FLOOD MANAGEMENT IN BOSNIA AND HERZEGOVINA: ROLE OF REMOTE SENSING AND GIS

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Abstract: The worst flooding that ever hit Bosnia was in May 2014. The official estimates indicate that over 1.5 million people were affected in Bosnia and Serbia after a week of flooding. The assessments of the damage in Bosnia go up to €2billion of euro. The loss in floods is estimated 5 to 10% of GDP (as per WorldBank estimate). The effective floodplain management is a combination of the corrective and preventative measures for reducing flood damage. These measures require integrating data from a variety of sources, including zoning, subdivision, or building requirements, and the special-purpose floodplain ordinances.There are varieties of tools to generate a flood forecasting model to identify the potentially affected zones, so as to prioritize for remediation or the damage assessment. Furthermore, it is possible to analyze the time-related data and to explore trends and phenomena, to conduct the historical analysis and "what–if" scenarios, and to track and monitor events such as excessive rainfall, track water levels, etc. Bosnia is just starting to develop these tools and methods and this could be the way to improve capability to tackle such natural disasters. This paper describes some applications of Remote Sensing (RS) and Geographical Information Systems (GIS) in identifying flood hazard zones and flood shelters and are therefore important tools for planners and decision makers. The purpose is to describe a simple and efficient methodology to accurately delineate flood inundated areas, flood-hazard areas, and suitable areas for flood shelter to minimize flood impacts.

Key words: Floods, Management, Bosnia, Remote Sensing, GIS.

INTRODUCTION

When an event such as an flood strikes a community triggering the destruction or damage of infrastructure, it is manifesting the fact that such infrastructure is vulnerable, i.e. prone to be damaged or destroyed when such an event manifests itself.
In the context of disaster-risk reduction, the disaster makes the following facts evident: The geographical area where the community is settled is exposed to such a hazard; infrastructure, assets and other processes and services which experienced damage or destruction are vulnerable.
Typically, floods can be represented through maps. Using remote sensing and GIS tools we can identify and delineate the area that can be exposed to floods. Such hazard area demarks the geographic extent of floods which can have a period of return of 100 or more years. Any infrastructure located inside this area is exposed to floods. Experts from the social and economic sciences can then assess the degree of vulnerability of the infrastructure located inside this area and can then assess the risk combining this information related to the flood hazard, the exposed elements and their degree of vulnerability.
The starting point for reducing flood risk and for promoting a culture of disaster resilience lies in the knowledge of the hazard and the physical, social, economic and environmental vulnerabilities to floods. Information on hazards is generated using catalogues of historic events and scientific models that describe the spatial and temporal

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dynamics of such hazards. Furthermore, information on places that may congregate vast amounts of people, including vulnerable groups, is used to improve early warning evacuation procedures and to establish evacuation routes in case of events that can trigger disasters.

Flood hazard maps are elaborated combining specific parameters. They are generated in coarse resolution when used at the national level and at a high resolution when used in urban areas. In many developed countries, flood hazard maps represent areas which could be flooded once every 50 or 100 years. In other cases where the historic catalogue is not complete or is not yet elaborated, flood hazard maps usually depict the areas which could be exposed to floods but without referencing to a period of return.

Information on vulnerability is more difficult to compile given its social and economic nature. In some cases detailed assessments of vulnerability are conducted using specific surveys at the level of individual houses or communities. Such approaches provide more precise information on the different dimensions or components of vulnerability and are better tailored to capture information on the vulnerability of various sectors of development. In other cases, proxies are used to estimate the vulnerability of communities using demographic data and other data derived from national censuses, as well as economic data such as the Gross Domestic Product (GDP). However, such estimates may only capture a fraction of the vulnerability.

A risk map is produced combining the information on hazard and vulnerability. Once the map is elaborated, it will be easy to detect which vulnerable elements or assets are exposed to hazards. In addition, it can be used to identify the types of measures that need to be implemented to minimize the risks and to improve disaster preparedness efforts.

FLOODS: THE ROLE OF REMOTE SENSING AND GIS

Generally, there are several uses of remote sensing observations for flood monitoring:rain rate and accumulated rain amount, snow melt rate, soil condition: soil moisture, temperature, land cover, reservoir/river level, storm water drainage system (urban floods), terrain.If floods can not be forecasted, they may be detected in near-real time. Recent availability of daily satellite observations can provide the mean to do so.

The use of sensors in the visible or infrared portion of the spectrum is limited due to cloud cover. The microwave portion of the spectrum is not restricted by cloud cover. Early work on active and passive microwave sensors for flood monitoring could not rely on satellites with daily revisit times. Since 1997 a set of new generation microwave instruments has been launched with improved performance and daily revisit capability. One of these, the Advanced Microwave Scanning Radiometer - Earth Observing System (AMSR-E) instrument on board of the NASA EOS Aqua satellite (launched in 2002), also has an extremely efficient data distribution mechanism making the data available for public download only hours after their acquisition (De Groeve at all, 2007).

There are three primary uses of remote sensing observations for flood monitoring:

1) To infer flooding conditions by using satellite-derived precipitation;

2) To derive streamflow and runoff to monitor flooding conditions by using rainfall and surface weather data in a hydrology model;

3) To detect flood water on previously dry land surface by using satellite-derived land-cover observations.

To better understand and predict floods there are hydrological models based on how much rainfall occurs and where the water will likely go once it hits the ground. They use several satellite precipitation datasets within these models to provide near real-time estimates of when and where areas may flood. While the majority of flood models currently focus on local or regional scales — taking into account one drainage basin or watershed — some recent research has shifted to estimating areas of potential flooding on a global scale. There are many examples on various scales which integrate Remote Sensing and GIS in flood alert system. The International Flood Network (IFNet) converts precipitation data from TRMM/GPM[1]into rainfall maps as part of their Global Flood Alert System (GFAS)[2]. IFNet determines flood risk based on a minimum precipitation threshold and in the future will alert communities of potential flooding in their region. There are useful information for flood forecasting and warning, such as global, regional rainfall maps, text data, and provides heavy rain information by precipitation probability estimates.

Near Real-Time (NRT) Global Flood Mapping provided by National Aeronautics and Space Administration (NASA)produces global daily surface and flood water products at approximately 250-m resolution, in 10x10 degree tiles.

The Global Flood Detection System monitors floods worldwide using near-real time satellite data. Surface water extent is observed using passive microwave remote sensing (AMSR-E and TRMM sensors). When surface water increases significantly (anomalies with probability of less than 99.5%), the system flags it as a flood. Time series are calculated in more than 10000 monitoring areas, along with small scale flood maps and animations.The Extreme Rainfall Detection System (ERDS), developed and implemented by ITHACA[3], is a service for the monitoring and forecasting of exceptional rainfall events, with a nearly global geographic coverage.

Relevance of remote sensing in emergency mapping is also evident from existence of the International Working Group on Satellite-based Emergency Mapping (IWG-SEM). According to Boccardo and Gulio Tonolo (2012), deferent types of sensors, platforms and techniques can be considered in the framework of emergency mapping. Modern agile satellites can be triggered in a very short time allowing, in best case scenarios, to have images covering the areas of interest a few hours after request. As far as the sensor type is concerned, radar SAR data are generally exploited when persistency of cloud cover make optical data unusable. Optical sensors are preferred choice to carry out damage assessment at a very high level of detail or when multispectral information is required, and are obviously the only choice when a visual interpretation approach has to be adopted for the post-event analysis. Concerning the spatial resolution, both optical and radar sensors can nowadays acquire very high resolution (VHR) imagery (with a ground sample distance up

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[1] The Tropical Rainfall Measuring Mission (TRMM), a joint mission of NASA and the Japan Aerospace Exploration Agency, was launched in 1997 to study rainfall for weather and climate research. The Global Precipitation Measurement (GPM) mission is an international network of satellites that provide the next-generation global observations of rain and snow. Building upon the success of the TRMM, the GPM concept centers on the deployment of a "Core" satellite carrying an advanced radar / radiometer system to measure precipitation from space and serve as a reference standard to unify precipitation measurements from a constellation of research and operational satellites.

[2] GFAS is promoted both by Ministry of Land, Infrastructure and Transport of Japan (MLIT)and Japan Aerospace Exploration Agency (JAXA), under which Infrastructure Development Institute(IDI) – Japanhas developed this Internet-based information system.

[3] ITHACA -Information Technology for Humanitarian Assistance, Cooperation and Action. The non-profit association, based in Torino, Italy, is a center of applied research devoted to support humanitarian activities in response to natural disasters by means of remote sensing techniques.

to 0.5 m for optical sensors). As far as the temporal resolution is concerned, availability of constellation and increasing number of earth observation satellites, drastically increase the satellite revisiting time, allowing to monitor fast dynamic phenomena (e.g. floods). Main interest of users are identification of flood affected areas. It is therefore necessary to identify the standing water on post event images and compare them to the water already present before the flood event.

The most adopted satellite sensors for flood-related analyses are radar SAR sensors, which offer following advantages:

SAR amplitude images enable easily identification of still water bodies in open areas, by means of semi-automated data processing;

The all-weather capability of the radar technology allows imagery to be acquired during night time or presence of cloud coverage (typical weather conditions during floods).

If flood impact has to be delineated in urban areas, or detailed damage assessment is required, a deferent approach based on visual interpretation of VHR optical data is generally adopted.

In recent years, national emergency operations centres (EOC) have began using **geographic information systems** as tools to generate maps and web-based mapping services such as Google Earth to visualize additional geospatial data.

THE EUROPEAN FLOOD AWARENESS SYSTEM (EFAS)

Floods are the most prevalent natural hazard in Europe. During the period 1950-2005, 240 flood occurred in Europe, 47 of those were major, i.e., the number of registered casualties is greater than 70 and/or the direct damage is larger than 0.005% of the EU GDP in the year of the disaster (Barredo, 2007).

The European Flood Awareness System (EFAS) is the first operational European system monitoring and forecasting floods across Europe. It provides probabilistic, flood early warning information up to 10 days in advance to its partners: the National Hydrological Services and the European Response and Coordination Centre (ERCC). The aim of EFAS is to gain time for preparedness measures before major flood events strike particularly for trans-national river basins both in the member states as well as on European level. This is achieved by providing complementary, added value information to the National hydrological services and by keeping the European Response and Coordination Centre informed about ongoing floods and about the possibility of upcoming floods across Europe. EFAS is running fully operational since October 2012.EFAS uses multiple weather forecasts and Ensemble Prediction Systems (EPS) as input. Its forecasts are based on two deterministic, medium-range forecasts from the European Centre for Medium-Range Weather Forecasts (ECMWF) and the German Weather Service (DWD), (and thus different models) and on two sets of EPS: One from ECMWF which covers the medium-range up to 15 days globally (with a spatial resolution of ~30 km and 51 members, and one from the Consortium for Small-scale Modeling (COSMO), a limited area model EPS covering most of Europe with a shorter range up to 5 days (with a spatial resolution of 7 km and 16 members). The reason for using the shorter term EPS is to enhance the spread of EPS within the first few days and to have a finer grid information in particular for mountainous areas. This allows to better identify the location of the floods within the river basin. In a case study it has been demonstrated that using the eight global medium-range EPS available worldwide can provide a higher reliability for the results, but is computationally intensive.

The hydrological model used for EFAS is LISFLOOD. The model is a hybrid between a conceptual and a physical rainfall-runoff model combined with a routing module in the river channel. LISFLOOD has been specifically designed for large river catchments. A particular feature of LISFLOOD is its strong use of advanced Geographical Information System (GIS), in particular as a dynamic modelling framework.
EFAS is providing information to the national hydrological services only when there is a danger that critical flood levels might be exceeded. Ministry of Foreign Trade and Economic Relations of Bosnia and Herzegovina has started initiative of access to EFAS during 2015.

Bosnia and Herzegovina case: floods in May 2014

Three months' worth of rain fell in only three days; it is the heaviest rainfall in BiH since records began in 1894. An estimated 1.5 million people in 60 municipalities in BiH are affected (39% of the population). The most affected are Bosanski Šamac, Odžak, Orašje, Doboj, Bijeljina, Brčko, Maglaj. More than 2,500 households in the Federation of BiH and approximately 8,200 in Republic of Srpska were without electricity.A total of 24 people had been killed, of whom 7 were from the Federation of BiH and 17 were from the Republic Srpska. 2,610 landslides have been reported as of 22 May (UNCT BiH 22/05/2014). Landslides and debris remain a danger in BiH, in areas worst-affected by the floods. Landslides have moved mines and warning signs to unknown locations. Nobody had been killed or injured, but several incidents have occurred, including a mine exploding in Brčko district in the north of BiH.
According to Report of Commission formed by city of Bijeljina, total damage only in that city is over €62 million, but some estimates goes to over €200 million. Over 60% of damage was citizen's property, 38% was property of companies, and about 2% of damage is on infrastructure.

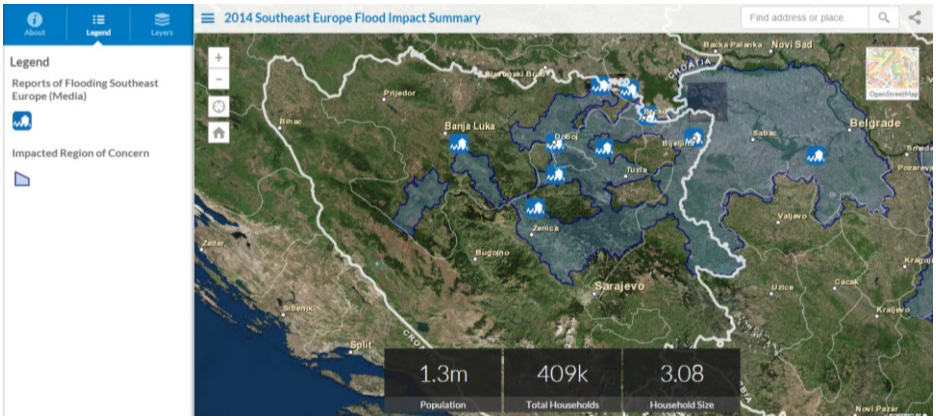

Fig. 1. Southeast Europe floods in May 2014, the most affected zones.

Relief efforts are being hampered by the infrastructure destroyed, broken telecommunications, blackouts. The problem of shifting minefields may also hamper the provision of aid and relief and debris clearance, with the governments warning international rescue teams not to use alternative roads without prior consultation with the Mine Action Centre and Civilian Protection Service (Bosnia and Herzegovina – UNDP

Flood Disaster Situation Report 20/05/2014). According to World Resources Institute and Water Risk Atlas, the most exposed to floods is northern part of Bosnia and Herzegovina with high flood occurrence recorded from 1985-2011 The number of floods recorded in that period is within 10-27.

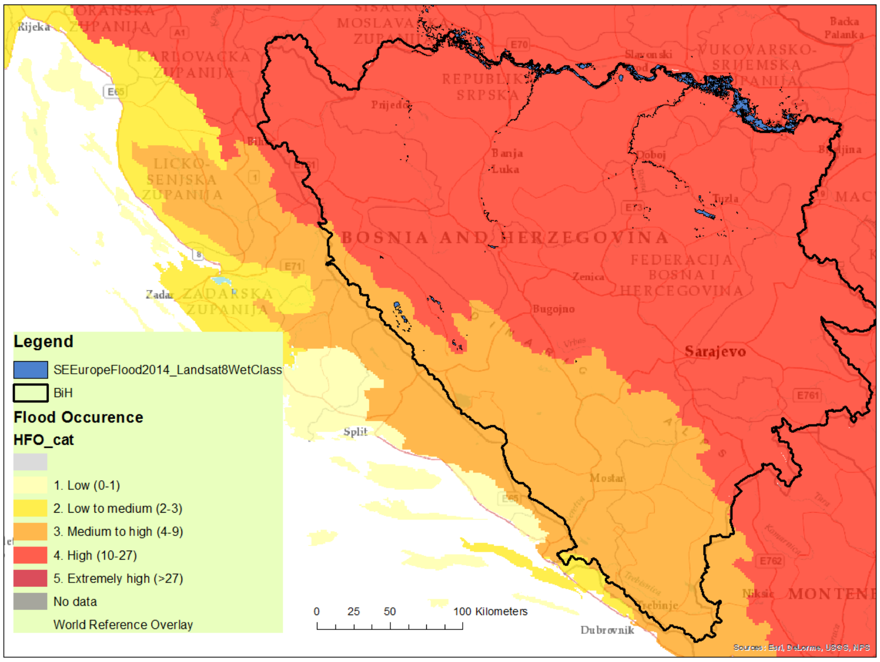

Fig. 2. Flood occurrence in Bosnia and Herzegovina from 1985-2011

Southern part of the country belongs to medium to high flood occurrence within 4-9 floods in given period. Small part in the coastal area has low to medium risk score. According to Aqueduct Global Flood Analyzer[1], floods are categorized by how likely they are in a given time period, i.e. their probability. For example, 1:25 means yearly probability of a flood is 4%. This means that on average this flood will occur once in 25 years. Statistically, however, it is possible to have the associated level of flooding more than once in that time period. The highest probability for floods occurrence are situated in major river valleys in Bosnia: Sava, Vrbas, Bosna and Drina. Probability of inland floods varies among 0 and more the 20 %.

[1] The Aqueduct Global Flood Analyzer is a web-based interactive platform which measures river flood impacts by urban damage, affected GDP, and affected population at the country, state, and river basin scale across the globe. It aims to raise the awareness about flood risks and climate change impacts by providing open access to global flood risk data free of charge. Analyzer identifies the future change in flood risk driven specifically by climate change and socio-economic development.

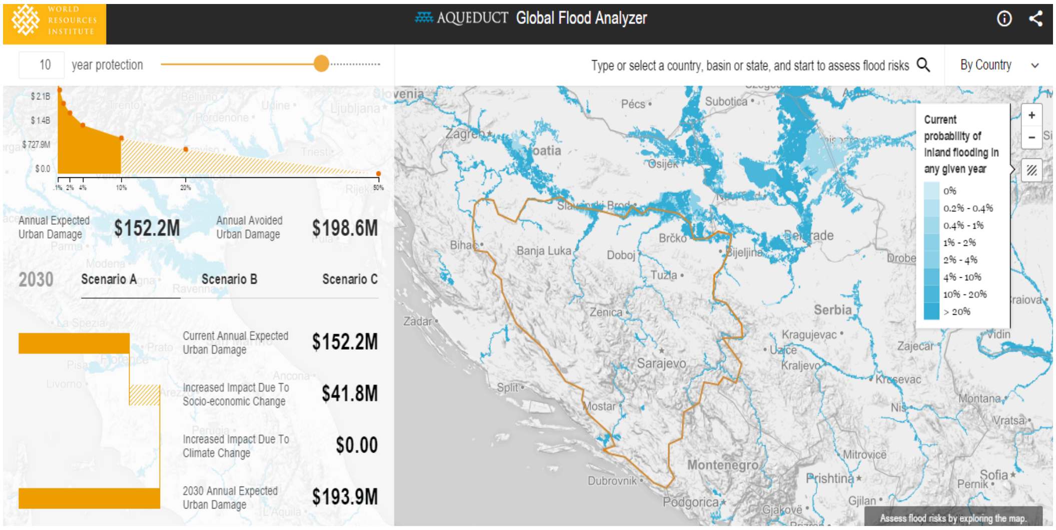

Fig. 3. Bosnia and Herzegovina probability of flooding
Source: http://floods.wri.org/#/country/29/Bosnia%20and%20Herzegovina

A 10-year flood has 10% probability of occurring in a given year (2010), and could cause roughly $ 1.1 billion urban damage in Bosnia and Herzegovina, if there is no flood protection. Annual expected urban damage is $152.2 million according to Scenario A[1], and $193.3 million in 2030. Urban damage estimates the annualized direct damage to assets due to inland flooding in urban areas. Affected Gross Domestic Product (GDP) estimates the annualized GDP by inland flooding in given area. Annual expected affected GDP for 2010 is $ 453.7 million and $ 899.4 million for 2030. A 10% probability of floods occurring in 10 years period could cause roughly 471.0 thousand affected population in Bosnia. Period extended on 100 years period could cause about 556 thousand affected population.

United Nations in Bosnia and Herzegovina implements two floods recovery programmes: EU Floods Recovery Programme implemented by the United Nations Development Programme (UNDP), the International Organization for Migration (IOM) and the United Nations Children's Fund (UNICEF). The Programme aims to rehabilitate 4,000 dwellings for approximately 14,000 people, 100 local roads and bridges, 90 educational institutions (including pre-school facilities), 10 water and sanitation facilities, three municipality buildings, four Centres for social welfare, and four healthcare facilities and sustain and help create some 2,500 income opportunities for vulnerable and excluded groups, affected farmers, agricultural households and those employed by affected SMEs. Programme value is EUR 43.5 million. Also, there is UN Floods Recovery Programme "Today, for us", worth USD 22.6 million.

[1] Scenario A is future scenario taking into account both climate change and socio-economic change.Difference between scenarios is in moderate (A) and severe (B) climate changes and severe climate changes and uncontrolled population growth and fragmented economy (C).

CONCLUSIONS

Conventionally, flood mapping is done by overlaying a pre-flood image and a peak floodimage to delineate the inundated area. Maps are the best way to display the geographical extent of such events and to overlay relevant information including the location of affected communities, road infrastructure and other areas.The use of satellite imagery and geographic information systems allows to become aware of relevant fact, such as the number of hectares affected by floods, households, or the number of kilometres of roads which have been affected or destroyed. Space-based information also allow to take note of roads which could be used as emergency evacuation routes or as roads to deliver humanitarian assistance to those who require it in remote areas.Bosnia and Herzegovina is a developing country which develop their capacities step by step. One of the most important initiatives is to join the European and worldwide network of early flood warning, considering the massive floods which hit the country in the past, especially during 2014. In particular, it is very important to build own capacities in order to minimize next flood damages.Joining to European Flood Awareness System (EFAS) is the first step in order to access the EFAS Information System (EFAS-IS), which provide services via web portal with a protected password. Services and information should be transmitted to the Emergency Operations Centres (EOCs) operated at the municipal, provincial or national levels depending on the extent of the flood.

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