HYDROLOGICAL FLOOD RISK ASSESSMENT FOR CEATALCHIOI LOCALITY, DANUBE DELTA

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Abstract. The paper presents a method to assess flood risk for a village in the Danube Delta. The Danube Delta was declared a Ramsar site in 1991 (Convention on Wetlands of International Importance, called the Ramsar Convention, is an intergovernmental treaty which provides the framework for national action and international cooperation for the conservation and rational use of wetlands and their resources). This delta is one of the largest area of wetlands in Europe and has the largest compact reed surface on the continent. In 1992 Danube Delta was declared a Biosphere Reserve, having two main features the rich biodiversity and the presence of human communities. Human communities in the Danube Delta are represented mainly by rural settlements (except Sulina, in fact, the only city in the delta). These localities are at risk from flooding as their location is in the vicinity of the watercourse. Flood risk has little significance without taking into analysis the anthropic component. Each village has its specificity in many respects, including the flood. Flood risk assessment which takes into account the fact that it is directly proportional with hazard and vulnerability. The method by which the risk calculation is based on the application of GIS techniques (Geographical Information Systems) in revealing hazard and vulnerability. As a result, this paper aims to obtain flood risk map for the area of the Ceatachioi village. The result of this work is useful to policy makers to draw up action plans to reduce and even eliminate the risk and the effects of floods. These plans may include structural and/or non-structural measures.

Keywords: *Danube Delta, flood hazard, flood vulnerability, flood risk*

1. **Introduction**

Ceatalchioi is a rural locality situated on the right bank of Chilia Branch (in the Danube Delta). This village has 296 inhabitants (according to the Population and Housing Census (PHC), 2011) (Fig. 1) .

The need to study the risk lies in the fact that in the last 20 years there has been an increase in extreme weather and water events because of climate change caused by humans. For example may be given the latest extreme hydrological events. The first notable event was linked to hydrological low water levels of the Danube River in 2003, when at Ceatal Izmail recorded value 0.737 m above Black Sea–Sulina level reference (rMNS) on 6 September 2003. Minimum liquid discharge was recorded the day before and its value was 2,060 m3/s. The second event was particularly hydrological high water levels of the Danube River. In 2006 , April 26-27 , at Ceatal Izmail , there was a water level of 5.4 m over the rMNS and an water discharge about 16,440 m3/s (April 26 there was a level of 4.93 m rMNS at Tulcea station) . A third important hydrological event refers to the high water levels of the Danube in

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2010: at Isaccea on July 6 , was recorded level of 6 m over rMNSm and 4.95 m in Tulcea over rMNS with 2 cm more than in 2006.

Extreme events (which occurs with a higher frequency) show the presence of an imbalance created over time between different components of geosystems. "B. V. Soceava identifies geosystem as: an open system, a whole composed of interrelated elements of nature, subject to its laws. He suffers from the most diverse influences of human society that turns its entirety and the whole system considerably. These influences affect the structure of natural processes and thus provide a new quality for geosystems "(Rosu, 1987). After many years regarding geosystem, the concept has changed. Today, the geosystem is "a territorial unit, functional, with its components (relief , water, climate, vegetation , soil, man and his activities etc.) are structured systemic (subsystems) interacting each other (through the exchange of matter and energy) and with the adjacent geosystems" (Ielenicz, 2000). Man and his activities constitute elements of geosystem. Man can not be treated as an external factor of geosystem , but as part of the biosphere (florosfera, faunosfera, antroposfera) (Romanescu, 1995, 2005). Sociogeosistemul, as a new form of organization of matter is in constant transformation (Donisa, 1977).

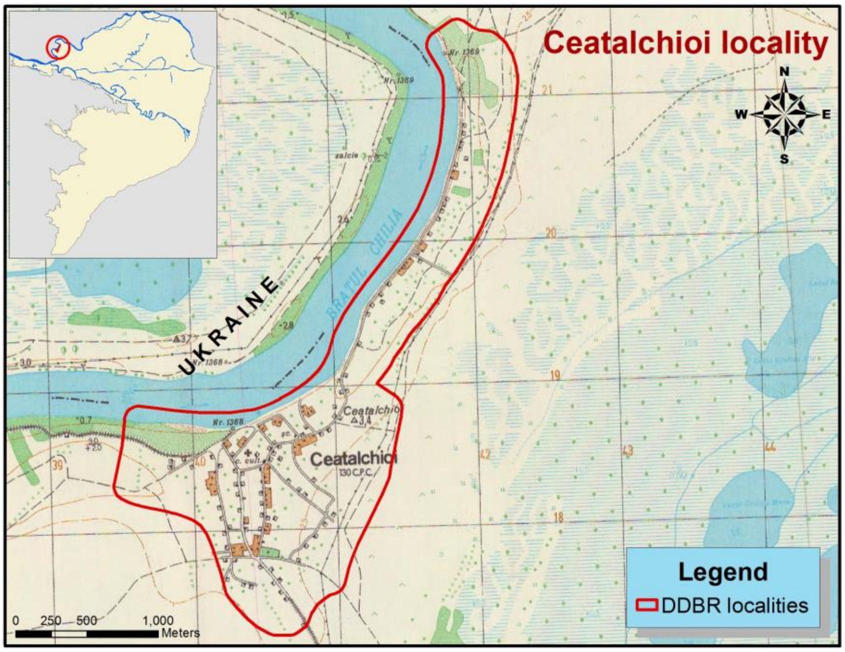

Figure 1: Location of Ceatalchioi locality

The term risk is considering anthropic element. Defining and assessing these risks is done with direct and indirect monitoring of the condition of human society. In the absence of human society changes "risk" is nothing more than forms of movement of a balance in one direction or another, fact which is very common in natural systems: changing seasons, increased water levels of rivers and decrease, the transition from day to night and back etc. These are examples of balance movements in one way or another, within certain defined tolerances and a predictable cycle. A disruption of this equilibrium would inevitably lead to the development of risk: for example, if a part of the globe such as at night one hour longer than normal and on the other part day would be shorter with one hour than normal. Risks can be associated with many phenomena and processes of nature.

Depending on how the event are its can be divided into many hydrological risks: the risk of floods and flood, hydrological risk associated minimum flow, risk excess moisture hydrological risk phenomena induced by lowering the water temperature, the risk of increasing ocean levels, tsunami and other marine phenomena affecting the coastal zone (waves , seismic etc.), risk of lowering the groundwater and land subsidence, chemical overload risk of surface water and groundwater, risk of overload of groundwater solid material; risk of morphological changes, seawater intrusion risk on the main river mouths etc.(Romanescu, 2009) .

Risk directly affects human society, is a notion that can not be attributed to any other components of the environment without involving socio-economic system. It is therefore very useful in the analysis, especially risk assessment to consider converting all vulnerabilities in the same unit to be able to sum vulnerability. This amount is useful in representing the true image as vulnerability to risk hydrological study area.

The simplest definition of risk is that risk is “the product of hazard and vulnerability" (Romanescu, 2009, Stanga, 2007). Risk is a quadratic function of hazard and vulnerability. Graphical representation of it shows that it is a second-order exponential function of hazard and vulnerability (Romanescu, 2009 , Stanga, 2007).

Phenomena of flooding risk are some of the most common hazards that have direct impact on the population. Therefore there can be many other examples and processes that have occurred recently (Grecu, 2009). A flood is caused by an excess of water that exceeds the carrying capacity of the minor bed and therefore flows into the floodplain covering land areas that usually are not affected by increases in medium or low levels (Grecu, 2009). A simple and comprehensive definition formulated Ward (1978) says that: a flood is "a body of water that covers land that is normally emerged."

2. **Materials and methods**

The first set of data used to determine hazard is the Digital Terrain Model (DTM). The model for the study area was developed using LIDAR data processing (Light Detection and Ranging). LIDAR is a modern method of purchasing data series with a collection system that provides 3D information for an area of interest or area involved in the study. They are useful for mapping land surface, vegetation, corridors and building 3D maps (Young, 2011). The LiDAR has a beam source inside of aircraft which flies over the investigated area. Waves are sent to the terrestrial surface are electromagnetic type. When the beam meets area there is produced a reflecting back response the source, where it is present also a receiver. There are some calculation for time spent between transmission and reception of light from source to receiver, and this time is turned to distance in order to reveal the elevation (Z coordinate). All records are stored in text files (.txt).

Files of .txt type were large, each file having registered about 9.5 million points, with all classes of surfaces and all responses recorded from the same area. The size of each file came to be between 330 Mb and 400 Mb. To work with these files should eliminate spike type errors. This removal was performed automatically by running a small set of commands in a programming language. The final points were automatically selected for each class: ground surface, surface objects on the ground. To develop the DTM there were used only points falling within the category of the ground surface. These files were loaded into specialized software for Geographic Information Systems (GIS) (in this case ArcGIS). The program recognizes the special.txt file type structure and produces through a command in ArcCatalog .shp file type. Files of .shp type are "files with different geometry (point, line, and polygon)"

(Mierla, 2013). In this case it was used point geometric type. For each point was assigned a pair of x, y and z coordinates, resulting in a specific file for GIS environment (Fig.2).

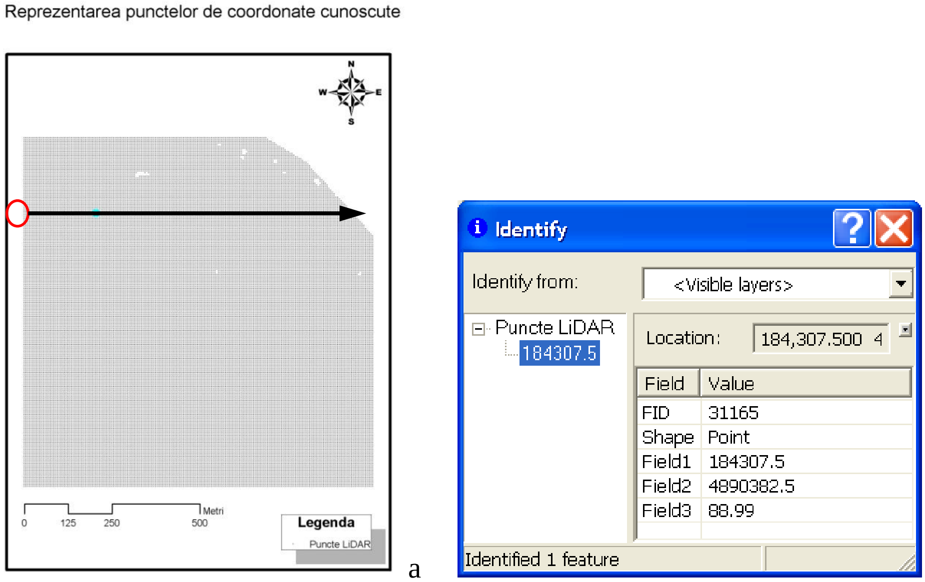

Figure 2: Graphical representation of the .shp file type (a - known coordinate cloud points, b - information about a point froma cloud of points: Field1 - coordinate x, Field2 - coordinate y and Field3 - coordinate z)

The points cloud, resulted from LiDAR data collection is sufficient to develop a DTM for a site region. The next step is to interpolate values of these points to obtain a continuous surface. As often as they are the points do not form a surface. Interpolation is very important since it may result in a method and another method can lead to similar results, but with some differences. Most important types of interpolation are: IDW (Inverse Distance Weighted), Spline (polynomial function), Kriging, PointInterp and Natural Neighbor.

IDW function should be used when the set of points is dense enough to capture the magnitude of the change required for local area analysis. IDW determine the cell values using a set of weighted linear combination of outlets. Weight is assigned based on the distance from a point of entry and exit from the cell. The greater the distance, the smaller the influence of the cell on the output value is. In addition to the DTM were used data regarding hydric component namely Danube water levels at gauging stations in the delta . These data have been selected to represent two extreme events: minimum water levels in 2003 and maximum water levels since 2006. To create water surfaces in the two cases mentioned above were the data were interpolated taking into account the data from each gauging station. Data interpolation was endorsed by correlation coefficients between hydrometric data (levels) from various gauging stations in the Danube Delta.

For the lowest historical water levels from 2003, from Izmail and Padina Ceatal stations, there is a very good correlation r^2 over 0.99 (Fig. 3). The very good correlation is due to the reduced distance between the two stations. The high waters of 2006 recorded at hydrometric stations Ceatal Izmail and Padina , have a very good correlation r^2 over 0.96 (Fig. 4). Correlation between hydrometric data expresses that they are interrelated and can generate more realistic surface actually exploited later in this paper. Correlation coefficients between the low water levels from 2003 (r2 = 0.9933) and high water levels from 2006 (r2 = 0.9676) have a slightly difference. This difference can be explained by the following reason: the water is fairly shallow and the water follows the thalweg of Chilia Arm were hydrometer station are located along , so the water which went through hydrometric station from Ceatal Izmail reach in higher proportion to hydrometric station Padina. In the case of high water (from 2006) a higher percentage of water was “lost" in the way to the other hydrometric station. This “loss” can be explained by the evaporation of seepage in dams, directing to other water ways etc.

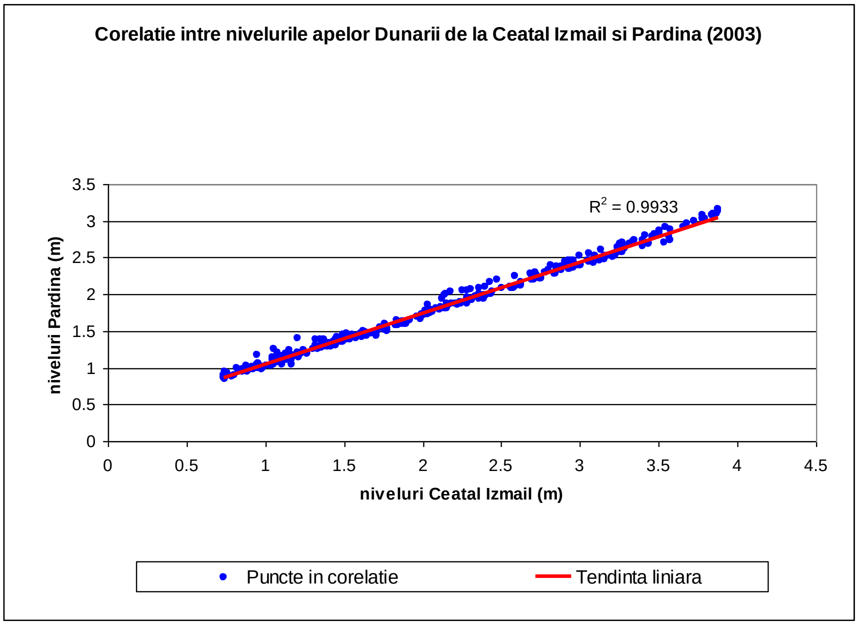

Figure 3: Correlation plot between levels values at Ceatal Izmail gauging stations and Padina station for 2003

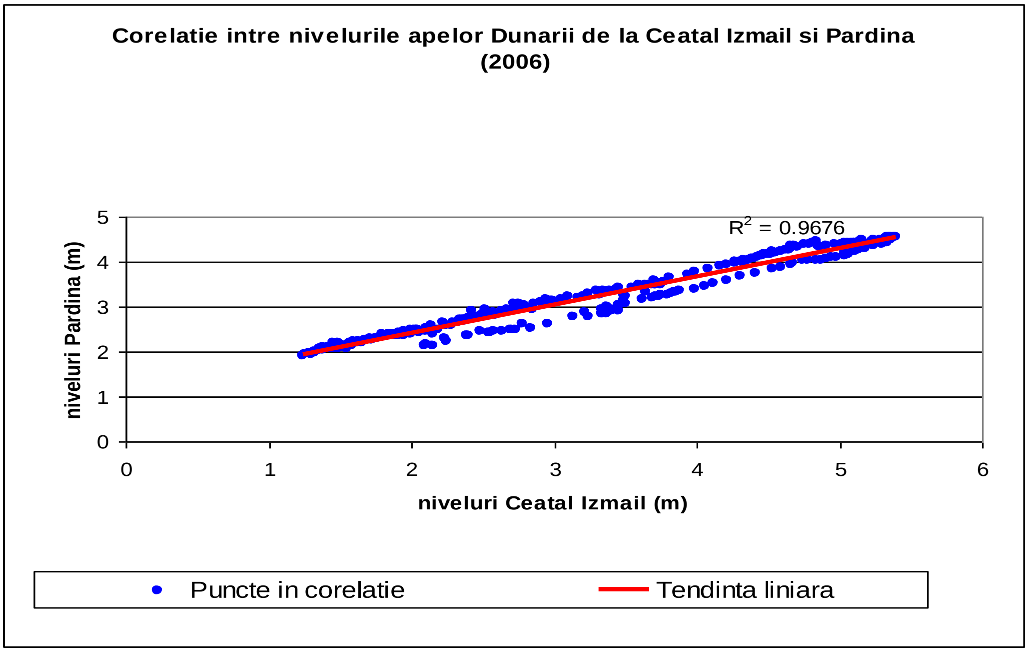

Figure 4: Correlation plot between levels values at Ceatal Izmail gauging stations and Padina station for 2006

Once surfaces created (datasets) for high and low water levels it could be created dataset of water levels magnitude by the differential process between high water levels and low water levels. Making the difference between the Digital Terrain Model and the high water levels surface it was obtained a data set with flood water depth after selecting only values below zero.

3. **Results and discussions**

The concept of risk combines the magnitude of the impact the likelihood of their occurrence, which captures the uncertainty in the processes underlying the extreme event, exposure, sensitivity and adaptation (Schneider et al., 2007)

From all hydrological risks, those related to floods have special treatment, in the sense of that at the European level has been issued stipulating concrete actions to determine the flood risk: the European Commission Floods Directive. European Commission Floods Directive (OJEU, 2007) foresees creation of flood risk maps for all river basins and sub-basins with potential significant flood risk in Europe. The most common approach is to define flood risk definition that risk is the product of hazard, namely physical and statistical aspects of real flood (return period flood extent and depth of flooding water) and vulnerability (exposure of human lives and flood values and sensitivity values at risk susceptible to suffer flood damage) (Mileti 1999 Merz, Thieken, 2004). Definition is adopted by Floods Directive (EU, 2007).

By combining the amplitude of water levels and flood water depth it was revealed one component of the risk, the hazard to floods (Fig. 5).

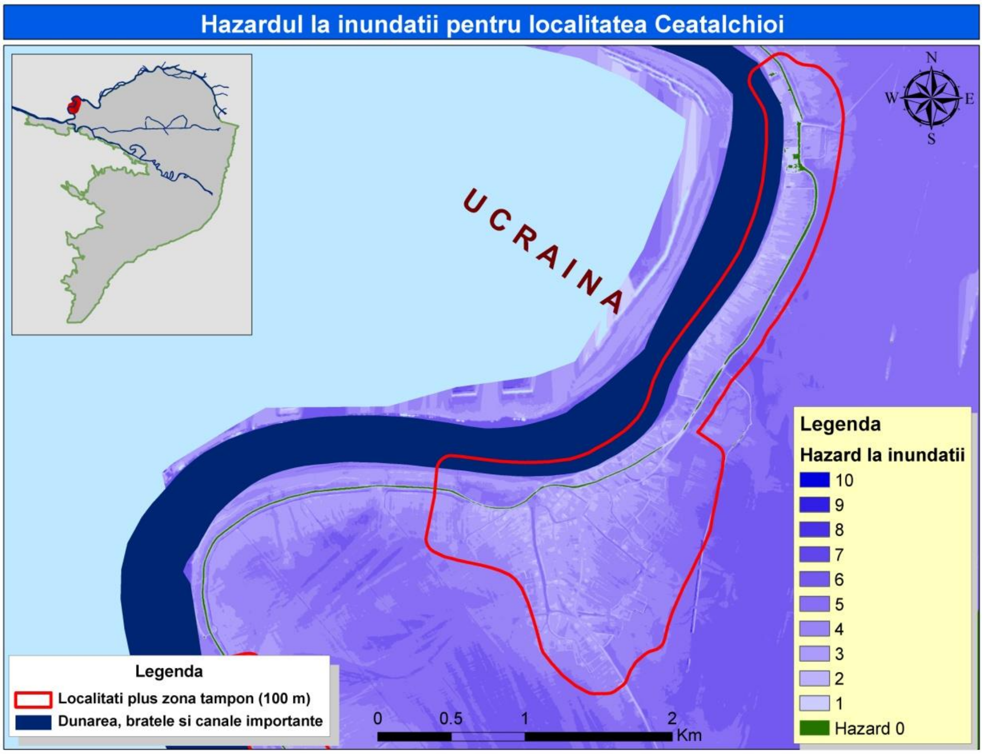

Figure 5: Floods Hazard Map for the Ceatalchioi locality

According to the map from Figure 5 , the center of the village Ceatalchioi has a hazard class 1 , which is a very good insurance . Floods can occur only at the highest levels, when the defense dam may be broken because of poor management. Across the entire territory of the village studied it can be seen that there are hazard classes 2, 3 and 4.

The second risk component is the vulnerability. A first definition of it is given by the Explanatory Dictionary of the Romanian Language , which is presented as " the property of an entity to be vulnerable " (Academia Romana, 1975). To be vulnerable is to be easily affected parties to have sensitive weaknesses before an external factor.

There have been tried many definitions of vulnerability in relation to extreme natural phenomena. In 1991 UNDRO defined vulnerability as "the degree of loss to a given element or set of elements at risk resulting from the occurrence of a natural phenomenon of a given magnitude and expressed on a scale from 0 (no damage) 1 (total damage)" (UNDRO , 1991). It is a definition that focuses on potential harm and can be considered a vulnerability scale.
The vulnerability is "characteristic of an individual or group with regard to their ability to predict, to face and to resist and recover from the impact of a hazard" (Blaikie et al., 1994). It is a definition that focuses on the anthropogenic component of vulnerability. Risk or vulnerability automatically devolves upon directly or indirectly anthropogenic component. Man is the only creature that does not comply, from the beginning; human kind did not revere the "determination" of the living environment. Unlike other creatures, man does not adapt to the environment it tries to adapt the environment to the special needs and requirements.

The vulnerability is "a human condition or process resulting from physical, social, economic and environmental results, that determine the likelihood and extent of damage to the impact of a particular hazard" (UNDP, 2004). It underlines the importance of anthropogenic component.

The vulnerability of the environment is seen through the human component parts. Vulnerability assessment has a high dose of homocentrism which inevitably leads to a high or low dose of subjectivity. Subjectivity is given to all items that are considered to provide a complete picture of vulnerability. In vulnerability researching to flood of the village was considered LPIS dataset (Land Parcel Identification System) . The data set was created under the direction of the Payments and Intervention in Agriculture (APIA). The system is used widely in Europe and aims to identify land use using orthophotos or other aerial images. In some cases there can be used also high resolution satellite images. From this data set were extracted only intersecting polygons with locality surface, plus another 100 m buffer. Settlement contour is extracted from the Corine Land Cover data set. Extracting parcels from the LPIS data set within localities was performed using command intersection. Following this extraction resulted polygons of different land uses (Table 1).

Some polygons have two uses of the land. The Ceatalchioi locality vulnerability is presented in Figure 6. For any land use which requires the existence of households with buildings the vulnerability class is highest (5): 0 - lack of vulnerability; 5 - maximum vulnerability. Vulnerability class 4 was attributed to the entire utilities field represented by agricultural units. The only cases where arable land is classified in Class 3 are the permanent pasture. Belong to the same class the ways of communication (roads). Floods can disrupt communication on input-output system. Value 2 of vulnerability has been assigned to permanent pasture because they recover quickly after the flooding, and forest vegetation, shrubs and hedges also. Gravel areas or dumps are not particularly vulnerable because they are not used directly. They can become a problem when flood waters change the morphology of dumps (class of vulnerability 2). Unproductive land, covered with reeds, reeds or other water-loving plant species falls within vulnerability class 1. Plants are adapted to the environment of excess moisture. Canals and ponds are not vulnerable, 0, because they are permanently covered with water.

Table 1: Classes of vulnerability for met polygons

Nr.	Land use 1	Land use 2	Class of vulnerability
1	Courts, constructions		5
2	Courts, constructions	Arable land	5
3	Courts, constructions	Permanent pasture	5
4	Courts, constructions	Mixt	5
5	Courts, constructions	Vineyards	5
6	Roads		4
7	Still waters		0
8	Unproductive lands covered with reeds or rushes, marshy vegetation		1
9	Running waters		0
10	Bogs and fens		1
11	Forest vegetation, shrubs, bushes		2
12	Gravel, dumps		2
13	Permanent pasture		2
14	Permanent pasture	Arable land	3
15	Permanent pasture	Mixt	2
16	Arable land		4
17	Arable land	Permanent pasture	3
18	Arable land	Permanent crops other than vines: orchards	4
19	Arable land	Mixt	4

Definitions applied to natural risks are confused with the terms of hazard and vulnerability. Hazard refers to a source of danger or, alternatively, to a risk which may result. The difference between the concepts of hazard and risk is that most risk definitions include explicitly the probability or possibility of an undesirable event. Vulnerability refers to the potential consequences if an undesirable event (Jonkman, 2007).

A risk assessment should include the interaction between the nature of the event (subject) and characteristics of the population or area at risk (objects) (Green et al., 2000, 2008). Studying only risk population without taking into account the characteristics of floods, involves accepting the fact that the entire community is exposed to the same level of vulnerability, independently of the type and magnitude of the hazard. If the analysis is focused only on flood hydrology studies, it is reduced to a conventional assessment of flood hazard. In this case the act of two components is required: the physical (hydrologic and hydraulic) and the socio-economic one (Cancado et al., 2008).

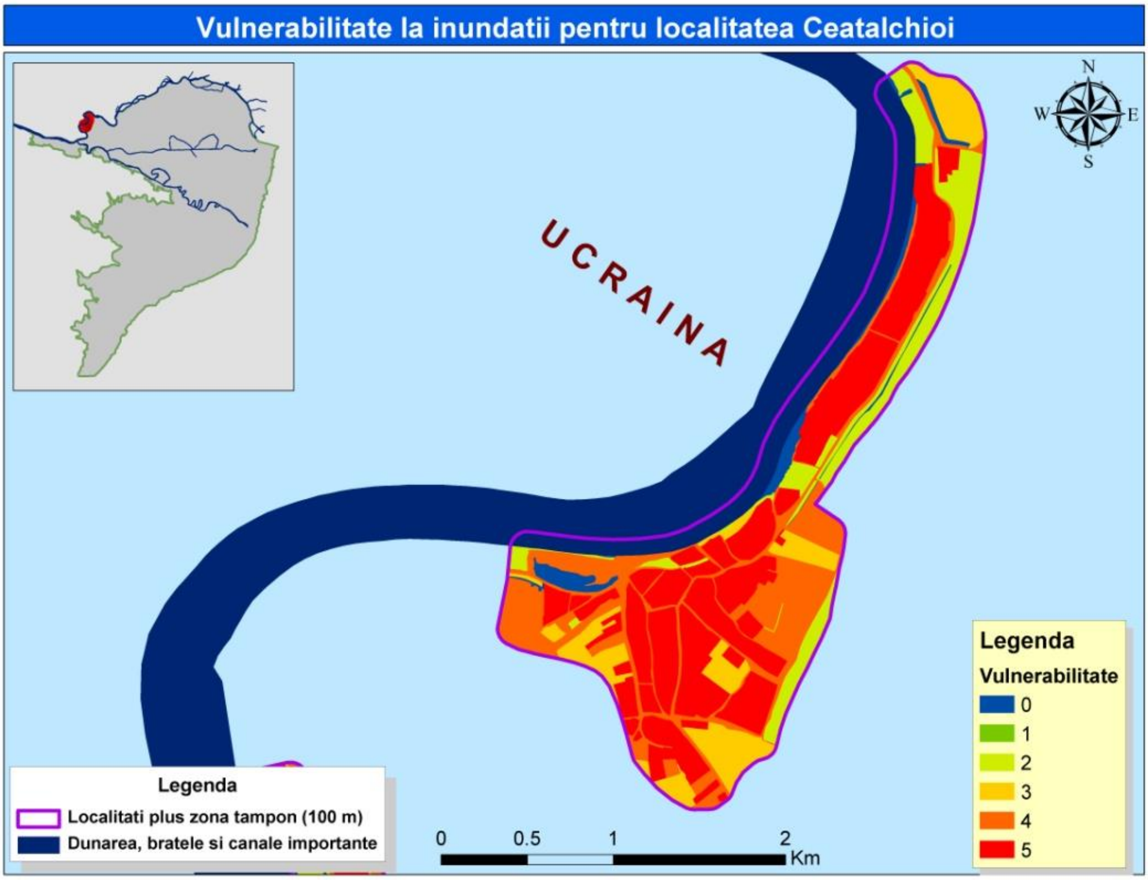

Figure 6: Vulnerability Classes to flood Map for Ceatalchioi locality

Flood risk can be described , analyzed and researched if taken into account the data on risk moving component (the waters and its flood default characteristics) , and the passive component of the risk (vulnerable elements very often depend on anthropogenic component). The dynamic component is studied in terms of two mainly parameters: the amplitude of water levels and the flood water depth. For research amplitude were considered two extreme situations: very low water levels, and maximum water levels. To determine the depth of flood water was used Digital terrain Model (DTM). Data set describing the flood hazard in the study area is filled with hydrological information. For passive component assessment there were used polygon data with information on land cover for each polygon. With the two sets of data, one for the representation of hazard, and the other representing the vulnerability elements throughout the village, there can be performed the flood risk assessment (Figure7).

Areas with very low risk from flooding (class 1) are often in the Ceatalchioi village and they are found only in the highest points of the river banks (Figure 7).

The southern part of the village falls within the middle flood risk classes (4, 5 and 6). High flood risk areas are situated farther from the main water course. High-risk areas are found in the inner part of the levee, where the altitudes are lower (Figure 8). Surfaces are distributed chaotically: classes 1 and 3 have large areas (over 146 ha), the average flood risk classes 4 and 5 are over 151 ha. High risk classes (7, 8, 9 and 10) are represented by small areas of land (1.56 ha).

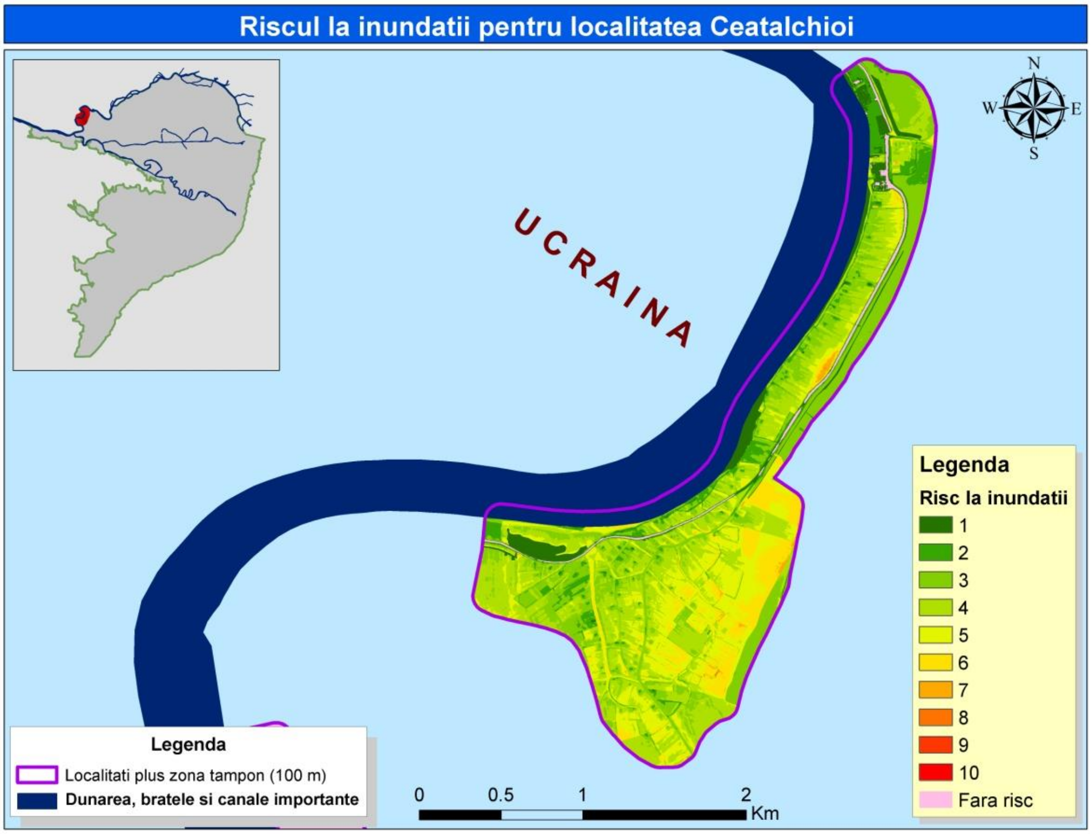

Figure 7: Flood Risk Map for Ceatalchioi locality

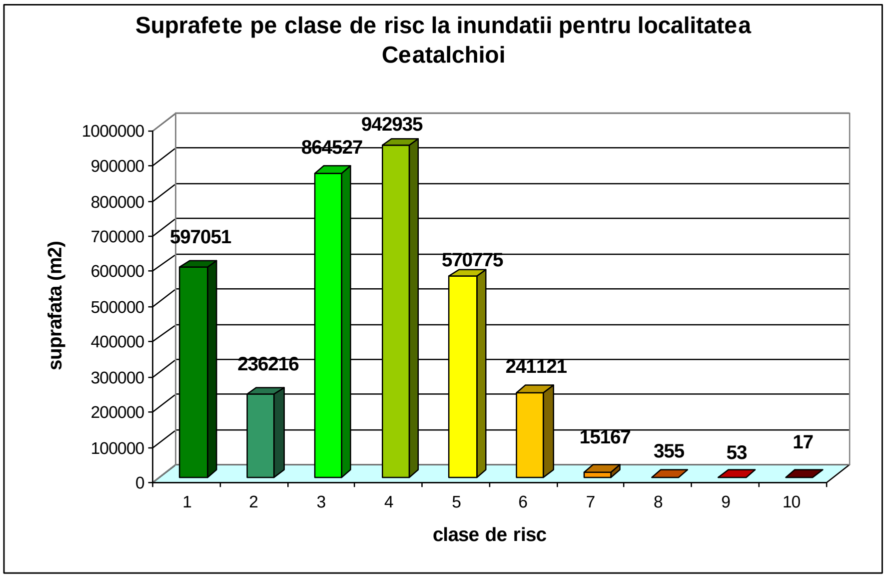

Figure 8: Areas of flood risk classes for Ceatalchioi locality

Conclusions

Ceatalchioi flood hazard area is present in low flood hazard classes, but includes the entire village.

Vulnerability to localities in the fluvial delta is related to the surface, the number of inhabitants, but especially is related to the use of the land and its arrangement.

Ceatlachioi village has a core area that does not follow the stream bank and a newer side that follows strictly the Chilia Arm bank.

Ceatalchioi locality has a high flood risk due to the hovering in the Western part of the Delta where the hazard is high given the amplitude levels of the Danube.

To reduce flood risk it can be tried one of the followings: hazard reduction, reducing vulnerability, reducing both simultaneously.

Acknowledgement

The data regarding Digital Terrain Model (obtained through LiDAR techniques) was made within the Project *Development of a high resolution digital cartographic support necessary for implementation of plans, strategies and management schemes in the Danube Delta Biosphere Reserve – CARTODD*, financed by European Union through Romanian Government with Structural Funds (POS MEDIU).

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