The Importance of using GIS in Hydrological Models for Flood Prediction: A Case Study at Danube Meadow, Romania

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Abstract
Recently, particularly between 2005 and 2010, Romania has been subjected to large-scale flooding, with wide areas affected by floods which led to serious damage to the infrastructure and left behind a significant number of deaths. The destructive intensity of these flash floods has highlighted the need of an integrated and sustainable approach to managing flood risk in Romania in order to reduce the severity of future damages caused by floods. A very important role lies in cartographic representations, namely in achieving analytical maps based on risk calculation and especially on the integration of a large volume of information contained in Geographic Information Systems (GIS). In this study, the Corabia-Turnu Măgurele-Zimnicea sector, located in the Danube Meadow (in southern Romania) was chosen, this area being very affected by floods, especially by those from 2006. The aim of this paper is to explore the potential of GIS in order to raise the awareness against the potential for spatial planning for water-related natural hazards and to reduce the risk of natural disasters affecting the population by proposing preventive measures in the most vulnerable areas.

Key words GIS, Hazard, Flood Simulation, Danube River, Meadow

Introduction

Current climate change, highlighted by the increased number of extreme phenomena associated with precipitation, e.g. rain with high intensity, in conjunction with more intense human activity (massive deforestation), lead to a more frequently flood production with a high impact on human component and its habitat. Flash floods are the main cause of catastrophic floods occurrence, therefore their event and its associated effects represent an important topic of current research.

Floods are a common phenomenon and imply serious risks for humans and their activities. Those events are caused by the groundwater level increase above the ground level threshold under the effect of a hydraulic gradient through seepage from riverbeds in the meadows where they occupy large areas, used for agriculture, habitat, communication paths, etc.

Being the most widespread hazard on Earth, it occupies the first place concerning the damage caused by natural disasters. Annually, large scale economic losses and deaths of ten thousands of people occur and affect in various forms and seriousness level other several hundred thousand of people.

During 1998-2004, in Europe were registered about 100 major flash floods that caused deaths of about 700 people, direct damages affecting nearly 1 million people, summing total losses of approx. 25 billion euro. The most affected countries by floods in 2005 were: Austria, Bulgaria, France, Germany and Romania. In the case of Romania, during 1992-2006, floods were responsible for almost 80% of damages caused by natural disasters and lead to the death of dozens of people. The main factors that led recording such damages are: the production of flash floods and flows with high values (as a consequence of climate change), the developing of economic objectives in areas with high risk of flooding and the high vulnerability of populated areas located in risk areas.
Floods are phenomena that cannot be avoided, but with a well-developed management plan of them, their effects can be reduced. In this context, the European Union requested that each country must have a plan for prevention, protection and mitigation of floods.

Flood management is facilitated by the predictability of flood event occurrence, often a warning being possible. In this context, the flood risk areas are mapped, and based on them it may be specified who and what will be affected by flooding.

During the last years, Romania has faced with large-scale floods that affected wide areas, causing major damage to infrastructure and losses of life. Especially, the catastrophic floods occurred in 2006 in the Danube Basin have highlighted the vulnerability of society to extreme natural events. Their destructive intensity has showed once again the necessity of integrated and sustainable approach of flood risk management in Romania, in the context of approval of the National Strategy for managing flood risk in the medium and long term and the EU Directive 2007/60 / EC on the assessment and management of flood risks (2007).

In the last 10 years, floods occurred along the Danube River proved that the hazard and flood risk maps are needed and must be achieved at transnational level by all countries located in the Danube river basin. In this context, the Ministry of Environment and Water Management of Romania, under the Presidency of ICPDR, began the translational Danube FLOODRISK project (“Stakeholder oriented flood risk assessment for the Danube floodplains”) (2009-2012). The main goal of this project was to lay the foundation for ensuring a sustainable development along the Danube River, by providing effective risk maps for the Danube Valley and disclosure of relevant information on flood risk which are necessary for spatial planning and economic requirements (Figure 1).

The research area of this study, the Corabia – Turnu Măgurele – Zimnicea sector, is characterized by a complex hydrology, conditioned by many factors continuously changing due to system dynamics.
The results of this study will be presented inline in GIS applications (Geographic Information System), which allow overlapping the flood boundaries obtained through hydrodynamic studies over various cartographic materials.

**Study area**

The geographical boundaries which provide support for this approach is an area of study with a total surface area of 1353.5 km². In essence, when this area was traced, the sector between three cities: Corabia, Turnu Măgurele and Zimnicea was included. It is located in the southern part of the country, on the administrative territories of Olt and Teleorman Counties. The natural area is located in the Lower Danube Valley, in the south-eastern county of Teleorman, in the vicinity of the national road DN54 (Figure 2). In geological terms, the area is characterized by alluvial deposits consisting of fine or coarse sands, small, large and extra-large gravels, true boulders, clay and banks with well represented thicknesses.

This sector represents an important sanctuary designed to protect the biodiversity and to maintain a favorable conservation status of spontaneous flora and wild fauna and natural habitats of community interest under the protected area. The sanctuary area (which is framed in the continental geographic bioregions) is a natural zone with rivers, sandy beaches, lakes, swamps, bogs, meadows, forest in transitions, deciduous forests and provides food, nesting and living conditions for several species of migratory or sedentary birds, some of them protected by law.

The Turnu Măgurele city and its surroundings are dominated by the vast Romanian Plain, being represented by two individualized formations: the so-called low-lying plains (meadows) and interfluvial spaces. In the first category is included the Danube meadow - the largest floodplain with the smallest altitude and the Olt meadow which is more extensive in the confluence with the Danube. The remaining part is reduced to a narrow strip consisting in softwood vegetation.

River network is dominated by the nearby presence of the Danube and Olt River. Depending on seasons and precipitation amounts, river flow reaches an average value of 5 800 m³/s.

![Figure 2. The study area](image-url)
Used data

To fulfill the purpose expressed in this paper and specified objectives, the research was based on the collection and drafting of databases and then on the information analysis and its synthesizing in thematic maps, GIS maps and areas developing.

Topographic and GIS data used in here consists of a digital elevation model (DEM) on 90 meters spatial resolution, available free of charge on CGIAR-CSI geoportal in WGS84 geographical projection (Reuter H.I, A., Nelson, A., Jarvis, 2007), which was re-interpolated to obtain a 30 m resolution and the vector data that was also needed (by using topographic map at 1:25000 scale with contour lines in digital format, rivers, channels, Danube river, roads and localities were digitized).

Hazard Maps and Risk Maps, available through the translational Danube FLOODRISK project, were used to obtain a better understanding of how this area can be affected by floods.

For the aim of this paper, the data was postprocessed using ArcGIS 10.1 software (namely ArcMap for achieving the hypsometric map and map of flood simulation and ArcScene for Map of 3D animation for flood simulation). The results are presented in the next section.

Results and discussions

An approach of combining flood management and GIS has been designed. In this context, various maps were generated for the analysis in the GIS platform, such as: hypsometric map, map of flood simulation steps and final map of flood simulation.

Analyzing hypsometric map (Figure 3), presented for the analyzed enclosure: Corabia-Turnu Măgurele-Zimnicea, it can be noticed that the distribution of hypsometric steps is almost uniform, the highest altitude at 119 m being located in the northeastern area, in Urluiului Plain and the lowest, at 20 m, in Danube Meadow. Also, an increase of altitude steps from the South of the study area in Danube Floodplain, to the northwest side, in Urluiului Plain, was observed.

Due to the wide meadow and low relief, Danube has a considerable width which involves smaller depths, providing only a ship draft of 2 that is improperly for navigation. Shore is higher in the south and is towards the Romanian Plain it is lower. It has a wide floodplain development which gives it a pronounced asymmetry; this “thrust” of the Danube to the south is due (among other things) to the direct tributaries from Romanian Plain (Olt and Călmățui Rivers).

![Figure 3. The hypsometric map of the study area](image)

After processing of spatial data into GIS environment, the next step was to model the terrain using an ArcGIS 3D Analyst extension, namely to imagine the scenario when the Danube level rises (Figure 4). In this context, there is a map document with data that was previously processed, specifically a boundary polygon...
for the investigated sector and an elevation raster that was clipped to the sector of Danube Floodplain. In order to understand the scenario, it should be known that the elevation raster is essentially a grid of cells, each cell containing an elevation above mean sea level. So, if it is assumed, for example that the Danube level rise by 5 meters for various reasons, then the number from the elevation in the raster should be substantial subtracted from the elevation in the raster and it is assumed that anything below zero (negative values) is essentially now below water. A tool from ArcToolbox called Map Algebra, specifically Raster Calculator was used. The new raster that was created has 2 possible values for every single grid cell: 1 if the cell meets the criteria (less or equal to 5) and 0 if contrary. The zero values should now be eliminated, so the raster is reclassified from a grid with two values in a grid with only one value in order to isolate flooded cells. The next step is the conversion of flooded cell raster into a polygon followed by selection of only areas hydrologically connected to the Danube and neglecting those not connected to the Danube line (they cannot be flooded during Danube flooding).

The output of final map of flood simulation shows an area of 455 sq. km (33.6% of total area) that is under the risk of inundation.

Finally, for a better view of the imaging scenario, it was created a 3D animation of the rising Danube level simulation in ArcScene software (Figure 5).
A way to analyze, visualize and interpret the phenomenon of flooding is by making use of remote sensing data from instruments which can be on board satellites, airborne instruments or on the ground.

There are two ways for monitoring floods from satellites, during the spread of this disaster. The first and the most reliable source of information can be provided by SAR and InSAR data that uses polarized microwave radiation to map the land and water. In the case of SAR and InSAR, data can be acquired during rain or cloudy conditions. Floods can be seen comparing two images, one before the flood and one during the flood, thus spots that are darker, in comparison with precedent data, could be areas that are under water. This process requires more experience.

The second way to identify floods is using optical or multispectral satellite images, which can provide a lot of information by applying different indices like NDWI (normalized difference water index) and NDVI (normalized difference vegetation index).

In Figure 6, it was chosen to show a way of visualizing this complex and devastating phenomenon using Landsat-5 TM time series for path 183 and row 30 from February 2006 (before the flood) to August 2006 (after the flood).
Conclusions

In this study, an application of GIS in flood modelling/mapping, showing the usefulness of GIS in flood management was presented. The practical importance of these cartographic products is recognized by all users, whether they are directly involved such as geographers, hydrologists, climatologists, pedologists, geologists etc., but also decision makers - the beneficiary of most accurate knowledge systems of land vulnerability, location, spatial delimitation of areas with different levels of exposure to natural disasters, that can effectively act to mitigate the damaging effects of nature phenomenal.

Thus, maps gains analytical and practical meanings, increasing its side in social utility in addition to those of scientific and practical importance, often called mathematical models of land.

Common technical specifications are necessaries for achieving a complex topographic database that includes a large number of orthophotos and digital terrain models (DTM) but also data vector used for usable many applications based on cartographic products.

Acknowledgements


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