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USE OF GIS TECHNOLOGY IN FLOOD RISK ANALYSIS. CASE STUDY MILA 23 LOCALITY FROM THE DANUBE DELTA

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Abstract
Floods are phenomena that occur quite often in the deltaic space, with an increased impact on the environment, localities on the water course, human health and economic activity. This paper presents flood risk analysis using GIS specialization programs for a vulnerable area in the Danube Delta. The target area of this study is shown in Figure 1. The results show the areas where water can reach quickly in the event of heavy precipitations from rains or behind the protection dam failure caused by a strong flash flood. The results are presented as digital maps processed in GIS software that shows the vulnerable flood areas in Mila 23 locality. The general information base used in the processing of all data is the digital terrain model with a meaningful content of land configuration information. Flood risk is a subject of great concern to researchers, in recent decades the Danube Delta has been beset by numerous natural hazards, of these the floods are the ones that most often manifest.

Keywords: flood risk, Danube Delta, vulnerability

1. INTRODUCTION

The Danube has shown geopolitical and geostrategic interest from antiquity to the present day. Throughout this period, the Danube has been a border between empires and states, a communication channel used for commercial or military purposes, a settlement area of human communities with rich natural resources, a zone with direct or indirect hydropower potential. Viewed from the Tulcea Hills, the Danube Delta appears as a stretch of greenery crossed by silver tufts. According to the specialized literature, the Danube Delta is the territory between the first bifurcation of the Danube (Ceatalul Chiliei), bordered to the east by the Black Sea coast, north of the Chilia branch and south of the Razim - Sinoie lake complex. The Danube Delta is the largest part of the reserve and has a total area of 4178 km^2, most of which is found on the territory of Romania, ie 3510 km^2, representing about 82%, the rest is on the left side of the Chilia branch, including its secondary delta, in Ukraine.

The Danube Delta is the youngest geographic region of Romania, with a distinct individuality between the deltas of Europe and the whole world. Located in the North-West Black Sea Basin part of the Black Sea basin, in a mobile land crust, the Danube Delta is practically the most important terminal plain of a European river (except that of the Volga River) [4].

The Danube Delta is located in the geological unit of the Pre-Dobrogene Depression, at the edge of the Scitical Platform, the boundary between the North-Dobrogean orogen and the delta occupied by the Sfântu Gheorghe fracture area. The Delta is located in a mobile area of the terrestrial crust characterized by subsidence (1.5-1.8 mm / year) and accumulation of sediment.

The sedimentary deposits of 300-400 meters thick accumulated during the Quaternary period when the Danube reached the Black Sea. The construction of the current Danube Delta was done during the Upper Pleistocene and in Holocene, during more than 5 phases of progradation and regression, characterized by the formation of successive lobes. During the Quaternary period, the level changes of the Black Sea influenced the delta evolution. The delta field begins at the first bifurcation of the Danube (at Ceatal Izmail) at 83.8 km from the mouth of the river. At Ceatal Izmail, the Danube divides in two arms, one in the north, the Chilia arm and the other in the south, Tulcea. The latter it bifurcate to his turn in two branches (17 km downstream), Sulina and Sfantu Gheorghe.

The Chilia arm, the most important of this system, is 117 km long and forms a border with Ukraine. At spill, he built a secondary delta with an area of approximately 24,000 hectares.

The Sulina arm, 71.7 km long and extended by another 8 km in the sea, located in the central part is the navigable arm due to numerous rectification works from 1868 to 1902, but also for dredging. It has consolidated shores to prevent shoreline erosion due to shipping.

The Sfântu Gheorghe arm is the southern delta arm of the Delta. At spill, it is morpho dynamically active and builds a secondary Delta.

Among the main distributors, the Danube has created a network of primary and secondary channels, both natural and artificial, which allow the circulation of water and sediment from the main arms to the inter-distribution depressions. This water circulation system is vital to the existence and evolution of deltaic ecosystems [3].

The evolution of the Danube Delta has been influenced by the intensive anthropic activities it has undergone in the last centuries. This factor has become determinant for the transport of water and sediment flows from upstream.

In the Danube Delta, it happens very often that this territory is flooded due to the flash floods that appear on the Danube at certain times of the year. This phenomenon usually installs when the Danube levels are high and it is a matter of concern because there is a danger that many localities in the Danube Delta will be flooded.

The anthropic interventions have had an influence on the Danube flow regime, on the sedimentary balance from the coastal area in front of the delta between Sulina and Sf. Gheorghe, as well as the morphology from the northwest part of the Black Sea [5].

2. THE HYDROLOGICAL DYNAMICS OF THE SULINA BRANCH

The speed of displacement of a water stream is determined by the correlation that is established between the gravitational force (parallel to the slope line) and the resistance forces generated by the friction of the water flows with the walls of the flow channel or with the bed of the surface over which it moves. The stronger the force of the contact with the substrate is less than the gravitational force, the higher the current velocity.

The hydrological measurements of the February 2007 campaign show the hydrological status of the Sulina arm when the waters are large with an input flow of 1120 $m^3.s^{-1}$, and at spill of 1331 $m^3.s^{-1}$ (the average flow on the Sulina arm being about 1248 $m^3.s^{-1}$).

The determinant role in the water circulation along the Sulina arm is represented by the adjacent channels of the boom and the breaches of the dams which connect it with the depression zones between the main branches of the delta and transfers flows between them in close relationship with water levels from upstream.

Level changes at the Sulina hydrometric station are lower because between Ceatal Sfantu Gheorghe and the area where it flows, the Sulina arm exchanges liquid and solid streams with the depression zones between the arms, considered "buffer zones".

These exchanges consist of losses located in the first half from upstream, from Ceatal to Gorgova (via the Papadia, Crisan channels, and many other smaller ones) and accumulations in the downstream half of the arm through the lateral inlets of the ponds (from Gorgova to Sulina). In addition, it is also necessary to consider the evapo-sweating factor by which water quantities are lost/accumulated by the main arm, thus modifying the flow of water at the spill. As for the type of water flow through the bed on most profiles, the flow is located at the transition between laminar flow and turbulent flow [8].

The laminar flow is favored by the existence of damed banks that facilitate the movement of the currents, of the small bed width but also the proximity to drain zone with low slope of the bed. Still analyzing on deep steps the directions of the currents on the transverse profiles, I noticed that the vectors are not always parallel to the flow direction but many times form angles with values between 5 and 300 depending on local morphological conditions. It has also been observed that in many cases, at the contact with the water bed there are inverse currents which create turbines thus producing a turbulent flow in the contact area.

These are actually the currents that mobilize the bottom sediments, eroding them from the water bed and transporting them in suspension and crawling. Thus, specific morphological forms (dunes, ripples, etc.) are formed. An example is that of the Mila 33.8 profile, the water flow keeps here a direction parallel to the bed at the surface of the section and up to a depth of about 3 m, after which the direction of the central flow changes its direction of flow sensitively [4], [10].

3. ANTHROPICAL CHANGES IN THE DANUBE DELTA

The Danube Basin has undergone, over the last few centuries, several factors of a natural or anthropic nature that have changed its course. It therefore falls within the overall context of the global reduction of liquid and solid fluxes that characterize most European rivers.

The delta area has also been subject to many local and global constraints natural but also anthropic. Being an important economic axis in Europe, at the receiving basin level, the river has undergone important transformations which have influenced the medium and long term (often at an unexpectedly high level) his whole route to downstream.

All the Danube arrangements (hydro-energetic arrangements, dams, dredges, and meandering rectifications) disrupted the natural water-sediment functioning of the river.

Prior to the arrangement, the Danube transits an impressive volume of water and sediment; this natural regime gradually changed for the economic purposes of the riparian countries, producing the progressive artificialization of the Danube.

At a local scale, successive arrangements out of the Delta from 1868 to 1902 (the rectifying the meanders on Sulina's arm, construction of dams and canals) caused variations in liquid and solid flows and local readjustments of bed morphology, with significant effects on hydro-sediment dynamics but also on the continental platform from the northwest Black Sea as the final receptor [6], [12].

As for the Sulina arm, at Ceatal Sfântu Gheorghe, hydrological dynamics are accelerated due to the artificial narrowing of the bed and the high value of the divergence angle from the bifurcation.

Downstream, depending on the typology of the banks (dammed or natural), the channel trajectory and the foundation of the bed, the hydrological processes evolve differently. The mainstream is concentrated in the central area on most cross-sectional profiles of the profiles following the line of the most highest depths [9].

At the entrance to the Sulina arm, the measured flow represented approximately 39% of the flow of the Tulcea arm. This value is typical of periods of medium to large water. Older data show that the Sulina arm transits a variable amount of water depending on the upstream water level (between 30 and 55% of the Tulcea flow rate at Sf. Gheorghe Ceatal).

Regarding the evolution of the flows along the arm, the flow from upstream to downstream increased during the measurements both due to the increase in the level at the upstream hydrometric station (Tulcea), but also due to inputs from the channels connecting to the inter- distributary.

At the same time, it was noticed changes in reverse, from the adjacent channels to the arm. It is rather difficult to quantify the quantities of water involved in these shifts because they are permanent and often in both directions (from the Sulina branch or to the Sulina branch).

At shedding, the hydrological dynamics is modified by the penetration of the salt water pillows from the Black Sea sometimes even to distances of 17 km to upstream. The interaction between marine and fluvial currents produce local hydrological changes by slowing down speeds. It changes so the flows through sea water intake on the branch [2], [7].

The results of the estimation of the capacity and the competence of the channel in the investigated transversal sections include the Sulina arm in the river system typology specific to the delta area. The most dynamic area is the one from bifurcation (specific power values located between 10.23 and 5.19 W.m-2, and traction force 10.41 N.m-2); downstream the river energy decreases (at about 5 - 6 W.m-2) due to the increase of the flow section and the decrease of the water speed.

With regard to historical floods, on the Danube between 1965-2012 there were flash floods with maximum flows higher than 10,000 m3 / s in 24 years, maximum annual floods that are grouped on classes of maximum flow rates between 10000 m3 / s and 13000 m3 / s in 20 years, maximum flow rates between 13000 m3 / s and 15000 m3 / s in 3 years and maximum flows higher than 15000 m3 / s per year [4], [11].

Table 1 presents the maximum flow rates of these floods at the entrance of the Danube into Romania and the moment of their occurrence.

Table 1. Maximum flows on the Danube

Year	**1965**	**1966**	**1967**	**1968**	**1970**	**1974**	**1975**	**1976**
Month	VI	II	IV	I	V	XI	VII	VI
Q_{max} (m^3/s)	12250	10810	11050	10500	13040	12100	12150	11400
Year	**1977**	**1979**	**1980**	**1981**	**1982**	**1987**	**1988**	**1998**
Month	III	II	V	III	I	V	IV	XI
Q_{max} (m^3/s)	12200	10900	11900	14800	10500	11610	12690	10280
Year	**1999**	**2000**	**2004**	**2005**	**2006**	**2009**	**2010**	**2011**
Month	III	IV	IV	IV	IV	III	VII	I
Q_{max} (m^3/s)	11100	12000	10800	12900	15800	10700	13350	10200

Typically, the maximum flows on the Danube occur in the spring-summer period, the peaks occurring more frequently in the months of April to May. However, there are some exceptions when flood waves occur either in December and January or late summer in August-September. The maximum flow values are detached those that occur during the spring-summer period these being actually considered large waters on the Danube.

When floods occur in the Danube Delta, they have a negative impact on the surrounding environment, affecting local infrastructure, human health and some or all of the economic activity.

The presence of floods in the Danube Delta often threatens localities along the river, where there is a danger of breaking the dams of defending the localities or if not the danger of passing water over the canopy of the defense dam flooding mainly vulnerable areas within the localities.

On the Old Danube, Mila 23 is a commune in Crişan commune in the Danube Delta, in the immediate vicinity of the Sulina branch, the city being 53 km away from Tulcea city - Figure 1.

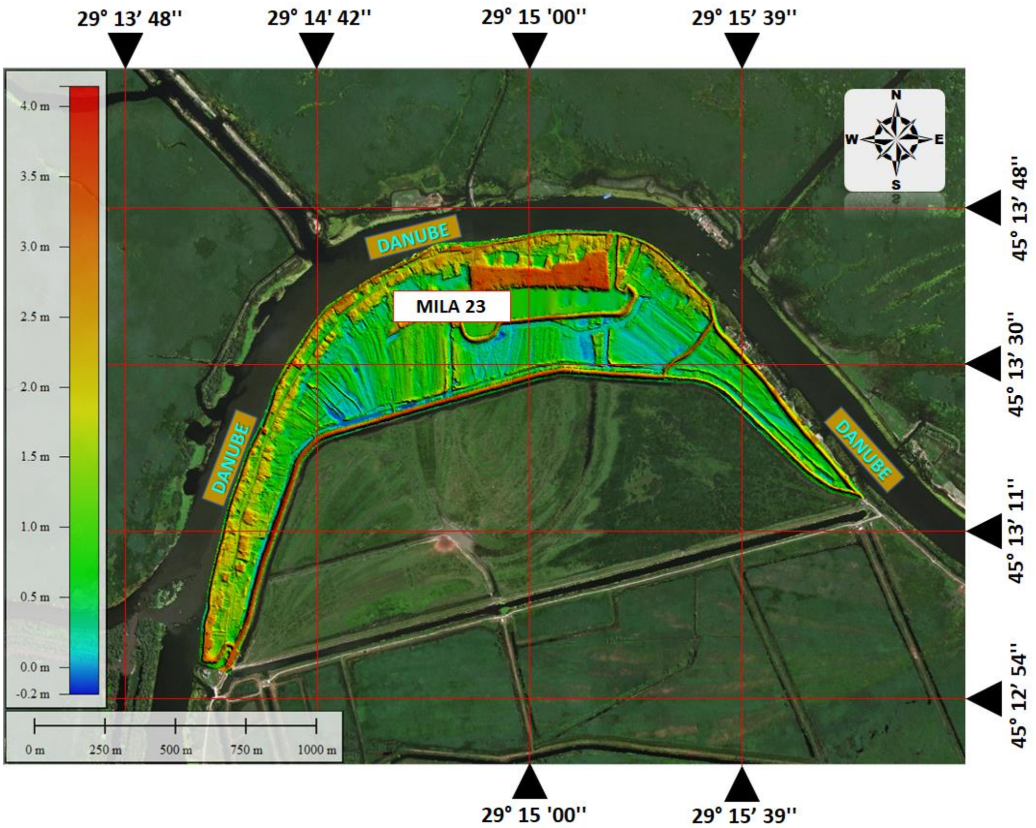

Fig. 1. The location of Mila 23 locality on the Old Danube

In the past the locality was heavily affected by the floods, especially in the 1970s. Thus an artificial platform was built around the locality that raised the land over the inundated quota.

The present paper analyzes the hypothesis in which the water exceeds the historical flood threshold and the locality is gradually flooded. These extreme phenomena can be encountered in the Danube Delta with the probability of occurrence once every 100 years or once every 1000 years.

4. FLOOD RISK ANALYSIS FOR MILA 23 LOCALITY FROM THE DANUBE DELTA

This analysis is based on the digital terrain model (DTM) and the surface digital model (DTS) of Mila 23 locality and its surroundings, which was made in a short period of time and has information on the terrain configuration. With this information base, flood scenarios are made using GIS (Geographic Information System) programs, generating, ultimately, relevant digital maps in this analysis.

DTS obtained from photogrammetric data is an indirect result of the orthophoto maps generation process. This is necessary for orthorectification of records, and is obtained from the correlation of airline records. The model for obtaining the digital surface model for this technology is to correlate photogrammetric records.

They are picked with a special sensor. The result of this process is getting a cloud of points. This process is automatically followed by a semi-automatic correction process. For validation, a reference pattern of the same area, generated from LiDAR records, is used. Depending on the input data, each digital model will have a specific coordinate system.

For the fusion process, both models must have the same spatial reference, so either or only one model will undergo at least one coordinate transformation. Areas that do not define the terrestrial surface will be delimited by polygons stored in a shapefile file.

Based on them, DTS areas will be removed from dense vegetation or other areas, and from the DTM will be extracted a complete model with the remaining DTS, with a variable coverage of 10-20 meters depending on the specificity of the relief or area. Given that the precision and data source from which the two models were obtained differs, a process of correcting the complementary model extracted from DTM has been proposed.

Thus, the coating area is brought into coincidence, with even uneven precision improvement, directly proportional to the distance from the coating area.

For this stage, based on the coverage band between the two, differences are calculated with a setpoint frequency based on the complexity of the relief. Furthermore, a correction surface is generated by interpolation, through which the complementary surfaces are brought into coincidence.

The final stage of the fusion process consists in mosaicing data sets, resulting in a digital model of the land for the entire area of interest [5].

In the flood risk analysis, the digital land model is very important because it is the information base with the most data and information that helps to create a representative image of an area affected by floods of small or large proportions.

Based on this digital model, Mila 23 locality is tested using GIS technologies generating by data processing representative digital maps in which critical / vulnerable areas are identified - Figure 2, Figure 3, Figure 4, Figure 5.

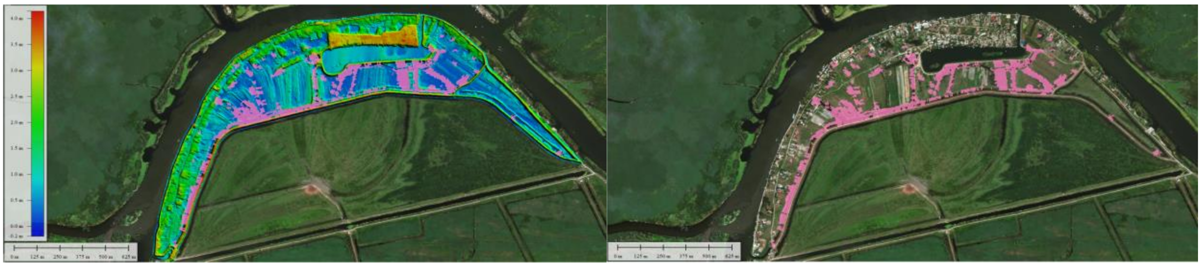

Fig. 2. Critical/vulnerable areas in Mila 23 locality +3.45 meters landmark BSS

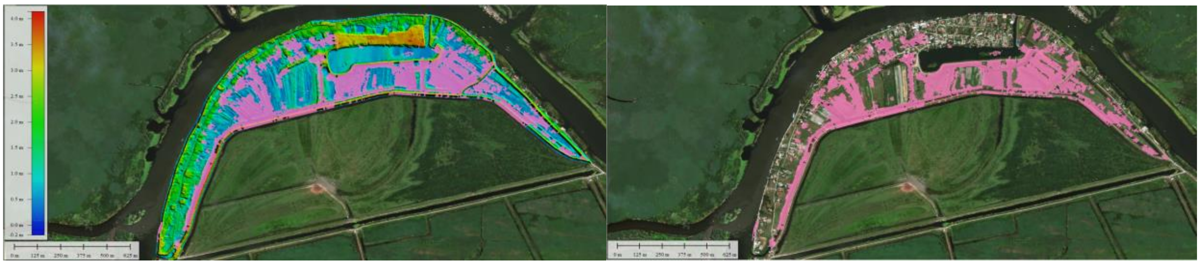

Fig. 3. Critical/vulnerable areas in Mila 23 locality +3.65 meters landmark BSS

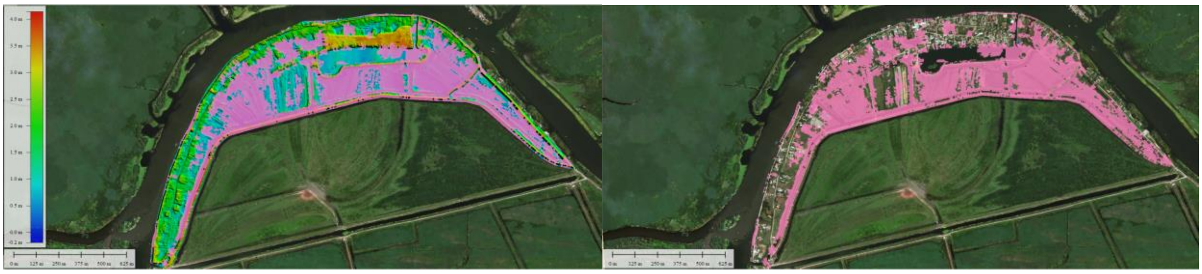

Fig. 4. Critical/vulnerable areas in Mila 23 locality +3.85 meters landmark BSS

Fig. 5. Critical/vulnerable areas in Mila 23 locality +4.05 meters landmark BSS

The GIS program used to identify critical / vulnerable areas is Global Mapper. The simulations were based on the digital model of the land, to which were added flood steps of 20 cm up to the highest level of +4.05 meters with the Sulina Black Sea reference.

In the first phase at a level of +3.45 meters with the Sulina Black Sea reference, the town is flooded by about 16%, in the 2nd phase at a higher level by 20 cm, the town is flooded by 46%, in a 3rd phase at a level of 3.85 meters, the town is flooded 78%, and in the last phase at a level of +4.05 meters with the Sulina Black Sea reference, the town is almost entirely flooded, about 93%.

5. CONCLUSIONS

In the last period, the evolution of the Danube Delta has been influenced by an intensification of anthropogenic activities.

The territory of the Danube Delta is often flooded due to floods that appear on the Danube at certain times of the year, endangering localities within the Delta.

The evolution of flows along the Sulina arm, the flow from upstream to downstream has increased over the course of the measurements both due to the increase of the level but also due to the contribution from the channels that connect with the inter-distribution depressions.

The digital terrain model is the most useful information base for flood risk analysis.

This paper presents the flood risk analysis for the Mila 23 locality using GIS specialty technologies to obtain digital maps that establish critical/vulnerable areas for flooding within the locality. In the digital map generation, flood steps of 20 cm were used, taking an initial starting level of +3.45 meters with the Sulina Black Sea reference and +4.05 meters with the Sulina Black Sea reference as the final level.

The results can be useful for the local authorities and interested citizens, the digital maps being an important means of visualization if the level of the river exceeds to the maximum historical threshold.

For many scientists flood risk is a matter of great concern; in the last period in the Danube Delta there have been numerous floods created by flash floods have always been and still represent a dangerous phenomenon for the Danube Delta localities.

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