composed the present fluvial system. After the deepening of the bottom in Dgerdap Gorge System and increasing the delta in eastward direction the river system reach till the contemporary situation. The present Danubian Delta is very young geomorphic formation with very fast development in the last 300 years. For example on a French military map of 1703 there is a very different topographical situation, where Danude Canal was divided in two branches and every of them were flowed in Black Sea throughout estuaries. The present Babadag Mountain use to be an island. Probably from the end of 18 century the southern canal was dried up and the present delta began its development around

the mouth of the northern branch, rising in the aquatory of the Black Sea. The new three present main canals of the Delta are formed in the last three centuries [1]. The dynamic of past and present erosion basis and all fluvial processes in the Lower Danube Basin influence significantly the state of the archaeological monument along the Bulgarian Danube bank. In addition there is pressure on these sites due to the current global environmental change (climate change, pollution, population and tourism, construction and transport systems) which increase the vulnerability of the archaeological heritage. In many cases the human impact on these sites like those caused from the treasure hunters is at least so dangerous for them as the pressure from natural hazards.

MATERIALS AND METHODS

Interdisciplinary approach which combines methods from different scientific fields: geography, archeology, cartography, geology, statistics, engineering sciences, etc. was implemented in this research. The risk analysis was the main methods used for delineation and estimation of the natural hazards and the level of risk for the investigated objects. GIS modeling was implemented to do a geospatial analysis and to estimate the exposure to the particular hazard of each archaeological site.

The terms "risk", "hazard" and "vulnerability" are widely used in various disciplines, especially in studies of the risk of various dangerous natural phenomena and processes. Moreover, their interpretation is often different and even when it comes to dangerous natural phenomena, we cannot say that there are common definitions and assessment approaches. In this regard, the clarification of concepts and general approach which these transdisciplinary investigations require is paramount. Modern risk studies are conducted according to a generally accepted conceptual framework within which risk is a function of hazard, exposure and vulnerability (Fig. 1).

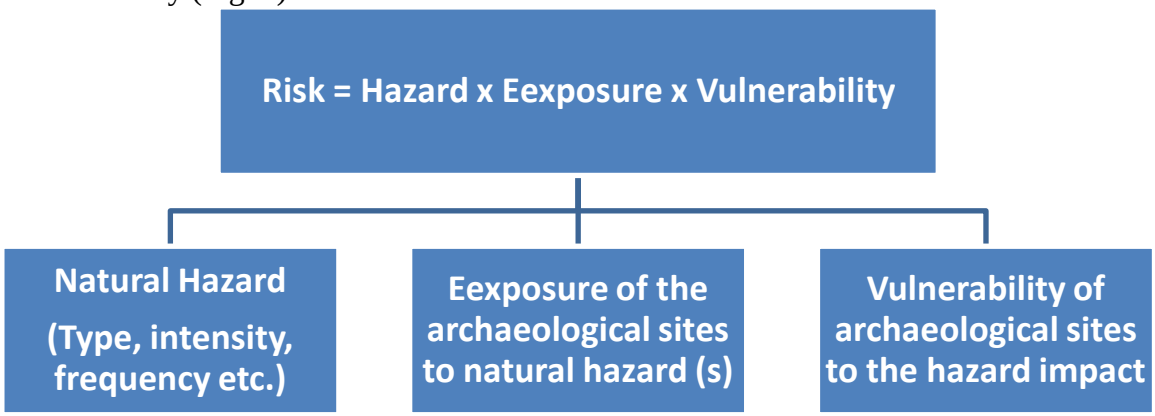


Fig. 1. Risk concepts.

Achieved is also a certain agreement among researchers about the terminology used and we will stick to the conventional terminology in our studies of the risk from natural hazards. It is of main importance to point out that the extreme geophysical events acquired nature of natural disasters only when they are realized in the environment that is perceived as that part of the geographic space in which production and the vital activity of human society takes place. Therefore it is important to emphasize that the risk of *natural disasters* exists only when the public is exposed to the impact of extreme events and unable to protect their adverse effects. In all other cases, it is a natural geophysical event with varying frequency and intensity, and not dangerous natural phenomena that can lead to disaster. For these reasons, it is right to stick to the terms "dangerous natural phenomena" or "*natural hazards*" and respectively "risk of dangerous natural phenomena" or "*risk of natural hazards*" and to avoid the use of semantically incorrect in relation to the term "natural hazards". The used terminology listed

below is internationally accepted from the United Nations [2] and it is in accordance with the chosen methodological approach:

- *Risk* is defined as "the probability of harmful consequences, or expected loss (e.g., death, injury, property damage), resulting from interactions between a given natural hazard exposure and vulnerability".
- *Hazard* is a potentially damaging physical event, phenomenon or human activity that may cause the loss of life or injury, property damage, social and economic disruption or environmental degradation.
- *Exposure* represents the density and value of people property and ecosystems located in hazard areas.
- *Vulnerability* is a set of conditions and processes resulting from physical, social, environmental and economical factors, which increase the susceptibility of a community to the impact of hazards.
- *Archaeological Heritage:* Includes all remains and objects and other traces of past times (structures, buildings, groups of buildings, developed sites, moveable or other monuments and their context) regardless of whether they are on land or under water [3].
- *Archaeological Site:* Place or group of locations, which are preserved traces of past events or human activities, to be tested (or can be explored) through archaeological research [3].
- *Monument of Culture:* All movable and immovable authentic material evidence of human presence and activities and processes in nature that have scientific and / or cultural value and has a social significance [3].

Risk analysis is performed in respect to each of its components determined by the nature of hazard, place, intensity, frequency and probability, of the dimensions of vulnerability and of the exposure. It includes the analysis of the response of the system under different scenarios for disaster realization and the ability to deal with it.

Risk assessment includes the entire process of analysis of disaster risk: availability of systematic information, hazard identification, the probability and intensity that may occur; zoning endangered areas in respect of a dangerous phenomenon, vulnerability mapping of these areas and assessment of risk and to what extend it is acceptable.

The geospatial analysis was carried out on the base of set of analytical procedures, algorithms and methods of modeling that apply when working with GIS for the creation of connections and relationships between objects and their characteristics in geographic space (ArcGIS - Kernel density function; MapInfo – Vertical Mapper Tool). The differentiation of the territory was carried out to delineate the areas corresponding to two sets of criteria: 1) Criteria for selection of dangerous phenomena threatening archaeological sites; 2) Selection criteria for model archaeological sites to be investigated in terms of particular hazards. Both sets of criteria satisfy the following conditions: *representation* of the phenomenon or object, *relevance* of the phenomenon or object and *applicability* of the methodological approach for risk analysis and assessment.

The main sources of information for the archaeological sites and for the frequency, intensity and type of the observed natural hazards were the data bases of the Ministry of Culture, National and Regional Museums of History, National Institute of Archeology, BAS, National Statistical Institute (hazard statistic data), previous investigations and projects, maps and publications, field observations and interviews with the experts from the regional museums of history. Sources of geographic (geospatial) data were digitized maps, aero-photo and satellite images, data from GPS, statistical tables, and other documents.

Selection criteria for dangerous phenomena threatening the archaeological sites according these requirements are as follow: 1) There is a genuine phenomenon manifested in the investigated region; 2)Existing hazards are demonstrated with a frequency and / or intensity, which cause or may cause damage to the archaeological sites; 3) The study of risk by phenomenon or group of phenomena have methodical and information certainty (including by developing new methods and / or building monitoring, etc.);

Selection criteria for the model archaeological sites are as follow: 1) The site is affected by actual or potential impact of one or more dangerous phenomena; 2) The site is designated as "significant" and / or representative of a region with high concentrations of significant archaeological sites; 3) There is available methods and information foe assessment of vulnerability of the site towards a hazardous phenomenon or group of phenomena.

RESULTS AND DISCUSSION

The natural hazards assessment was made based on the base of surveys in the Regional Historical Museums, expert's assessment carried out during the fieldwork on specific archaeological sites, publications and maps of natural hazards developed in our previous investigations [4].Identified as the most dangerous for the archaeological sites were the following hazards: weathering, river bank erosion, earthquakes, landslides, subsidence, flooding and rising groundwater. According to the hazard assessment the essential archaeological sites in the investigated area were affected mainly by earthquakes, loess subsidence, landslides and other gravitation processes, floods and high level of the groundwater. Earthquake hazard is estimated according the Medvedev – Shponhoyer – Carnik (MSC) intensity scale as high as VII degree between the inflow of the rivers Timok and Iskar in Danube and up to VIII eastward. This scale is descriptive and indicates the effect of the earthquakes on the Earth surface and the consequences generated by them.

A specific feature for the investigated area is the diversity of types and of the thickness of loess formations all over the Danube Plain. Typical geomorphic forms and processes there are subsidence and loess dish-like forms, loess walls, landslides and tunnels. The archaeological sites situated in areas prone to these hazards are often very badly affected by them, as the ancient city Raciaria near to the village of Archar, (Pic. 1 - 3).

There are favourable conditions for activation of different hazardous gravitation processes along the most of the Danube bank. It is due to different factors between which the high right Danube shore, the type of rock foundation, river bank erosion and climate conditions are of main importance. At the same time these processes have really very destructive effect on the archaeological sites in the study area.

For the period of 50 years (1950 – 2000) there were registered more than 15 catastrophic landslides with volume of more than 10 million m^3 [5]. Most of them are observed in western part of the Bulgarian Danube shore. The most dangerous landslides are concentrated between towns of Dunavtsi and Oriahovo and in the area of Tutrakan and Nikopol where are concentrated also numerous of essential archaeological sites.

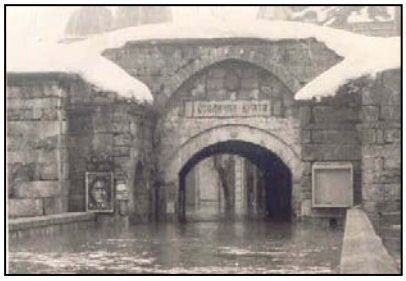
Picture 1. Raciaria

Picture 2. Raciaria

Picture 3. Raciaria

The earthquake hazard in combination of the loess formations and favourable prerequisites for landslides result in a higher level of hazard pressure in this geographical region.

In addition to this the river bank is permanently affected by erosion, river rising and floods. The last catastrophic flood in Lower Danube Basin was in April 17-19, 2006. The river discharge at Vidin on April 17 is 15 800 m3/s. Devastating floods in Vidin are registered also in the years 1895, (15 900 m3/s), 1972, 1838, 1897 and in March 4-12, 1942 (Pic. 4-6).



Picture 1. Vidin, March, 1942

Picture 2. Vidin, March, 1942

Picture 3. Vidin, March, 1942

(Source: Regional Museum of History, Vidin)

The water level reaches its highest values recorded ever at cities of: Ruse (879 cm), Vidin (968 cm), Oriahovo (740 cm), Kozloduy (815 cm) [6]. The critical water levels were exceeded with 15 to 40 cm in many parts of the river bank and significant material losses were cause in the settlements situated over the floodplain, including the town of Vidin and the fortress "Baba Vida". The area exposed to higher potential flood hazard is delineated by MapInfo Vertical Mapper Tool shown on figure 2. It gives good visualization of the threatened areas and provide basis for spatial analysis of the flood risk for each one of the archaeological sites situated around Vidin, Archar and Lom (Fig. 2 and 3). However the existing system of dykes plays important protective role in the region.

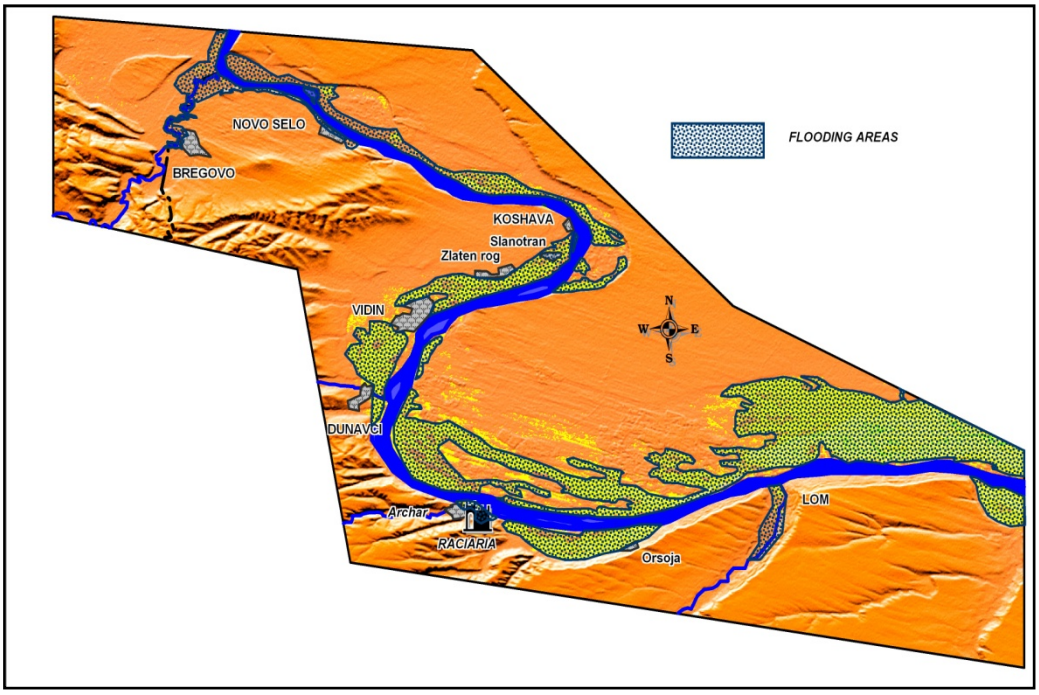


Fig. 2. Floodplain area exposed to higher flood hazard between towns of Lom and Novo Selo.

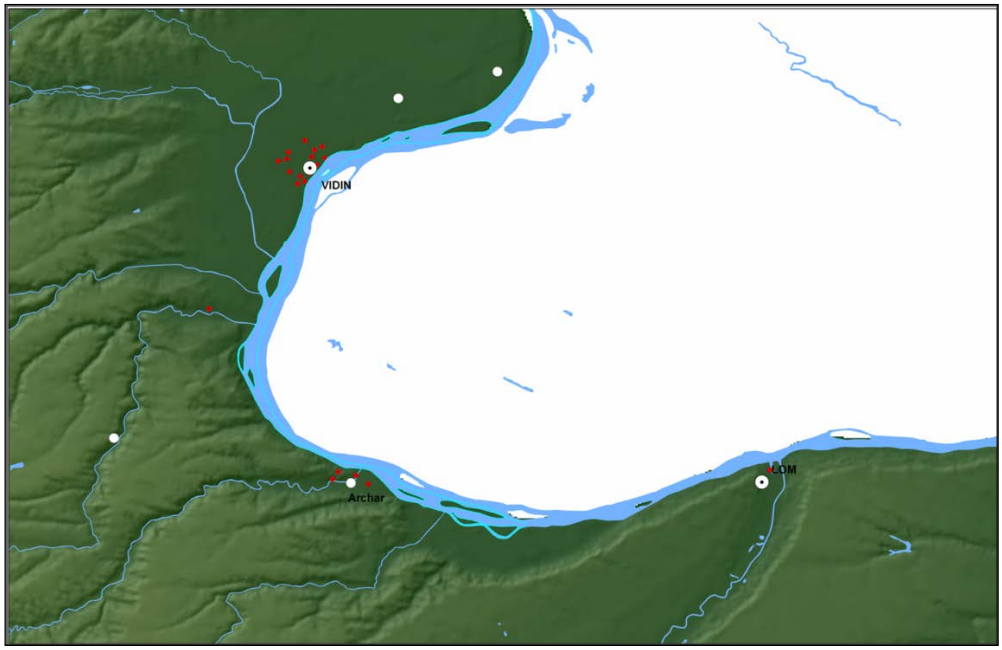


Fig. 3. Sites with high concentration of essential archaeological monuments in western part of Bulgarian Danube floodplain

Although the fact that vast areas of the investigated territory are prone of different extend to the range of hazards mentioned above not all archaeological sites in these areas are equally affected or threatened. Identification of the endangered essential archeological monuments within the zones of natural hazards and integration of both the data bases for natural hazards and for essential archaeological sites were carried out through consecutive overlay of layers with spatially referenced data (Fig. 4). For this reason overlaying spatial-analytical operations are used, which allow the spatial identification and "separation" of the areas, which indicate coincidence of localizations of essential archeological monuments and conditions for impact of natural hazards. On the basis of these analytical operations the key areas under high risk from natural hazards were determined. From totally 467 essential archaeological sites in the country only 4,71% are situated in the investigated territory. The study area is characterized by low to medium density of archaeological sites [7] and they have a linear distribution along the Danube bank. As results of the risk analysis and assessment in these areas were selected five archaeological sites which are exposed to very high environmental risk and are completely or partly destroyed by them or it is just about to happen in near future. Urgent rescue measures have to be implemented in those archaeological sites where it is still possible (Table 1).

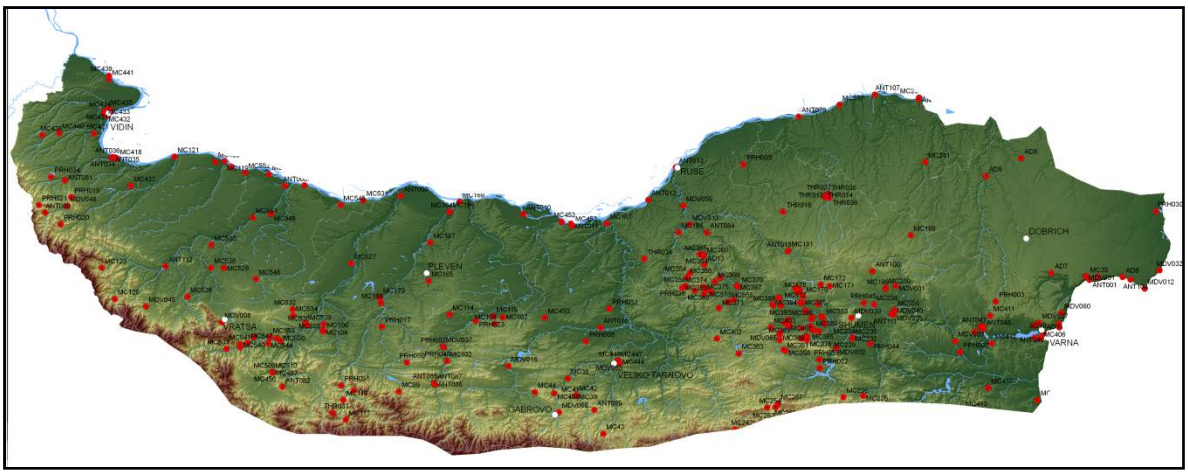


Fig. 4. Spatial distribution of essential archaeological sites in North Bulgaria [11].

Table 1. Archaeological sites situated along the Danube bank and heavily affected by natural hazards.

Archaeological sites	Location	Caused damages
"Dorticum" castle	v. Vrav, Vidin	40 m of the river bank are lost from erosion
"Quintodiumum" castle	Belene – 6 km SE	Partly destroyed from the Danube water
"Valeriana castel"	v. Dolni Vadin, Oriahovo	Destroyed by gravitation processes in the loss deposits
"Apiaria fortress"	v.Riahovo, Slivo Pole	Completely destroyed from Danube bank erosion
"Prehistory village"	v. Malak Preslavets, Glavinitsa	Completely destroyed from landslide

CONCLUSIONS

Natural disasters risk analysis and assessment in the investigated region shows that the archaeological sites along Bulgarian Danube bank are exposed to the combined effect of different hazards with varying intensity and destructive potential. Often the effect of the impact of natural disasters cannot be clearly distinguished from the effects of anthropogenic pressure, pollution and various other influences associated with global change in general. However, the impact of certain groups of natural disasters such as flooding, erosion, landslides and other gravitational processes is dominant in coastal areas. Through the use of geo-information technologies and opportunities for spatial analysis in GIS study of environmental risk can be carried out successfully on a regional basis. This would allow not only to assess existing risk for the archeological sites, but also to implement prevention practices from sites in areas with similar problems, but also to provide potential adverse impacts where they do not yet have shown.

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