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Spatiotemporal floodplain mapping and prediction using HEC-RAS - GIS tools: Case of the Mejerda river, Tunisia

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ABSTRACT

The floods have become a scourge in recent years (Floods of, 2003, 2006, 2009, 2011, and 2012), increasingly frequent and devastating. Tunisia does not escape flooding problems, the flood management requires basically a better knowledge of the phenomenon (flood), and the use of predictive methods. In order to limit this risk, we became interested in hydrodynamics modeling of Medjerda basin.

To reach this aim, rainfall distribution is studied and mapped using GIS tools. In addition, flood and return period estimation of rainfall are calculated using Hyfran. Also, Simulations of recent floods are calculated and mapped using HEC-RAS and HEC-GeoRAS for the most recent flood occurred in February –March 2015 in Medjerda basin.

The analysis of the results shows a good correlation between simulated parameters and those measured. There is a flood of the river exceeding 240 m^3/s (DGRE, 2015) and more flowing sections are observed in the future simulations; for return periods of 10yr, 20yr and 50yr.

1. Introduction

Numerical modeling of shallow water flow is an important research topic for flood risk management. The simulation results play a significant role in national decision-making on flood prevention and control. One-dimensional shallow water models are quite often preferred in the field of engineering (Fread, D.L., 1993; Ervine and MacLeod., 1999; HEC-RAS; ISIS; MIKE11), mostly due to the fast computation (Syme, 2011) and its easy application (An et al., 2015). Also 2D models are developed and used (i.e., Bates and De Roo, 2000; Yoon and Kang, 2004; Mignot et al., 2006; George and LeVeque, 2008; Kim and Cho, 2011).

Worldwide Research studies since the 1970 have greatly improved the capability of flood modeling. The models are widely used in flood risk mapping and have been developed to simulate flooded areas (Apel et al., 2006; Dutta et al., 2006; Baky et al., 2012), flood damage assessment (Bhuiyan and Dutta, 2012; Merz et al., 2010), real-time flood forecasting (Arduino et al., 2005), and water resources planning (Vaze et al., 2013), as well as having served as an important prerequisite for investigating river bank erosion and floodplain sediment transport (Marriott, 1992; Pizzuto, 1987), and river system hydrology (Dutta et al., 2013). Combined with hydrological models, and river models, the application of flood modeling has been extended to modeling that aims to formulate climate adaptation and risk mitigation strategies.

Some studies which are carried out in Tunisia and have the aim the protection of flooded areas using statistical methods, simulations, hydrological models (Euchi, 2013; Selmi, 2013). On the other hand, the innovation of this work when comparing to local studies is the prediction of flooded areas for different return periods and the mapping of flooded zones. So decision makers can intervene effectively to protect areas with risk. and reduce the impact of floods in the future.

Flood modeling has greatly improved in recent years with the advent of geomatic tools and especially Geographic Information Systems (GIS). In fact, in this study the combination of HEC RAS, HEC–GEORAS and GIS are used to delineate the flood inundation zones, to proceed with a simulation for different dates.

The specificity of this work is to shares data with the GIS, HEC GEORAS and HEC RAS interfaces. Flood management should be considered a spatial problem because flood intensities and characteristics vary with geographic location (Foudi et al., 2015). As newer GIS software was developed that improved geospatial visualization and computational efficiency, newer versions of HEC-

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GeoRAS followed (HEC, 2002; HEC, 2005; HEC, 2009; USACE, 2016). So the main goal of this study is to estimate the extent of floodplain inundations, corresponding to Sidi Salem outflows, in order to create management plans for flood risk. Specific objectives of this work are: i) Modeling and simulation of River reach extends from the Sidi Salem dam of to Al Aroussia one using HEC RAS ii) flood risk mapping using HEC GEORAS software iii) Estimation of flood zones at return periods of interest.

2. Study area characteristics

2.1. Geographical location of the study area

The Medjerda, the major Tunisian river (Ben Mansoura et al., 2001), with its delta located on the western shore of the Gulf of Tunis (Fig. 1). It originates in northeastern Algeria and then flows eastwards to Tunisia then entering the Gulf of Utica of the Mediterranean. with a catchment covers approximately 24,000 km^2, of which 7700 located in Algeria (Bouraoui et al., 2005), an approximate water flow of 30 $m^3 s^{-1}$, Water from Medjerda is used for irrigation and is pivotal to the region's agriculture (Mlayah et al., 2009), 90,000 ha are irrigated with water from the Medjerda to which must be added 18,000 ha (DGRE, 2009). The climate is Mediterranean, characterized by mild, rainy winters and hot, dry summers with no marked intervening seasons.

In fact, temperature is characterized by a maximum of 37 °C to 38 °C measured in July and August and a minimum of 2 °C–6 °C in December and March.

The most important and recent event is the flood of February 2015 which will be considered in this study. In fact, it covers the Medjerda Watershed especially Béja, Jendouba, Bousalem, Medjez el Bab and Bizerte localities and caused two deaths. In fact, in February the highest volume of rainfall is measured when comparing to the rainfall mean (Fig. 2). The rainfall ranges between 70 mm and 180 mm in February 2015.

Consequently, these events proved that the risk of flood downstream of Sidi Salem Dam remained very high. They also emphasized the need for more reliable predictions of flood levels, which in turn call for accurate simulation.

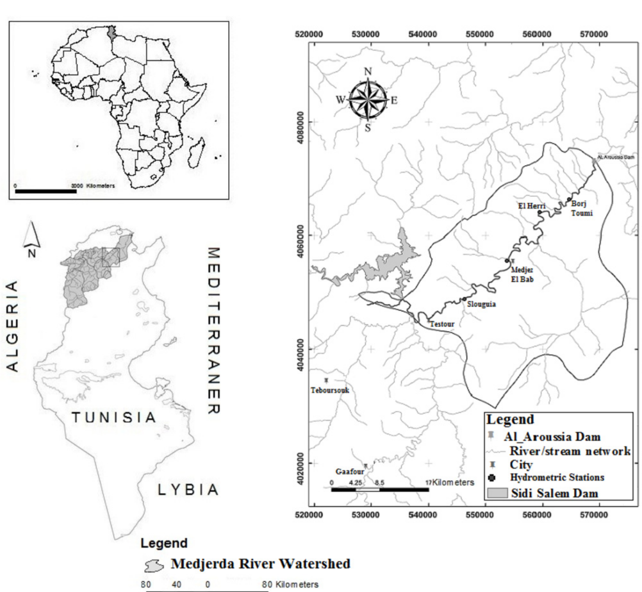

Fig. 1. Localization of the study area.

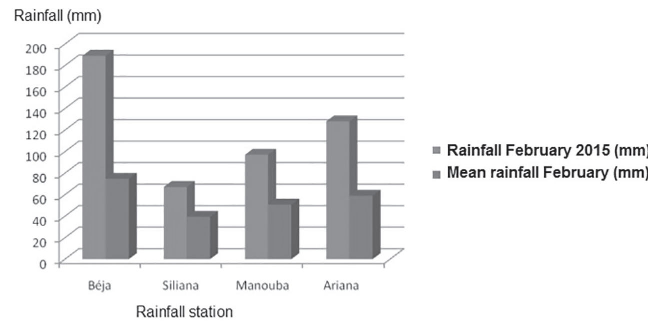

Fig. 2. Comparison between rainfall measures in February 2015 and the mean Rainfall in rainfall stations of the study area.

2.2. Hydrologic characteristics of Medjerda River

For our study case, we opted for the middle valley of Medjerda. We will pay a particular attention to the reach located between the two dams of Sidi Salem (the largest dam in North Africa) and Al Aroussia (Gharbi and Soualimia, 2016) (Fig. 3). This reach is extended over a length of 85 km; it is powered by tributaries which are (Ben Khalfallah, 2015);

- The Siliana hydrographic network/Wadi: This is a major tributary of the Medjerda which drains a basin with an area of 2220 km^2. The annual average supply to the dam is estimated at 6 50.10^6 m^3 year $^{-1}$ (Ben Khalfallah, 2015);

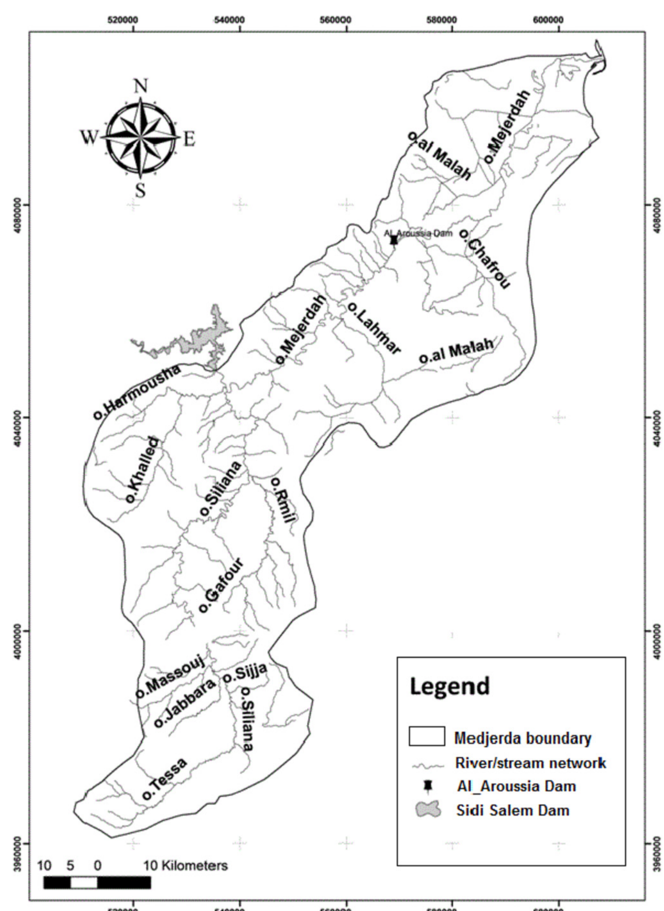

Fig. 3. Hydrographic network tributaries of Medjerda River (Ben Khalfallah, 2015).