Using GIS and Analytical Hierarchy Process (AHP) for flood hazard assessment based on morphological and hydrological criteria, case of the Meknes region, Morocco

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Abstract. Flooding is one of the most significant natural disasters affecting North Africa. Its impact is increasingly intensified by climate change. Flood risk is a combination of natural and anthropogenic factors, highlighting the importance of understanding its spatial distribution in order to plan effective land management strategies. The main aim of this study is to identify and map areas at risk of flooding in the R'dom catchment area (Meknes, Morocco). This hazard is assessed by taking into account morphological criteria (slope, altitude, density of the hydrographic network, curvature) and hydrological criteria (drainage density, stream power index (SPI) and rainfall data). The methodology adopted is essentially based on a multi-criteria analysis using analytical hierarchy process (AHP), with the use of GIS tools and satellite data. A flood hazard map was drawn up, with classification according to degree of susceptibility. The resulting map reveals that 26.3% of the study area is characterized by a high to very high flood hazard. Moderate flood risk accounts for 56.9% of the study area. These results underline the crucial need to implement effective flood mitigation strategies to protect communities from flooding.

Keywords: Meknes, GIS, AHP, morphologic, hydrologic, hazard flood

1 Introduction

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Floods are a major risk in the contemporary world. They are at the forefront of natural disasters in the world. Like other countries, Morocco, and more particularly certain regions, is subject to floods, which are becoming more and more aggressive and recurrent, especially in the context of climate change.

This study is conducted with the aim of identifying and mapping areas sensitive to flood risks; because optimal flood management requires a good knowledge of the causes of the phenomenon and a good mapping of its extension [1]. The methodology used is based on a multi-criteria analysis associated with geographic information systems (GIS). Using multi-criteria analysis, it is possible to evaluate the relative importance of each criterion and sub-criteria (factor) inducing flooding, by assigning it a weight [2-4].Finally, the flood hazard map will be developed taking into account morphological and hydrological criteria.

2 Study area

The study area is located in the Saïss basin. This basin is a vast plain located between the Rif mountain ranges to the north and the Middle Atlas to the south. It constitutes the upstream part of the R'Dom watershed just after the confluence of the Boufekrane river and the Ouislane river [5, 6].The R'Dom river crosses several agricultural and urban areas such as the city of Meknes and the city of Boufekrane. The area of the study area is of the order of 1284Km2. The altitudes of the region decrease from South to North. They vary from more than 1200m in the South to less than 300m in the North.

The climate of the region is Mediterranean, with hot, dry summers and relatively mild, rainy winters.[7-9]... Precipitation is mainly concentrated during winter and early spring.

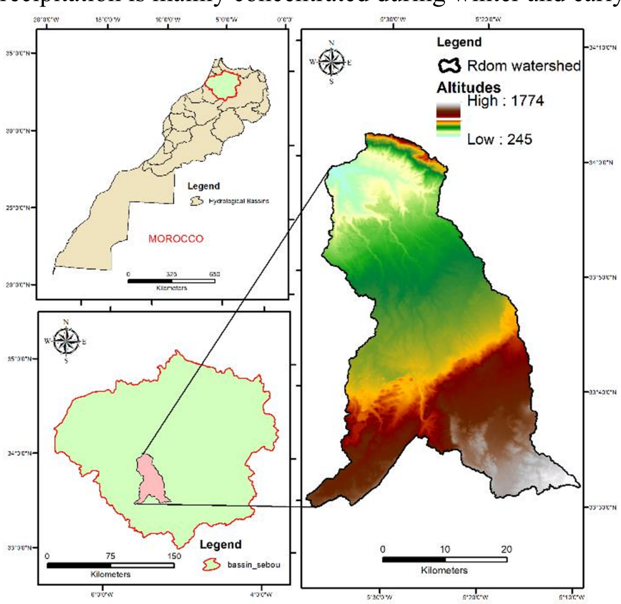

Fig. 1 Geographic location map of the study area on the scale of Morocco and the Sebou basin

3 Material and method

3-1. Material

The physical data used in this study were collected from various sources (Table 1)

Table 1. Types and description of data used [10, 11]

Data type	Description	Resolution/Scale	Source
Digital Terrain Model (DTM)	ASTER GDEM, Downloaded	30m	Earth explorer
Landsat 9 image	Downloaded	30m	Earth explorer
Land use (LULC°	Downloaded	10m	Sentinel-2 at 10m resolution (ESRI)
Precipitation	Daily, monthly data	Climate stations	ABHS and World Climate website

2-2. Method

In this study, to produce the flood susceptibility map, the AHP multi-criteria analysis technique combined with GIS was used. This technique provides a systematic approach to assess and integrate the impacts of various factors that involve different degrees of dependent or independent, qualitative and quantitative information. The process of the method can be summarized in three steps: factor selection and evaluation, AHP multi-criteria analysis, and flood susceptibility analysis.

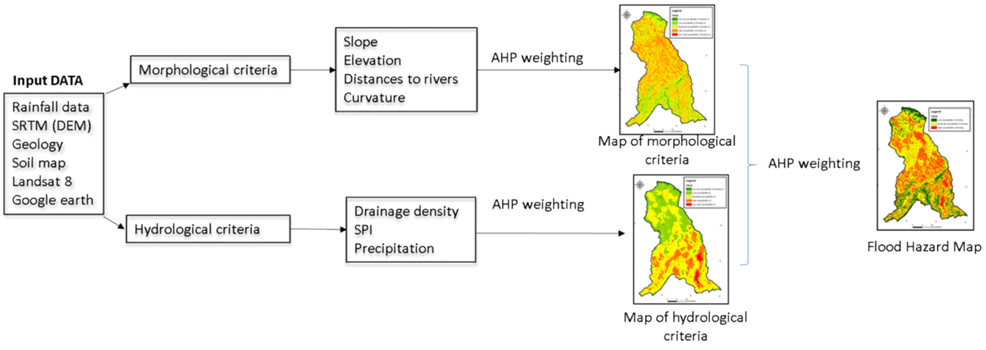

Fig. 2 Flowchart of the adopted methodology

AHP (Analytic hierarchy process) [12-16] is the multi-criteria analysis technique used in this work. It's considered, as an optimal method to prioritize multiple factors in order to generate spatial information of flood susceptibility [17-23]...The map thus produced will be validated by historical flood data and field observations.

4 Results and Discussions

4-1 Map of morphological criteria

The morphological parameters used are elevation, slope, distance to rivers and curvature[24, 25]. These four parameters were used to develop the morphological criteria map using GIS and AHP method. After peer comparisons of the parameters were carried out and the results of the different weightings generated revealed that the slope factor with 0.581 as weighting has the greatest influence on the occurrence of floods in the study area. Next, come the distance to rivers (0.235), elevation (0.130) and curvature (0.081). The consistency ratio (CR) value is 6%, which indicates that the weighting of the factors was consistent (i.e. CR less than 10%).Thus the morphological map is obtained using the expression

Morphological map = (Slope*0.581) + (Distance to River *0.235) + (Elevation*0.103) + (Curvature *0.081)

4-2 Map of hydrological criteria

The hydrological parameters used are drainage density, stream power index (SPI) and precipitation.[26].... These three parameters were used to develop the hydrological criteria map using GIS and the AHP method. After peer comparisons of the parameters, the calculation of the consistency coefficient (RC) is of the order of 2% (less than 10%). The weights obtained for the drainage density, precipitation and SPI parameters are respectively 0.557, 0.320 and 0.123. Thus the hydrological map is obtained using the following expression:

Hydrological map = (Drainage Density * 0.557) + (precipitation * 0.320) + (SPI* 0.123)

4-3 Flood hazard map

The flood hazard map is obtained from the two morphological and hydrological maps[27]... with respective weights of 73.8% and 26.2%. This map is classified into three according to the degree of flood hazard: low hazard, medium hazard and high to very high hazard. The areas with high and very high susceptibility to flooding represent 26% of the surface area of the study area. The moderate susceptibility class represents the dominant class with 57% of the surface area of the study area. On the other hand, the low susceptibility class to flood hazard represents only 17% of the watershed.

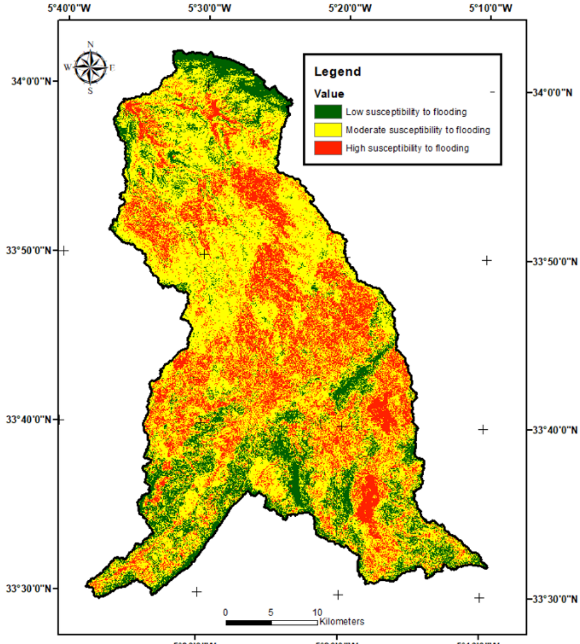

Fig.3 Flood hazard map in the R'Dom watershed

The superposition of this map with the map of the urban sector (Meknes, Boufekrane, etc.) allowed us to identify urban areas with high to very high susceptibility. These areas must be taken into account in all land use planning actions.

5 Conclusion

This research deals with the mapping of susceptibility to flood hazard as a preliminary approach to the prediction of this natural risk in the upstream part of the R'DOM watershed (Meknes Region). The susceptibility to flooding was mapped by applying the AHP method based on multi-criteria analysis integrated into the GIS. The map of morphological criteria is developed from the parameters (sub-criteria) elevation, dip, curvature, distance to the hydrographic network while the map of hydrological criteria takes into account the parameters (sub-criteria) precipitation, drainage density and river power index (SPI). For both criteria, and after validation of the consistency coefficient (CR <0.1), weights were assigned to each sub-criteria. The flood hazard susceptibility map obtained was classified into three classes: high to very high, moderate and low to very low with respective proportions of 26%, 57% and 17%. Since our analysis depends only on physical factors rather than social or economic, this map will be indicative of flood susceptibility rather than risk. Flood hazard mapping, using Hierarchical Process Analysis (HPA) and especially in a climate change context, is very useful for decision-makers and land use managers in the Meknes region.

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