Application Of Geographic Information Systems Towards Flood Management In Shkodër, Albania

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The aim of this paper is to show the advantages of GIS in monitoring and improving flood response management in Albania. A full statistic overview of the last flooding occurred in the region of Shkodra will be presented. The delicate area balances as far as water management is concerned, have turned into repetitive problematic that have become endemic to the region. The flooding in 2010 and 2011 due to heavy rain, snow melting and hydropower management caused a strong impact in the socio-economic life of the population. According to the last statistics, numbers referring to population displacement, house inundation, property damages seems to be a growing concern for the State Emergency Service. This scenario involves the role of the government institutions in both planning and the operational contexts. Uncoordinated measures between emergency groups, delayed actions from the hydropower specialists, the lack of updated geoinformation followed by a limited remote control occur due to a continuous distant approach created toward GIS technology in our country. As a solution to this scenario it will be presented a concrete platform based on calculations and statistics of dam capacity, allowed water levels, maximum rainfall levels, climate factors, population density and movements. GIS carries the potential for flood plain management, flood mapping and forecasting, also population education and awareness. Geospatial information and remote
sensing utilization serves as bridge between flooding security measures and damage evaluation. Integration of the population distribution model toward flooding classification which aims the developing of an index mapping is the first step to be initiated. In our case it is important to denote that the usage of GIS utilities is more effective in the pre-flood than the post-flood phase.

**Keywords:** GIS, remote sensing, web mapping, database, hydropower, flood, Shkodër

### 1 Introduction

The Albanian hydrographic territory has a surface of about 44,000 km², that is about 57% more than the overall country surface. The average perennial total inflow of all the Albanian rivers is about 1245 m³/s which turns the country into a vulnerable area affected by continuous inundation where Shkodra is the most affected region. According to statistics (figure 1), flood occurrences in the last twenty years report more than 40% of the natural disasters in our country.

Shkodra region is located in the north-western part of Albania. It is situated beneath three high hydroelectric power dikes which present a great risk for the area [6]. The plain of NënShkodra is part of the lowland of Shkodra situated in its southeast between the cities of Shkodër in north and Lezha in the south and covers an area of 638 km² (63 800 ha). This area represent a complex of wetlands being one of the most interesting and important not only in the Adriatic sea but even in the Mediterranean (figure 2). The lowland of Nënshkodra and the Shkodra lake shore areas during the period of intense rainfall, especially in the years 1952, 1960, 1962-1963, 1970-1971, 1979, 1994 have been flooded time after time, causing significant economic damage to agriculture land, housing, etc. Even after the construction of the Vau Dejes hydropower station on the cascade of Drini river followed by the hydropowers of Koman and Fierza that consequently made it possible for the waters of Drini river to be commanded by “the man”, but without being able to take control of floods occurring in the lowland of Nënshkodra, which still remain a threat to this area.
Having observed the annual performance level of Shkodër lake, an increase of its surface is basically affected as a result of massive floods from the rivers Drini, Kir, Gjadër, Përroi Thatë, etc especially when the hydropower gates tunnel of Vau Dejes are opened, bringing excessive blowing of the Buna river which changes it’s flow toward the lake.

### 2 Scenario

Especially in the last two years, the period between November-December has been the most critical throughout the history of emergencies
(figure 3). The irregular rainfall density is clearly stated in the annual distribution, which shows that in the half of the wet period falls approximately 65-70% of the annual quantity of precipitation.

Fig. 3. Aerial pictures of the flooded areas, Shkodër December 2010

This is the most delicate period, which on the other side followed by unusual seasonal temperatures like that of December 2010 where gauging stations revealed values reaching the (15-170C) at a time where the average values come around 40C, followed by a quick process of snow melting, which triggered an unusual increase of the Drini river flows, which has consequently increased the water levels in the three hydroelectric power lakes. The situation complicated with the risk of a possible hydropower burst that could lead to incalculable damages, due to this, in a short-time decision-making process authorities were obliged to release water which supported by heavy rain caused inundation (figure 4).

These floods have been more difficult to manage due to it’s specific size, geographical extension, type and problematic, the number of people involved in this situation, the quantity and diversity of structures that took part in their management. The consequences are evident, during the period of 1-30 December, 2010 there have been 14310 ha of drowned land, 4660 destroyed houses, 5540 houses surrounded by water and more than 14210 evacuated
people. Inundations have been caused due to a certain number of factors which will be mentioned in a row according to their coefficient of importance. Although it seems strange, the primary factor has “human” origin and derives from a poor hydropower management.

![Fig. 4. Flood extend in Albania, January 11, 2010](http://www.zkl.dlr.de)

Some floods occur slowly, some others within a night. Throughout the night of December 25 Fierza basin was almost in it’s highest allowed quotes compared to the rates approved by the coordination committee for the hydropower management. This has caused water levels in Fierza to reach the 293.1 meters from 290 meters which is the maximum limit allowed to keep the water level in the lake. Only during the night the water level increased by 3.1 m.

The maximum capacity or limit of the Fierza Lake is 296 meters and if this level is exceeded then there would be consequences. The other hydropowers run into an analogue situation. In the Koman hydropower the water level reached the 173.86 meters from an allowed maximum of 175 meters, in the Vau Dejes hydropower the water level reached the 75.4 meters from the 76 meters allowed, while in Ulëz and Shkopet hydropower the situation seemed to be even more critical, the water level was only 78 cm from the critical point (figure 5).
This precarious situation was aggravated by weather conditions still favorable to further growth of this quota which lead the hydropower authorities to open the discharged gates, which become a key factor in causing flooding. The worst possible scenario is that when the gates should be put to use, they won’t be functional, the water of Fierza lake will damage its dam and this will cause a chain reaction to the hydropowers of Koman and Vau Dejes. Then, neither Shkodra nor Lezha city will longer exist, at least.

The overall estimation of flood damage during December, 2010 was calculated over €60 000 000. More than 75% of the population of NenShkoder and 25% of the population of the city has been directly affected from the inundation consequences. The percentage is thought to be even higher if included the indirect impact caused by floods.

![Hydropower water levels, December 25, 2010](image)

3 Analysis of existing flood maps and intervention points

The analysis of this problematic must be concentrated in the missing interconnection between the rings of the chain of the flood response management process. The first step consist in defining the right schema and the exact intervention points. It must be taken in consideration the fact that floods in Shkodra have been caused as a combination of “human-natural” factors.

As already known natural factors are part of an inevitable environmental process that reduces minimally the intervention chances, so this leads our efforts to a better management of human factors. On the other side the second factor leads into a further categorization based on a
combination between timing and responsibility evaluation index, the pre-flood and post-flood phase. Figure 6 reflects a comprehensive overview of the basic precautionary processes related to flood occurrences according to the respective phase.

On the basis of this scheme stands the GIS framework which is the actual missing link, working as a regulatory concerning data flow management and administration. All these processes already run into partial or full implementation by the State Emergency Services, local authorities or private agencies, but the key issue is the lack of organization and interaction which leads to effective measures.

Fig. 6. GIS Framework (human factors)

3.1 Pre-Flood Phase

The implementation of a GIS framework first of all must serve as a platform to enable interconnectivity between several phases of the process and as a reliable solution of defence from flood in the current and future perspective. The pre-flood phase include in a degree of importance and responsibility the following issues.

3.1.1 Hydropower Management

The human factor in the pre-flood phase must be part of a correction process due to an accurate and updated data collection which will allow hydropower specialists to better manage “opening of the discharge gate” process, avoiding in this way unexpected inundations in the near lands. “It was
a routine picture on the night of 25 December, when we normally fall asleep in a quiet situation followed by an unexpected awakening in the morning aware of being sorrounded by water reaching a height over 1 meter” - is the most usual expression by most of the affected people.

The decision to be taken was a double-edged knife; On one side the security of the entire north population caused by a possible burst of the hydropower dikes from the high water level, on the other hand an immediate discharge of the waters inundating the near lands. Although for a long time the risk of exposure toward floods was highly present there was no communication or warning toward the population. The short time of reaction was insufficient to handle the situation, people where caught in surprise leading to chaos and disorder. Figure 7 shows at a comparative level the difference in a short time interval (9 hours) of what happened during the hydropower discharge process.

There were 90 small hydropower plants (sHPP) in Albania constructed before the year 1990. Actually in Albanian there are 6 big HPP and 37 sHPP in operation. Statistics rank Albania as a contry with great potentialities in the water sector for a further development in the HPP construction. Digital mapping should serve as first input data for the project initiation. These projects can be exploited to achieve a better management for the river flows creating a sustainable platform for possible inundations.

Fig. 7. Inundation phenomenon (interval 9 hours), January 2010
3.1.2 Remote Sensing

Through remote sensing and data transmission implementation it is possible to monitor the situation of illegal constructions and uncontrolled urban deposits. We can find the most critical points that needs urgent intervention by expanding and deepening the bed of river Buna which has become shallow and narrow, a process that has been exacerbated by human and natural factors, deepening of the pit lake on the outskirts of the city at various urban deposits is strongly recommended, tweak a very large amount of herbs, canebrakes, etc. Integration of remote sensing technology is a necessary step to face all these issues. Through satellite images it will be possible to identify the critical points of damaged embankments, drainage systems that need urgent intervention, also design new emergency routes.

Finding the most efficient areas for the construction of the evacuation shelters with maximum utilization. Identify the most affected areas from inerts exploitation. Imagery emphasize the importance of banning and restricting the deforestation process as an undisputed factor for inundation. An approximate evaluation of the above mentioned solutions request a found of over €5.000.000. Several projects mainly financed by European organization funds took the initiative to support and offer solutions to the management of the situation which on the other side will be inappropriate if it doesn't exist a complete set of digital maps containing a panoramic of the hidrological nodes and a repository database including previous floods occurrences data.

3.1.3 Flood risk communication and the dynamic transactional approach

One of the topics that needs immediate intervention is an educating and informing platform towards the category of population that is mostly affected by flood hazard. Especially in the last 20 years a dense inplace migration occured from the mountainous areas to the plains of NenShkodra. In this process we face two categories of groups; the first is unconscious of the risk being exposed cause they are unknown to floods as mountaineers; the second group is semi-aware of the risk but still take the chance due to their socio-economic situation.

Flood management platforms in Europe are strictly based on the use of Internet as the most effective and updated way of communication to the
population, which remains detached from time, location and offers different perspectives of the problem. On the other hand the mentioned categories don’t have a close approach to the internet and find difficulties in retrieving information. During flood management media served as one of the basic information source.

At this point we face one of the most delicate issues which is the communication and education process. Up to now there have been no concrete steps taken. The government position is far away from a guidance authority. Intermediate initiatives must be performed with the aim of achieving a strict policy awareness bypassing internet issues, trying to find optional informative possibilities like newspaper, television, direct contact through local scale meetings or reunions, etc. There is a close connection between the community reaction and the policy of the situation management. A well informed community reacts in an apparent positive way towards emergency situations.

3.1.4 Online Survey and Web Mapping Services

An adequate monitoration system is required, followed by periodically measures (meteorological and hydrological records) and comparisons between values. Updated data is among the key issues to handle the situation in the proper way. Many of the above mentioned tools are out of order or work partially reducing significantly reliability and efficiency. Information basically is retrieved from European agencies through internet use or personal knowledge causing latencies and losing the possibility for an immediate reaction which is the backbone of hazard risk response. Gauging stations stay far away from the European standards. Continuous revealed problematics have turned into serious obstacles in the daily measurements. A well evaluated monitoration system is the initial stage from which derives the whole flood response management process.

On the other side internet evolution in our country is based on matured conditions strongly supported by government directives which aims to push Albania among the countries with the highest internet usage in Europe. From the year 2005 where only 0.01 of the population had internet contracts (broadband), it sustainably increased reaching a value of 2.01 during 2008, which means that approximately 2 inhabitants from 100 where regular clients of the broadband internet services offered in Albania. During 2010 the indicator reached a value of 3.29 (figure 8). The evolution of GIS in Albania
has been strictly connected to the evolution of Internet, as a result there are favorable circumstances for Web Mapping Service development based on GIS systems.

![Fig. 8. Internet evolution, (2005-2010)](image)

### 3.1.5 Alternative Projects

A serious project has been presented by the municipality of Shkoder for the construction of the by-pass which will perform two functions, first as a dike to protect the western part of Shkodra (which occupies 1/6 of the total area of the city) from floods, second as a connection road between Montenegro and Albania. This road will have a length of about 45 km and a width that ranges from 11-54m. The cost of this project amounts to €55,000,000. Anyway it will be interesting studying the impact the by-pass will have to the flooded areas, however deeper studies need to be performed finding new routes for the evacuation process.

As a future perspective we must consider the great potentiality of the area for hydropowers construction and exploitation. Already two new HP Ashtai and Ashtaz are under construction, near the Drini river. A serious project which intend not only energetical benefits but also must be considered as a regulatory construction work which will normalize even more the large plots of Drini River more over in case of facing repeated large scale discharges from the hydropowers of Drini River (Vau Dejes, Koman and Fierze). According to the project the flow of the riverbed will be changed through the construction of a new channel between the two plants. This design will minimize flooding in the nearlands.
3.2 Post Flood Phase

The post flood phase is strictly connected to the terrain data. Emergency group coordination, evacuation routes, analogue simulation cases clearly tend in reducing the complexity of the problem. Actions must be fast and organized. Time evaluation is the key issue. The human factor in the post-flood phase must be part of a well organized process where emergency groups need to strictly collaborate with each other by exploiting satellite data which lead them to the location of the most critical areas that need urgent intervention in human life rescue, distribution of aids and materials, people displacement into safer areas, positioning of logistical equipments, better cooperation between center control unit and the outside units, etc.

3.2.1 Emergency Group Coordination

Emergency situations develop distantly in time, anyway local structures must raise up a complete platform policy able to manage flood risk. For two years the lowland of Nënshkodër has been facing almost an identical situation. A civil local emergency plan is indispensable. Periodical emergency groups are not enough. Experience showed that lack of information about the number of cattle, buildings, affected population, density, etc causes a huge wasted amount of time and energy trying to give a correct evaluation of the situation rather than immediate actions.

Schemes developed for people evacuation resulted feasible only for a short term cause the situation went rapidly out of control causing a massive block of the mobility corridors. Cooperation between emergency groups is difficult to be established without an effective communication route based on updated data from reliable sources.

3.2.2 Evacuation and Simulation

Infrastructure is said to be the backbone of modern society. On the other hand infrastructure can turn into the main issue for the population evacuation during flood occurrences. In these regions socio-economic situation is a primary factor, affecting people behavior during the evacuation process. Despite repetitive appeals by the authorities to women, children and older people to leave their homes, their difficult economic situation and strong
family relationships affects their decision-making in keeping closer distances than the settled safety distance, tending to safeguard their homes and cattles, or worse, refused the evacuation process at all, fearing for possible losses in the floods. In these conditions emergency groups need to find the most appropriate routes and locations that meet the population request.

Many times the evacuation process turns out to have a higher dangerous impact than the flood itself. A not well organized process can turn into a delicate situation not only for the evacuated population but also for the emergency groups themselves, increasing this way the complexity of the problem. The fact that for two years in a row the University of Shkodër served as a temporary shelter for affected population due to a short-time decision-making process, interrupting the studying process for more than four weeks, creating in this way a further disorder in the city, is the most obvious scenario of how the management policy needs to be reviewed. Population displacement from the areas with high flood impact into safer areas is a necessary process to be performed for the safeguard of the affected population. Their decision in living in those areas exposes into a continuous risk not only them but also the whole community.

Simulation is the assessment mirror with the scope of heightening numerous situations based on specific factors. Effective simulations help to improve the response management system. In Albania the lack of digital maps for the region makes it difficult to act out different circumstances, hence simulation must principally rely on repository databases referring to the historical events in the past like the previous floods and response measures. Anyway the obtained efficiency won’t be at a satisfactory level, requiring immediate elaboration of digital data with the aim of implementing updated digital maps. Statistics show up a high percentage of failed evacuation missions. The most usual scenarios reveal emergency groups in a clearly doubtful decision-making process during route selection.

The result consist on many missions turned back without success, inappropriate routes containing inconsistent directions and distances, etc. All this due to an apparent absence of digital maps usage and a lack of simulation methods based on previous inundations which would lead to more specific routes and evacuation places. A complete monitoring system of the zone containing risk areas must be performed. Updated imagery and precalculated scenarios should serve as an important step forward. GIS is fundamental for hazard monitoring, analyze and evaluation.
3.2.3 Evaluation

In terms of the post-flood measurements we must consider the flood evaluation process as an important supporting column for future reactions toward potentially hazards. A correctly developed assessment process is a necessary step to increase readability and usability of the collected data in service of a an explicit decision-making process. The offered post disaster satellite maps indicating the inundation depth and the flood extent are based on TerraSAR-X (DLR/ZKI).

The project SAFER (Services and Applications for Emergency Response) provided the necessary framework for taking on this task [3]. The results were also cross-checked against ENVISAT ASAR IMP data gathered on 8 January, 2010. Figure 9 presents the assets map for the Shkodër region in Albania according to EUROSENSE. This map displays the maximum assets values in €/m² (yellow to brown color range). The produced map should serve as an input data for further evaluation maps.

Fig. 9. Assets map for the Shkodër region in Albania; http://www.eurosense.com

The combination of Assets Mapping results with the flood characteristics allows assessing the damage caused by the January 2010 flood in Albania [3]. The Flood Risk Map shows the damage values for the flooded
areas as detected on January 9, 2010 (Figure 10).

Fig. 10. Flood Risk Map for the Shkodër region in Albania; TerraSar-X

The values are expressed in €/m² (yellow to brown colour range). The finalization of this map makes possible to redirect European funds considering the existing panoramic of the situation following a fair process. The evaluation process trend not only for humanitarian organization but also allows local and central authorities to increase readability and usability of data through a healthy civil protection policy to direct relief efforts to the right places and to analyze the progression of the event afterwards, so that the effects of future disasters may be diminished or even prevented.

4 Conclusions

Floods have turned into an endemic problematic in the northern region of Albania. Apart from historical events the last two years reoccurrence have revealed a worrisome reality concerning the flood response management system. Unlike from previous years the last occurrences showed to be strongly conditioned by “human-natural” factors, a combination that makes responsible a great number of authorities.

Our future efforts must be concentrated mostly in the human factors part of a complete restructuring process. Several issues need to be faced, beginning from the awareness of people or relevant structures, related to the establishment of a GIS platform for flood management as a necessity for the situation. By properly integrating the technological equipment and software we could have a full monitoring of Shkodra district, which would allow us
in the future to make more accurate decisions. Conditions are now mature, the rapid evolution of the internet due to several government policies is an incentive factor which leads to the development of Web Mapping based on a GIS system.

A better management of the human factors heighten the necessity of a detailed structuring schema, where several processes are categorized based on a combination between timing and responsibility evaluation index, creating this way the pre-flood and post-flood phase. On the basis of this scheme stands the GIS framework which is the actual missing link, being as a regulatory concerning data flow management and administration. All these processes already run into partially or full implementation by the State Emergency Services, local authorities or private agencies, but the key issue is the lack of organization and interaction which leads to effective measures.

In addition to a current and future perspective we must insist on using the remote sensing technology as a short-term solution to increase the region monitration and identify the intervention points of the main problematics like illegal constructions, uncontrolled urban deposits, deforestation, critical points of damaged embankments, drainage systems, expanding and deepening the bed of river Buna, also the pit lake on the outskirts of the city.

On the other hand existing historical repository databases should be used as the basic platform to develop the digital mapping process. Most of the information is already available in hard copies in local government institutions of municipalities or districts. Through the right tools, responsible hydropower authorities create a comprehensive overview which allows them to be one step forward toward unexpected fluctuations of the geographical data values, increasing availability and response management system. Suddenness should be a forbidden concept in these cases, and the past errors should serve as a future incentive for further improvements in the management program.

As a continuing study, it would be interesting to concentrate in setting up an integrated communication, ontime warning and notification system. The institutional structure for disaster management needs strengthening at the national level and regional level. It is important to delineate the fact that GIS technology must not serve as a replacement of the already existing solutions but should strictly cooperate with them for the benefit of producing better results.
References