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# Coupling Field-SIG-Remote Sensing to Map Flooding. Case of Urban Agglomerations of Bou-Salem and Mjez El-Beb (Northwest Tunisia)

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## Introduction

Considered as the "granary of Rome" in Roman times, the principal cereal basin and the first water tank of Tunisia today, the study area is also known, however, for its problem of flooding. Crossed by the important river system in the country, the Majerda valley, it seems to live under the threat of water. In consulted archives (1886-2012), many large floods are mentioned and heavy damages are recorded. In this period (126 years), thirty large floods occurred, therefore almost a one flood every four years. According the archives, the most catastrophic floods have been occurred in 1907, 1931, 1947, 1973 and 2003. Damages are often heavy: more than 190 dead since the late nineteenth century. The cost of losses has reached, for instance, at the city of Bou-Salem, in 2003, eight million euros! More recently, renewed outbursts (6 times between 2003 and 2012) with sometimes huge losses, sowed fear among the population and raised voices seeking development solutions. However, management, zoning frequently flooded areas is still lacking; hence the objective of this contribution. It aims to trace through cartographic and photographic documents the major event in February 2012 taken here as an example for two agglomerations of Bo-Salem and Mjez-El Bab.

The approach in a GIS environment jointly uses the data collected from the field as well as optical and radar imagery. Work processing and analysis leads finally to two types of results. The first is the product of both direct observation and geospatial application (geomorphologic mapping, photo-interpretation of satellite photos Google Earth, GPS, MNT, etc.). The second is the result of established treatments on optical images (MODIS and SPOT 5) and radar (ENVISAT-ASAR).

## Presentation of the risk of floods in the study area: brief history

-the risk of flooding in not new….since Antiquity;
-more than 185 dead since the late nineteenth century;
-between 1886-2012 (126 years), 30 large floods occurred, almost a one flood every four years;
- according the archives, the most catastrophic floods have been occurred in 1907, 1931, 1947, 1973, and 2003;
-damages are often heavy: 8 million euros in 2003 and 2.2 million euros in 2002, only at Bou-Salem city;
-concerning the recent event of February 2012: 2 dead and enormous damages.

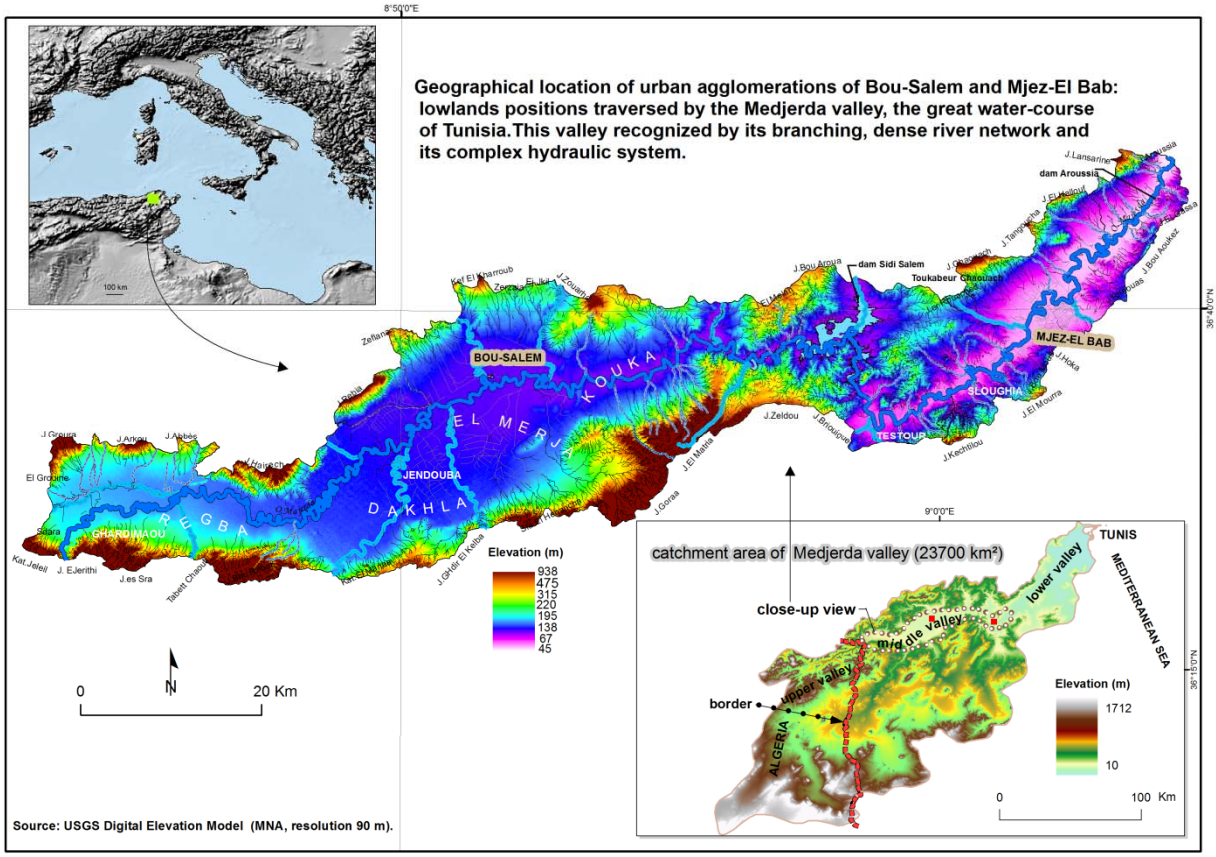


Figure 1. Localisation of the study area.

## Methods and tools

The approach used in this study is based on two types of work: the fieldwork and the laboratory work. Remote sensing and GIS (Geographical Information System) are used.

### Fieldwork

It is to make direct observations during the day and after the floods. In the affected areas, we did some interviews with citizens in order to have a preliminary idea of the extent of the floods. Their comments and remarks helped us to draw up draft outlines of flooded areas. These drafts were further clarified by visiting the affected zones. We took the GPS coordinates, took pictures, and noted the water levels and overflow points.

### Laboratory work: use of remote sensing and GIS

We aim to compile data provided by the wire Net, social networks, print and audiovisual media.

*Remote sensing*

Optical and radar images are used in remote sensing. The goal is to compensate for deficiencies in flooded areas that have not been visited. This is explained by various reasons (impassable terrain, roads cut, insufficient time…). In fact, our research has focused on

images provided free for lack of means of acquisition. It led to obtain three types of remotely sensed data.
-MODIS-TERRA
It is the MODIS sensor (Moderate Imaging Resolution Spectroradiometer) on board the Terra Satellite launched in 2002 by NASA. Its images are provided via NASA's Land Processes Distributed Active Archive Center (LP DAAC).

-SPOT 5
In the archives Geostore of Airbus, Defense and space, we found a multispectral image of 2.5m resolution. It contained some clouds at the time of the satellite overpass. However, for reasons of cost, we used only pictures. Once geo-referenced, the picture was introduced in a GIS to delineate the contours of flooded areas.

-Radar image: ENVISAT-ASAR
After acceptance of our research project, the European Space Agency's has graciously allowed us to use the radar image of ENVISAT-ASAR. ASAR (Advanced synthetic Aperture Radar) is one of the sensors on board the platform ENVISAT od ESA launched in 2002. It provides images of 30m resolution while overcoming the constraints of clouds.

*GIS environment*
It is to build a GIS application able to assemble hybrid data collected on the terrain or from other sources, cartographic and photographic documents of different dates and scales as well as alphanumeric information.
The first step is to make geo-referenced documents using the software Erdas Imagine-2010. Then, proceed to digitize certain information layers with ArcGIS 9.2 software. Next, perform a spatial analysis by crossing multiple information plans. Finally, establish thematic maps such as those used in this study.
We propose, among other things, a map of flooded areas of the city of Bou-Salem, a large-scale DEM (1/3000) showing paleo-channels through which the city is developed.
It is worth noting the use of Google Earth Globe that was of great help to pinpoint particularly the paths of water flow.

## Results

The results relate to the flood mapping of the event of February 23, 2012 in the middle part of the Majerda valley. We propose here the results for the two agglomerations of Bou-Salem and Mjez-El Beb, strongly affected by the overflows.
Occupying sites of marshy plains where the branches of the river system converge, both cities are potentially vulnerable and at high risk of flooding. Beyond conventional generators and flood factors, this event was accompanied by snow which is unusual in Tunisia. On the northern heights of Majerda watershed, the thickness of snow reached 1.5 m.
Thus, the effect of conjugated rain and snow caused overflows over large areas. The illustration is given by the result of the processing of the two MODIS images before and after the floods. Images are of medium resolution (250m) and correspond with the dates of February 18, 2012 (pre-flood) and February 24 (post-flood).
In order to extract flooded fields, we made the calculation of the difference between the NDVI (Normalized Difference Vegetation Index) before and after flood. The result is very acceptable but too general.
With the aim to see better the details, we suggest another methods and techniques.

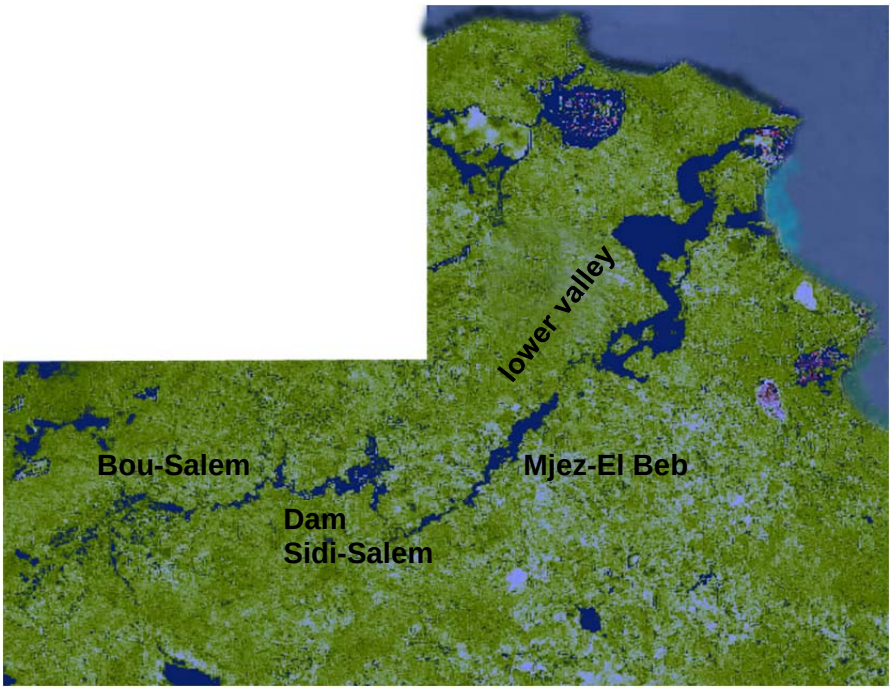


Figure 2. Flooded fields extracted by the difference between the NDVI before and after flood.

**Case of Bou-Salem**

The city occupies a low background and is surrounded by steep slopes. It is located on the passage of the main collector of Majerda and is enclosed to the right and left by two major rivers: Wadi Bou-Hertma and Wadi Kesseb. In addition, the hydrologic MNE created shows that the city has grown at the expense of the field of water. Today, it has 31000 inhabitants (2013). Moreover, the flood map drawn on the basis of fieldwork and confirmed by the satellite image Spot5 shows that the whole city was almost submerged. In total 2027 hectares or 20.3 km2.

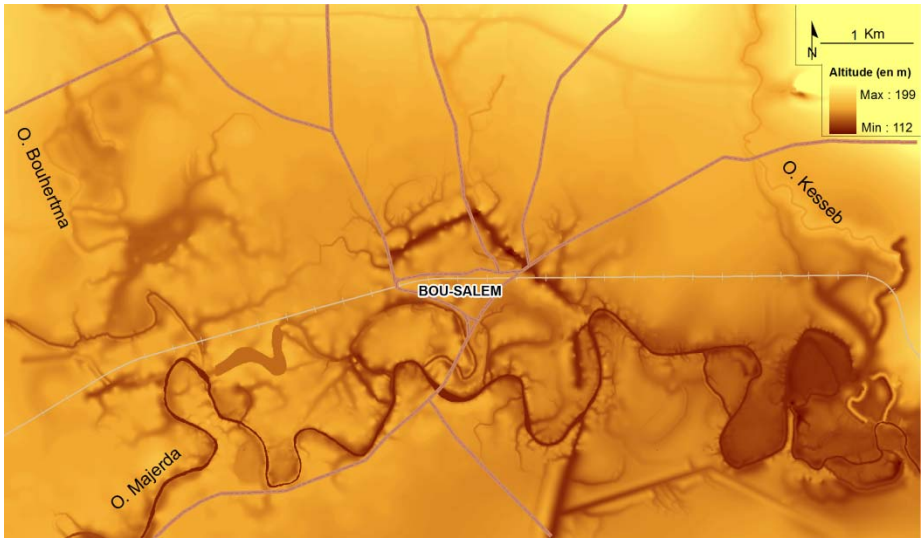


Figure 3. The hydrologic MNE.

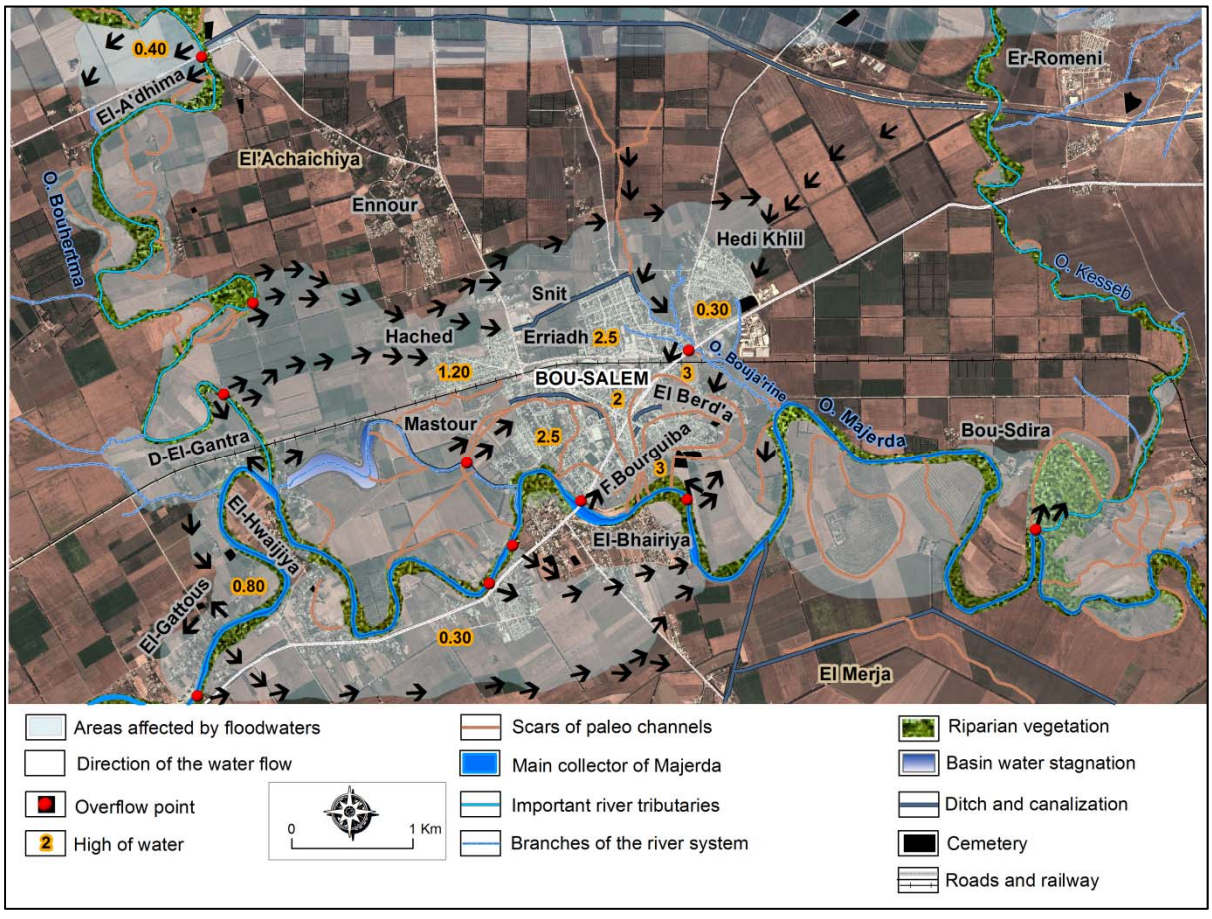


Figure 4. Flood map of Bou-Salem.

Figure 5. Spot5, (resolution 2.5 m)

Figure 6. Illustrations of inundations in the city of Bou-Salem.

**Case of Mjez-El Beb**

Located at 60 km downstream of Bou-Salem, this city also occupies a site at a high risk of flooding. Containing about 41.700 inhabitants of whom almost half are rural, it sustained substantial damages. The radar image processing ENVISAT-ASAR (30m) in synthetic color image shows that it is mostly a farmland inundated with floodwaters. The flooded areas are about 962 hectares or 9.62 km2.

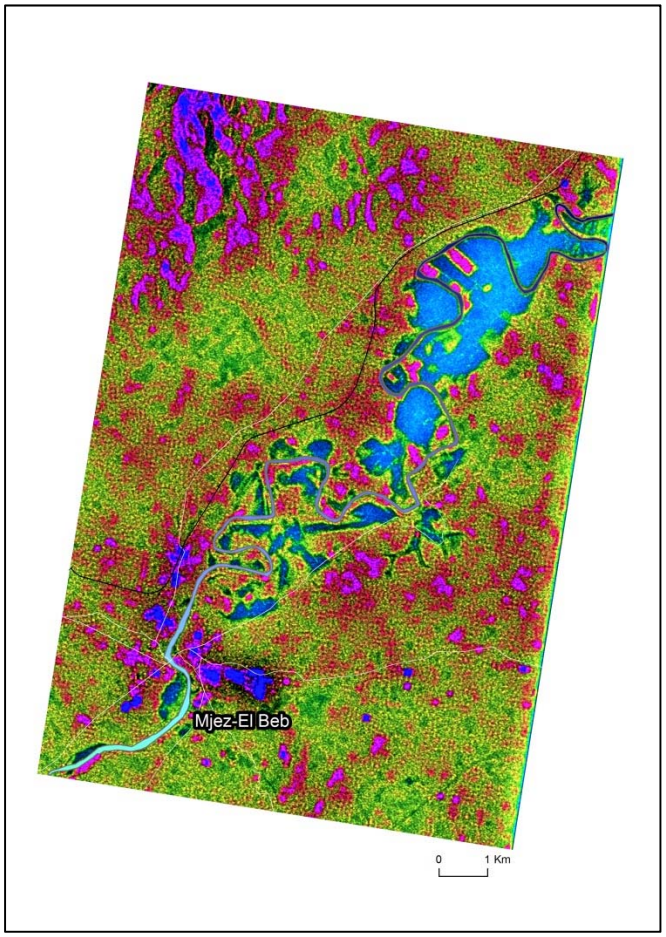


Figure 7. Synthetic color of radar image ENVISAT-ASAR


Figure 8. Illustrations of inundations in the city of Mjez-El Beb

## Conclusion

This paper presents the results of the approach used for flood mapping recorded on February 23, 2012 in the regions of Bou-Salem and Mjez-El Beb. Apart from the usual, customary damages, the event was marked by the emergence of a new factor which is snow. This event was marked by more losses and by the appearance of a new fact whig is snow. This has disrupted the calculations and predictions of hydrologists. Cartographically, direct filed observations were the starting point of this work. Similarly, the use of optical images (MODIS, Spot5) and radar image (NEVISAT-ASAR) has been of great benefit to get a fairly complete view of the flooded areas. Finally, computer processing, within a GIS, of different collected data allowed us to establish more than cartographic documents.

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