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GEOSPATIAL PARTICULARITIES OF FLOOD RISK MANAGEMENT IN BANAT HYDROGRAPHICAL AREA

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Abstract: Before presenting in detail the theme that this paper deals with, it is necessary to integrate the research on this matter within the larger context of global change, which is at this time in a stage of unprecedented evolution. In the last decades, the number of meteorological and hydrological disasters has gradually grown worldwide, thus affecting hundreds of million people every year. As a consequence, it is absolutely necessary to understand the vulnerability and the sensibility of the human community on medium and long term to hydro meteorological risks and the stringency for interdisciplinary studies related to flooding. Therefore, the experts in this field are faced with the assignment of developing disaster risk management strategies. Floods represent the most frequent disaster that can occur on various scales, ranging from large to small rivers, with impact on the state of the environment, including not only economic loss and ecological imbalance, but also claiming numerous human lives. As Geographic Information Systems (GIS) and spatial database technology are forthcoming tools for the tight circles of experts, working in the fields of geodesy and geography, managing areas prone to floods by means of this technology represents the optimal solution. Moreover, disasters, regardless of their type (natural or anthropic) will continue to appear, this leading to the need for different users in the disaster management sector to share and access the information.

Keywords: flood, GIS, global change, disaster risk management, geospatial data.

1. INTRODUCTION

The beginning of the third millennium finds mankind in the face of a considerable number of unsolved problems. One of the most concerning, through the immediate long-term effects, is related to environment. The society is more conscious of the profound significance natural hazards have in its development [1]. Continuous development of industry, demographic expansion, especially in underdeveloped regions, globalization, contemporary agriculture, greenhouse gas emissions [2], transportation and greater energy consumption have created a number of problems on a worldwide scale, called “Global Changes”. This term encompasses the fundamental changes in our planet system, changes representing direct results of human activity. Global changes are an essential component of contemporary ecological crisis.

Together with the general increase of the vulnerability degree change when talking of demographic, socio-economic and technological conditions, unplanned urbanization, buildings in areas at high risk, insufficient development, striving for increasingly precarious resources, global change will cause hazards to present an ever-growing danger to human civilization.

Current trends, in terms of changing vulnerability degree and the character of natural ecological and biological threats which endanger human civilization [3], highlight the fact that hazards are capable of generating extensive and complicated effects both on economy and population, also with mutual influences.

The risk of hazard gains more and more a global character, its manifestations in a region exerting a clear influence on the risks from other regions and vice versa. Risk represents the probable level of loss in human lives, of injured persons, of damage to property and economic activities by a certain natural phenomenon or group of phenomena in a certain place and at a certain time.

Conventionally, risk may be calculated as:

$$R = H * V \qquad (1)$$

In the formula H represents hazard and V represents vulnerability, so it can be said that risk ca be found at the intersection between hazard and vulnerability [4].

A hazard is a very damaging natural or anthropic phenomenon, whose occurrence is due to the overstepping of safety measures each society has to observe. A hazard turns into a disaster if there are at least 10 human lives lost or 50 people injured and material losses of over a million dollars. Therefore, in case of disaster’s occurrence, the top priority should be to prevent the consequences, especially to avoid human and material losses. Having a flash effect, hazards seriously undermine the expected results of

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development investments and represent one of the major obstacles to sustainable development. Moreover, one of the most important challenges the world community is facing in the 21st century is managing hazard risks which intensify vulnerability and reducing the danger represented by them, aiming to ensure sustainable development [5] of human societies.

Floods represent one of the most destructive natural disasters worldwide and, as it is highlighted in the figure below (Figure 1), they are the most widespread type of hazards on our planet, representing up to 37% of the total number of hazards. Between 1998 and 2002, Europe suffered over 100 major damaging floods, including the catastrophic floods along the Danube and Elbe rivers in 2002. Since 1998, floods have caused some 700 fatalities, the displacement of about half a million people and at least €25 billion in insured economic losses [6]. The flood risk as well as the number of people and economic assets located in flood risk zones is increasing permanently as a result of climate change [7] (higher intensity of rainfall as well as rising sea levels) [8].

As a results, the impact of floods is expected to increase due to population growth, population migration to coastal areas, and climate change effects [9], [10] though risk assessment projects are needed. They involve (1) hydrological, (2) hydraulic, and (3) socio-economic studies and usually require a large amount of data. Unfortunately, high costs and technical difficulties are involved in the implementation of each project component and limit flood mitigation efforts [11].

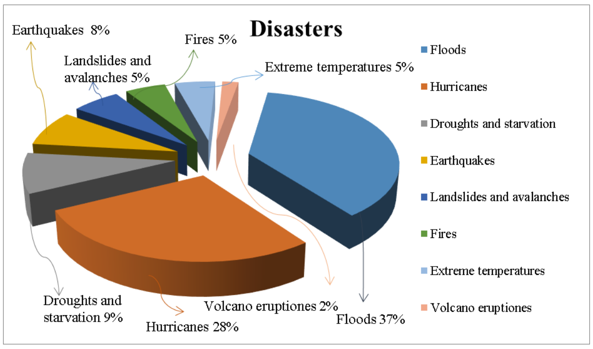

Figure 1. The proportion of different disasters (%) worldwide at the beginning of the 21th century

River floods may occur whenever the capacity of the natural or manmade drainage system is unable to cope with the volume of water generated by rainfall or when flood defences fail. Experience has shown that local flood protection measures taken in one place will have a knock-on effect for upstream/downstream areas. For example, if one area implements engineering solutions to evacuate the water from its stretch of the river as quickly as possible, this simply means that the water arrives faster to their downstream neighbours. Therefore, it is imperative that flood protection is dealt with in a concerted and co-ordinated manner along the whole length of the river. River floods vary considerably in size and duration. In the case of large rivers such as the Danube, the Rhine and the Elbe, floods can occur a considerable time after the rainfall and last for days, weeks, or even months. On the other hand, flash floods are usually due to highly localised, very intensive rainfall.

1.1. CHARACTERISTICS OF GLOBAL CHANGES MANIFESTED IN ROMANIA

Romania is not exempt from the incidence of natural hazards. The national strategy for sustainable development of Romania, drafted in 1998, recognizes the existence of the disasters produced by earthquakes, landslides and floods and the necessity of preventive measures. On Romanian territory, located in the temperate climate zone, a wide variety of hazards [12] and climatic risks which can be grouped depending on the season (summer/winter hazards and climatic risks etc.) are produced.

All of these bear the seal of the general dynamics influence of atmosphere and the orographic basin of the Carpathians, which limits them, being quartered, one side or the other. These hazards are the more dangerous, the consequences become causes for other risks, which chain triggers and progress in cascade, printing deep tracks into natural landscape, and most importantly, in the agricultural landscape.

The aridity tendency, manifested especially in the last two decades of the past century and continuing in the current century, is due to the rising of air temperature, associated with the decreasing in precipitation quantity. On this climatic background, respectively arid, at least in Romania, many floods occur, caused by the large quantities of precipitations, which fall in short intervals of time, in the order of hours, sometimes even minutes. An analysis on the periodicity of the meteorological and hydrologic regime on the territory of Romania on 120 years (1881-2001) outlines three regime states: rainy, normal and arid, with periods ranging from 11 to 20 years.

What is happening in Romania, referring to the two categories of hydro meteorological phenomena – droughts and floods – represents a consequence, firstly, of the global climate changes or the variations of climate at global and regional level, and secondly, of the anthropogenic intervention in the landscape.

The studies [13] undertaken by the Intergovernmental Committee on Climate Changes [8], [10] and the European Environment Agency [6] show that the average temperature of air on planet Earth has increased with 0.6°C in the last century and that, this increase in temperature has been three times faster after 1975, on one side, and that the atmospheric precipitation increased with 10-20% in Romania (like in other European regions), on the other side. If in terms of the thermic regime, predictions can be made with a certain degree of accuracy, the precipitations regime is seldom, with a high degree of unpredictability. These climatic states [14] can be attributed to the increase of greenhouse gases and aerosols, significant deforesting at global level – which modifies the circulation of air masses – and the expansion of the irrigated areas and of the reservoirs on major hydrographical arteries.

In Romania, due to these overall changes, the accentuation of floods occurrence in the small hydrographical basins is caused by uncontrolled deforestation effectuated after 1990, triggering a rapid flow of water on slopes, the intensification of soil erosion [15] and landslides, the warping of river beds and house holdings construction and other utilities in floodable areas.

The necessity of this study arises from the chronicler's records which show that catastrophic floods have occurred with regularity in Romania, these being a consequence of the temperate continental climate: in the 16th century 10 major floods have occurred, while in the 17th century there have been recorded 19 floods, in the 18th century 26 floods are mentioned, in the 19th, 28 and in the 20th century 42 floods. As it can be observed, the frequency of floods has increased, first of all due to climate changes, but also as a consequence of the reduction of the transport capacity in the river beds of the hydrographical arteries, as a result of river deposits, damming, deforesting in the reception-collection basins and different constructions in the floodplains.

The year 2005 can be considered a year of floods for Romania. The high floods that later produced the floods in 2005 in Romania have been generated, in the first month (from February to April) by the superposition of rains and snow melting, especially in the Banat area (Figure 2); afterwards from June to September, the high floods were caused by brief torrential rains (heavy rains) with a high intensity in short intervals of time, in the order of 2 to 3 days.

Figure 2. Geographical location of the studied area

An analysis of the floods produced in Romania in the last 35 years, taking as landmarks the years 1970 and 2005, underlines the following:

- ✓ floods in 1970 have been restrained, as interval of time, to the months May to June and have occurred especially on the Rank (Order) I rivers – Someş, The Criş rivers, Mureş, Olt, Argeş, Siret, even on the Danube;
- ✓ in the year 1970 there have been recorded the largest homologated river flow rates;
- ✓ in the year 1970 there were fewer reservoirs to mitigate the floods and fewer dammed areas in the river beds;
- ✓ material damage and life loss have been much greater in 1970 in comparison with the ones in 2005;
- ✓ floods in 2005, with the exception of some first order streams (Siret and its tributaries, Buzău, Trotuş, Putna, Mureş, Ialomiţa), have occured on small rivers, but have had a greater degree of territorial expansion, sometimes with a repetitive character (Trotuş, Buzău, Ialomiţa).

1.2. THE BANAT HYDROGRAPHICAL AREA

The Banat hydrographical area is limited in the north part by the Mureş River and in the south part by Danube, until the junction with Cerna, with 18393.15km^2 total surface that represents 7.7% from Romanian territory. The Banat hydrographical area is situated in the south-west part of Romania, between 20^{o}18`and 22$^o$52` East longitude and between 44^{o}26`and 46$^o$08` North latitude. The rivers that collect waters from this area have characteristics specific to the southwest part of the country, but in the same time they are individualized like river systems with specific characteristics to each river basin. The human influence has an important role over the water flow in this space, some of the hydromechanics' facilities are been used for more than 250 years.

The Banat hydrographical area is adjacent in the west part with Serbia and Montenegro, in the North West with Hungary, in north with Mureş River Basin and the Hungarian border, in south with Danube, in the east with Mureş RB and Jiu RB (Figure 3). The Banat Hydrographical Area is in totality overlaid of two administrative –territorial units (Timiş County and Caraş Severin County), where the Water Management Systems take actions. In addition, The Banat hydrographical area is partial overlaid to 3 more administrative units (Arad county, Gorj county and Mehedinţi county).

Table 1. The Banat hydrographical area administrative and demographical characteristics

Number	County	Surface (km²)	% from total surface of the R.B.	Population (inhabitants)	% from total population of the R.B.
1	Arad	571.89	3.11	17,282	1.65
2	Timis	8,585.17	46.68	677,926	64.71
3	Hunedoara	24.73	0.13	0	0.00
4	Caras-Severin	8,402.40	45.68	333,219	31.81
The development of West region		**17,584.19**	**95.60**	**1,028,427**	**98.17**
5		229.38	1.25	125	0.01
5		579.58	3.15	19,086	1.82
The development of South West region		**808.96**	**4.40**	**19,211**	**1.83**
Total Banat R.B.		**18,393.15**	**100.00**	**1,047,638**	**100.00**

The total theoretical water resources from Banat hydrographical area are appreciatively 4,58×109m^3/year, from which surface water 3,38×109m^3/year and 1,20×109m^3/year, underground water from Banat RB and them repartition on basins is like this: in the Bega RB: 0,56×109m^3/year, in the Timis RB: 1,51×109m^3/year, in the Caras RB: 0,22×109m^3/year, in the Nera RB 0,46×109m^3/year and 0,38×109m^3/year in the Cerna RB. The theoretical underground water resources are distributed as follows: 62% ground water and 38% deep underground water.

The total water resource technically used from Banat hydrographical area are 1,50×109m^3/year, from which surface water 392,2×106m^3/year and underground water 1,11×109m^3/year. The spatial distribution of the theoretical water resources RB is represented in the following manner: in the Bega RB: 301,3×106m^3/year, in the Timiş RB: 30,9×106m^3/year, in the Caras RB: 12,6×106m^3/year, in the Nera RB: 30×106m^3/year and 17,4×106m^3/year in Cerna RB. The theoretical underground water resources are distributed this way: 62% in the ground water and 38% in the deep underground water.

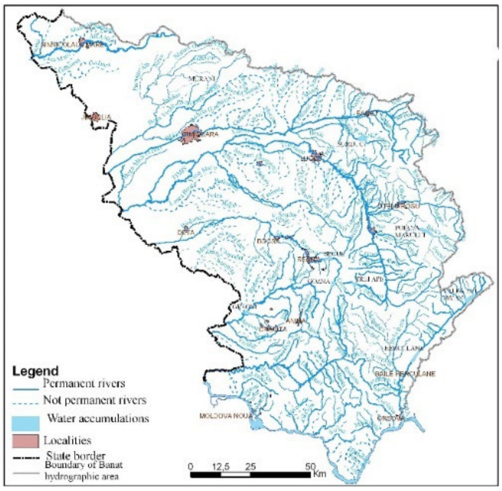

Figure 3. The Banat hydrographical area

The Banat hydrographical area is characterized by the presence of all relief units, with a decreasing altitude from South – East to North – West (Figure 4). The maximum altitudes are in Godeanu Mountain (2229m) on the watershed between Cerna RB and Mures RB. There are some prolongations of the Godeanu Mountains formed only from divergence range disposed around the highest point, Olahu Pick-1991 m. Gorhale Range (that starts from Olahu Picks to the north) and together with the Prislop range make connection with the Tarcu Mountain (2196m).

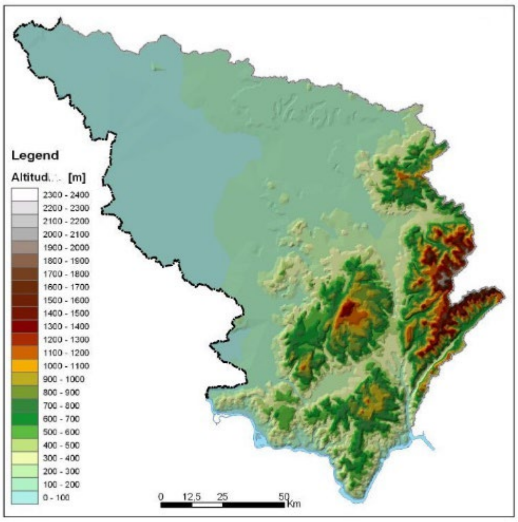

Figure 4. The Banat hydrographical area's relief

Earthquake, landslide, flood risks and investigations on these themes have become increasingly more complex and must deal with a large amount of spatial data, as well as large amounts of analytical results. Managing flood risk areas by means of GIS technology can serve as a basis as for creating flood warning systems which are developed all over the world with the fundamental aim of increasing safety and reducing the harmful effects of floods [16].

2. GENERAL FRAMEWORK

Given that natural hazards and those caused by humans will continue to emerge, a major problem is the ability of different users to share and access information required. To make sense, the technological capabilities must satisfy human needs-understanding the causes of drought and starvation, considering the spread of disease, monitoring storms at sea, and allowing us to respond to natural disasters, such as those which have occurred recently around the world.

Previous studies [17] have already shown that the problems of urban and rural planning and environments resources planning represent a very complex activity regarding interdisciplinary interest for technical, economic and social development improvement, being able to provide accurate and efficient solutions in order to cover basic needs of land administrative information and decision making for the Local Authorities. Incredible development of GIS technology in recent years and the increased availability of geographic data have changed the traditional use of GIS, now focusing on communication geographical information to a wider audience.

Geographic Information Systems are suitable for handling vast amount of geospatial data characteristic to both urban and rural areas. Beside the ability of producing maps and plans, GIS is the right tool for managing network utilities (water-supply, sewerage system, mains, district heating, roads and railway system etc.), identifying the optimal location for an investment, the study of the impact of a certain objective upon the environment complying with the general policy of sustainable development [18] in lower costs. Constructing a GIS is a difficult process, where a complex of scientific, engineering and organizational problems should be solved [19].

The modern GIS was used for creating the experimental part of this paper as it includes traditional flood mapping and represents a pillar in the decision-making phase referring to the management of areas affected by the flood phenomena.

2.1. GIS FOR FLOOD MANAGEMENT

Our methodology was based on using the GIS technology due to its advantages for the management of flood risk areas in Timiş County.

For creating the application, the following phases are necessary: creating a connection to an existing database, adding the feature classes (layers) which are of interest into the map window, introducing control points (with known coordinates), inserting the raster images scale 1:100.000 (Figure 5) and the image containing flooded hydrographic basins (Figure 6) and their georeferencing.

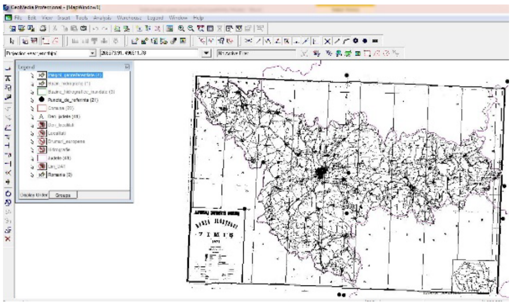

Figure 5. Timiş county map scale 1:100.000

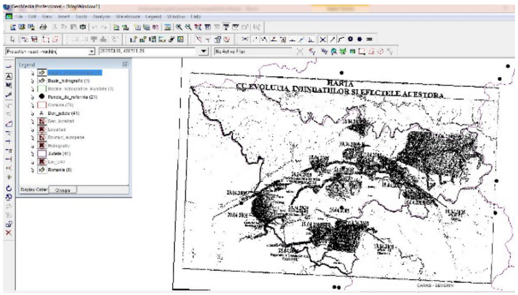

Figure 6. Timiş county map with hydrographic basins

The next step was vectorizing the graphic elements that were important in the study, such as localities' areas, villages, agricultural land affected by floods, hydrographical basins etc. [20]. At the end of each vectorizing process, attributive data characteristic to the respective graphic element has been introduced (Figure 7).

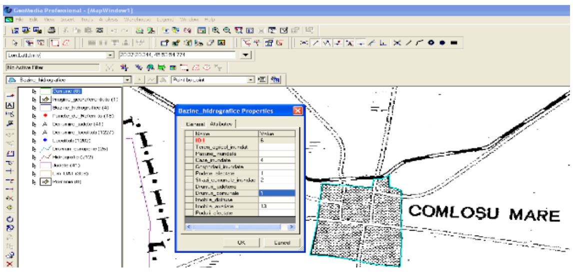

Figure 7. Defining attributive data for the new feature class

The study continues with spatial analysis of data according to the final user's needs. For example, an attribute query can be realized for visualisation [21] of hydrographic basins in which the flooded agricultural lands have an area greater than 5000 square meters. The result of the query is displayed both in the map window (2 hydrographic basins contain flooded agricultural lands with an area greater than 5000 square meters) (Figure 8) and data window (Figure 9).

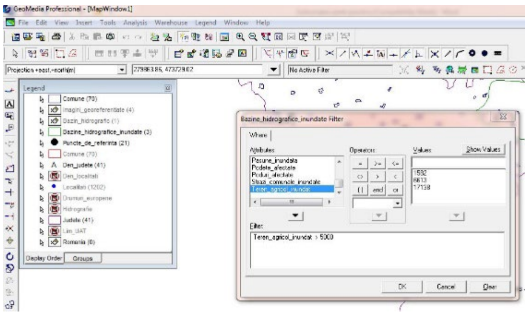

Figure 8. Defining the attributive filter

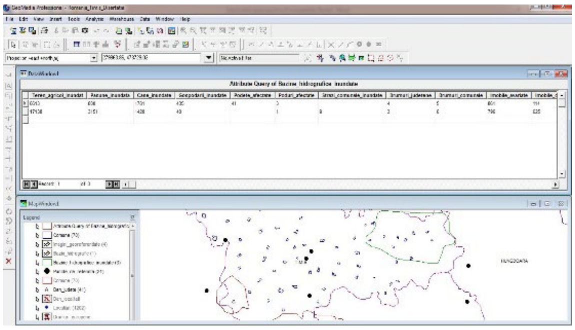

Figure 9. The interrogation results

Another example of spatial analysis involves using 10 km buffer zones around the flooded hydrographic basins in Timis county. In this case we have used the option of merging touching buffer zones. The result can be seen in figure 10.

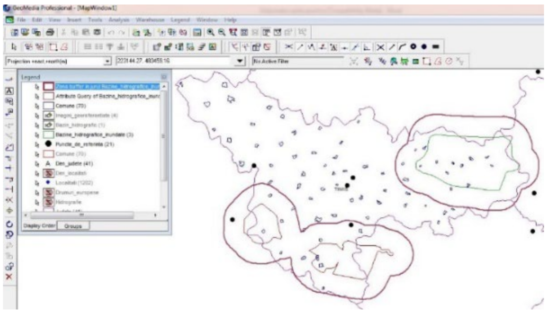

Figure 10. 10km buffer zones around flooded hydrographic basins

A spatial query which requires information regarding 2 different graphic feature classes (layers) contained into the database or queries depending on the relationship between two feature classes is illustrated next (Figure 11). It will create the possibility of finding the localities with a population greater than 2000 inhabitants which are situated into the buffer zones created at the previous phase.

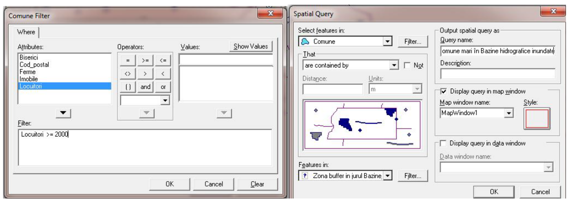

Figure 11. Defining the spatial query

The localities which are framed into the buffer zones are displayed in the map window (Figure 12).

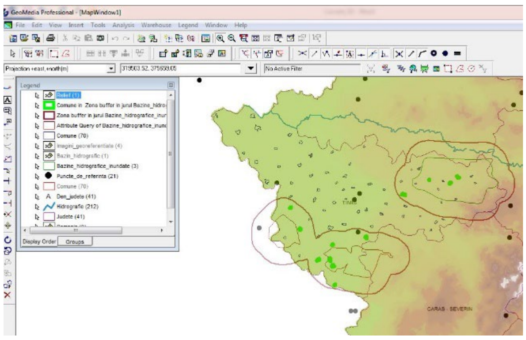

Figure 12. Displaying the localities with a population greater than 2000 inhabitants inside the buffer zones

A spatial query of the hydrographical basins which intersect European roads is shown in the picture below. The result shows the graphic element (represented in green) and its attributes (Figure 13).

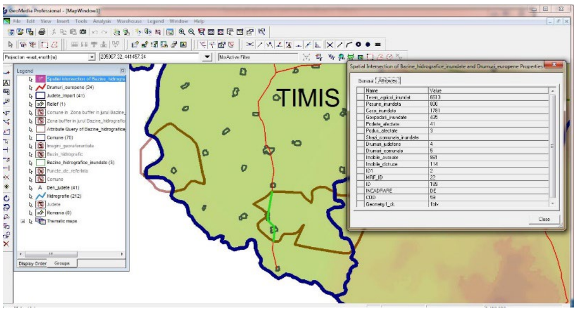

Figure 13. Intersection spatial query

The geospatial information can also be displayed as thematic maps. A competent analysis of the floods produced in Banat hydrographical area takes into account the causes that led to the floods: precipitations, average snow weight and the values of temperature (Figure 14).

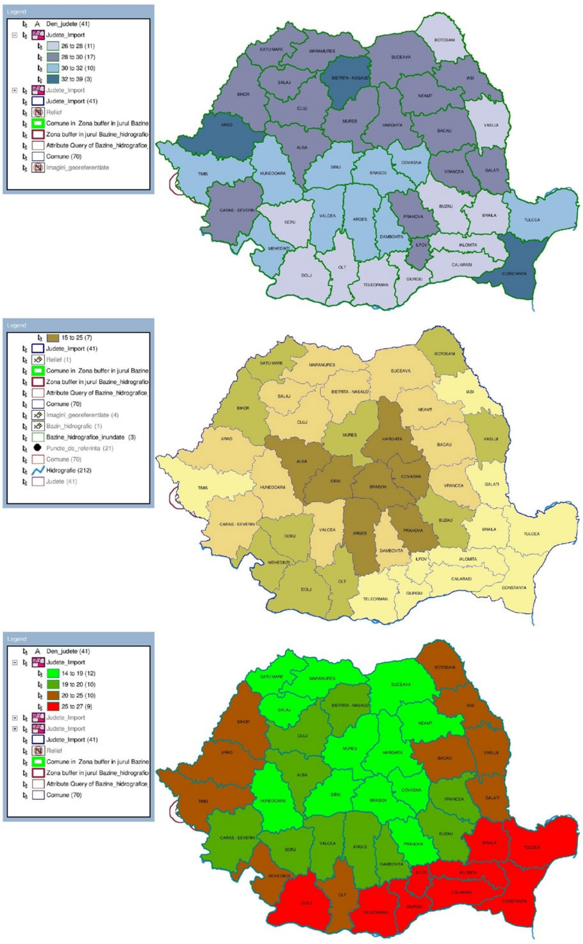

Figure 14. Precipitations, average snow weight and the values of temperature thematic maps as causes for floods

3. RESULTS AND DISCUSSIONS

GIS, as modern technology of analysis and graphical-textual database processing method, is a very important element environmental resources management [22]. The methodology presented has several advantages, the most important one being the creation of digital maps which can be subjected to spatial analysis and interrogation of the data from the associated data bases. The maps of spatial distribution of flood risk areas can clearly indicate the most affected hydrographical basins, where preventive arrangements are necessary in order to stop or improve this phenomenon.

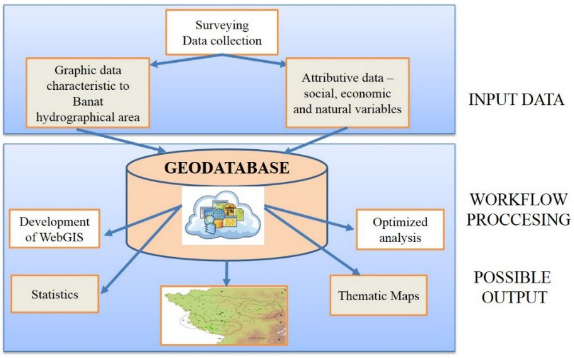

Figure 15. Flood management workflow

A good management of flood risk areas by means of GIS technology implies reading the adjacent digital maps in order to select those areas where the risk far exceeds the limitations conventionally (standardized, possibly) established and act locally through preventive and remedial measures.

3.1. STRATEGIES FOR MINIMIZING FLOOD IMPACT IN TIMIŞ COUNTY, ROMANIA

Studying floods evolution over time, in geographic context, allows obtaining results that can be classified as follows:

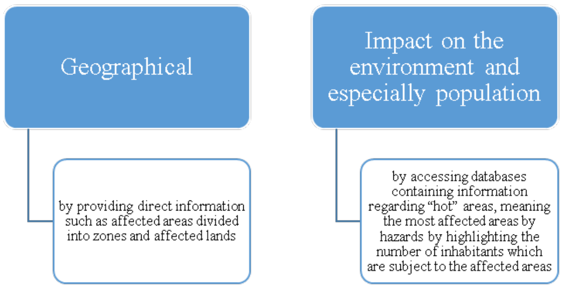

Figure 16. Floods evolution results classification

Managing flood risk areas by means of GIS technology makes effective use of all available data regarding floods and streamlines the activity of Local Authorities through easy access to associated databases. By means of GIS technology, after a thorough analysis of the map created, measures can be adopted in order to reduce the risk of flooding, such as:

- ✓ the development of maps with the areas in our country, alongside rivers, susceptible to flooding, but also of the areas cvasi-horizontal in the plains, where water can stagnate during periods with excess humidity;
- ✓ giving up on the generalized impoundment of the floodplains and of meadows and the

construction of polders, as “breathing space’ in times of flooding;

- ✓ the construction of anti-erosive works in drainage basins and the de-warping of river beds;
- ✓ prohibition of any type of construction nearby the river beds, susceptible to flooding, on the strips marked with red;
- ✓ improving the efficiency of warning systems for dangerous hydro-meteorological phenomena;
- ✓ firm commitment of the authorities with responsibilities in terms of environmental protection, but also those of the national and local levels for the implementation of measures to prevent flooding and protect the population and the environment;
- ✓ educating the population to protect river beds from liquid and solid waste pollution [23] and informing people about these phenomena and how they should behave if they occur.

In this context, managing the risk of floods aims to reduce the likelihood and/or the impact of floods. Experience has shown that the most effective approach is through the development of flood risk management programmes incorporating the elements shown in the figure below:

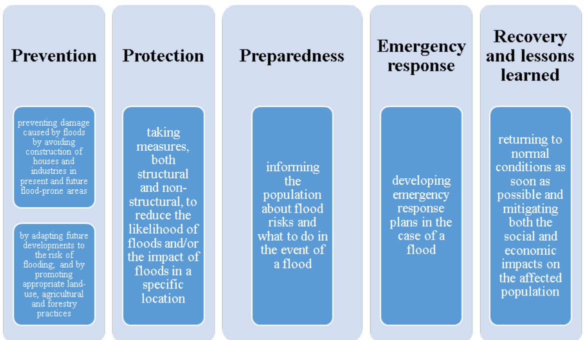

Figure 17. Necessary elements for flood risk management programmes

If Local Authorities in Romania would implement such systems, the management not only of flood risk areas, but also of landslides, erosion, earthquakes and fires affected areas would be facilitated. Thus, establishing risk ranges and colouring the map divided in sub domains, statistical study of the distribution of flood risk in the territory, extracting the areas of maximum attention on the map in order to locally prevent or remedy [24] are some of the applications that could be available at a glance.

In order to carry out a study and an efficient management of floods, the following factors should be taken into account:

1) Risk assessment of future floods based on hydrological data, types of floods (due to melting snow, heavy rainfalls) which should be consistent with the impact of climate change and land use trends of agricultural/forest lands.
2) Forecasting estimate consequences of future floods (identifying floodable areas using buffer zones) with effects on health, the environment, economic activities (bridges, destroyed roads and partially shut down) in the light of long-term evolution of such phenomena in the context of climate change.
3) Flood risk management measures – reconsidering and building infrastructure.
4) Evaluation of the existing infrastructure efficiency.

This type of practical application brings plus value for local authorities (such as Banat Water Basin Administration, the General Inspectorate for emergency situations), as it enables more effective monitoring of risk areas, and more accurate inventory of flooding events can be kept. The advantage of current geospatial information, possibly including high resolution, georeferenced digital representations products, makes the local situation to be useful to decision-makers in command-and-control centre, which are normally separated from field operations.

Also, the advantages of using such a GIS project arise from the ease with which an enormous amount of data is handled, immediate access to information, and the ability to carry out spatial analysis (creating search filters or queries depending on a number of criteria). Using GIS technology, following a brief analysis of the digital maps used, quick decisions which may be the subject of valuable development projects at micro and macro level can be adopted.

3.2. FURTHER DEVELOPMENT OF THE WORK

GIS application carried out within the framework of this paper can later be used for the creation of a webGIS, accessible to all Internet users. This type of project (WebGIS) has been successfully implemented in developed countries even by local authorities, being used for prevention (through continuous monitoring of problematic areas) and recovery purposes (such as finding the fastest paths to a location in the case of an emergency).

Subsequent decisions/support efforts when life is endangered and seconds count, are backed up by rapid communications and availability of updated spatial and precise situational data. For example, it is now possible for all participants in the activities of the rescue/recovery to know at all times the location using satellite positioning. With the availability of modern communication technology, it is possible that the same information from a location to be readily accessible to all agencies coordinating and managing specific aspects of recovery efforts.

4. CONCLUSIONS

In order to effectively prevent disasters, risks need to be evaluated and also the necessary measures have to be taken before disasters actually occur.

The level of development can reduce vulnerabilities through an increased capacity to assign resources for improving the utilities system or for constructions that have a higher level of security, to use new technologies, to implement rural development programs and forestation, and through improving the public authorities' capacity to intervene, the local authorities most of all.

In order to prevent the implications and sometimes catastrophic consequences of such hazards, it is essential to develop comprehensive monitoring programs using state-of-the art techniques, technologies and equipment covering a wide palette of phenomena based on natural and environmental conditions. This system will provide a solution for on-line monitoring of an area at risk of flooding.

Flood risk management is not only about protecting human settlements but also about maintaining ecological balance. Floodplains are essential for biodiversity and ecosystem services, such as water filtration and groundwater replenishment. GIS tools allow planners to assess the impact of flood management structures on local ecosystems and identify areas where flood management and ecological conservation goals can align. Geospatial tools and data are indispensable for effective flood risk management in the Banat Hydrographical Area. By analysing topography, land use, hydrology, and climate data, authorities can create more accurate flood models, implement better mitigation strategies, and improve flood forecasting and early warning systems. Furthermore, with the increasing challenges posed by urbanization and climate change, it is essential to continuously monitor and adapt flood management strategies using geospatial technologies to reduce flood risks and enhance the resilience of communities in the Banat region. Another approach to deal with flood risks in the studied area is represented by implementing cross-border cooperation projects with Hungary and Serbia. Effective flood management requires cooperation between different countries, especially in shared river basins like the Timiș River. GIS data and remote sensing play a crucial role in harmonizing flood monitoring and management efforts across borders, ensuring that flood control measures in one country do not negatively impact neighbouring regions.

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