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Flood risk assessment and mapping using multi-criteria analysis (AHP) model and GIS: Case of the Jendouba Governorate – Northwestern Tunisia

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Abstract

Flooding is one of the main natural disasters in Tunisia, especially in the Jendouba region (northwest) along the Medjerda River. Frequently updated maps of flood areas should be used as a decision-making tool in managing flood risk. This study aims both to map those areas of the Medjerda River within the Jendouba Governorate which are at risk of flooding, as well as to draw up management maps to prevent against flooding. The approach taken was based on both geomatics tools (satellite imagery and GIS) and multicriteria analysis of the Medjerda River watershed. Flood risk was mapped by taking into account some causative factors at watershed scale: average annual rainfall, land use, surface slope, soil type, drainage density and hydrogeological maps. The relative impact of these factors was weighted using the Analytical Hierarchal Process (AHP) method. The greatest impact was attributed to annual rainfall (30%), followed by drainage density (21%), hydrogeological factors (21%), slope (17%), and land use (11%). These maps were then integrated in the GIS to generate a final flood risk map of the studied area, according to which can be seen that flood areas are mainly localized: 1) on both sides of the major bed of the river, resulting from overflow of the river, and 2) in low altitudes where the water table is very close to the surface. The flood risk map is published and shared via Web-GIS in real time.

Key words: flood risk, Web-GIS, Medjerda River, Jendouba, AHP

Évaluation et cartographie des risques d'inondation à l'aide du modèle d'analyse multicritères (AHP) et du SIG: cas du gouvernorat de Jendouba - Nord-ouest de la Tunisie

Résumé

Les inondations sont l'une des principales catastrophes naturelles en Tunisie, en particulier dans la région de Jendouba (nord-ouest) le long de la rivière Medjerda. Des cartes des zones inondables fréquemment mises à jour devraient être utilisées comme outil de prise de décision dans la gestion des risques d'inondations. Cette étude vise à la fois à cartographier les zones qui sont menacées d'inondations de la rivière Medjerda dans le gouvernorat de Jendouba, ainsi d'établir des cartes des risques d'inondations. L'approche adoptée était basée à la fois sur des outils de géomatique (imagerie satellitaire et SIG) et sur l'analyse multicritère du bassin versant de la rivière Medjerda. Le risque d'inondation a été cartographié en tenant compte de certains facteurs causaux à l'échelle des bassins versants: précipitations annuelles moyennes, occupation du sol, pente de surface, pédologie, densité de drainage et cartes hydrogéologiques. L'impact relatif de ces facteurs a été pondéré à l'aide de la méthode de processus d'analyse hiérarchique (AHP). L'impact le plus important a été attribué aux précipitations annuelles (30%), suivies de la densité du drainage (21%), des facteurs hydrogéologiques (21%), de la pente (17%) et de l'occupation du sol (11%). Ensuite, ces cartes ont été intégrées dans un SIG pour générer la carte finale des risques d'inondations de la zone étudiée, selon laquelle on constate que les zones inondables sont principalement localisées: 1) de part et d'autre du lit majeur de la rivière, inondées suite au débordement de la rivière, et 2) à basse altitude où la nappe phréatique est très proche de la surface. La carte des risques d'inondations est publiée et partagée via le Web-SIG en temps réel.

Mots clés : *risque d'inondation, Web-SIG, rivière Medjerda, Jendouba, AHP.*

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INTRODUCTION

Floods remain among the most frequent disasters in recent decades (Ballais et al., 2005; Maihepireti et al., 2013). They represent 34% of natural disasters in the world (Ben Ouezdou, et al., 1991). In Tunisia, the most damaging floods were those of 1969, 1973, 1990, 2003, 2007 and 2012 (Daoud et al., 2009; Fehri 2014). The governorate of Jendouba, in the north-west of the country, was one of the most affected areas of Tunisia. The meteorological and hydro-geomorphological characteristics of the region appear to be among the natural factors causing floods. These floods are of great concern to the riverside populations and to the Tunisian authorities.

To ensure the management of this phenomenon, a good knowledge of the causal factors as well as a good mapping of the flood extent appear necessary. Remote sensing and GIS can play a leading role in this quest for knowledge (Maurel et al., 2011; Ezzine et al., 2020). In fact, remote sensing and GIS are particularly powerful tools, especially in flood monitoring (Meyer et al., 2001). These tools can also be used to study flood risks at different scales (global, regional and local), as well as in decision support for the implementation of a risk prevention plan. Flood risk could be calculated by multiplying hazard components by vulnerability ones. Hazard represents the random natural phenomenon reflected by the overflow of the watercourse and the flood extent of water in the flooding field, whereas vulnerability is characterized mainly by the sensitivity of the land use to the phenomenon of flooding (Pottier et al., 2005). The hydro-climatic factors, mainly distribution of the annual rainfall and drainage network (Abidi et al., 2019), generally characterize the hazard (Meyer et al., 2001). Among factors influencing flood conditions and thus potentially vulnerability are: geology, pedology, land use, hydrology and relief (slope) (Benson, M. A., 1959).

Several multi-criteria decision-making (MCDM) methods with different complexity and assumptions could be used in order to assess weights of factors influencing flood risk. According to Tscheikner-Gratl et al., (2016), these methods could be categorized into three categories:

1) Value measurement models: assigning a weight to each factor according to its importance (e.g., Analytic Hierarchy Process, AHP; Weighted Sum Model, WSM);

2) Goal, aspiration and reference level models: measuring how good alternatives reach determined goals (e.g., TOPSIS);

3) Outranking models: comparing the alternatives pairwise for each factor in order to find the strength of preferring one over the other (e.g., ELECTRE, PROMETHEE).

The Analytic Hierarchy Process (AHP) has been and still the most common used approach in evaluating flood risk (Danumah et al., 2016; Tscheikner-Gratl et al., 2016). It was used in urban flood management in order to find out the priority of flood vulnerable zones taking into account the environmental, technical and social phenomena. It is also a widely used for estimating factor weights for a variety of research fields (e.g., landslide vulnerability of areas and forest fire risks (Feizizadeh, B., et al 2015).

The main objective of this study is to: 1) identify and characterize the vulnerability of the factors contributing to the flood phenomenon using the hierarchical analysis process (AHP) and geomatic tools, and 2) delineate areas at risk of flooding. The study area is Jendouba governorate, often flooded by Medjerda River during large flood.

MATERIALS AND METHODE

Study area

This study has been carried out in Jendouba Governorate, northwestern Tunisia. It is bordered by the Kef and Siliana Governorates in the south, the Beja Governorate to the east, and Algeria to the west (135 km) and the Mediterranean see to the north with a coastline of 25 km (Fig1). The Jendouba Governorate covers 3102 km², with 416,608 inhabitants, representing 4.2% of the national population. The rate of urbanization of the Governorate remains very low, 28% in 2009 (Atlas Jendouba and INS, 2012 and 2016). Jendouba Governorate has a highly wet climate with annual rainfall reaching 1 000 mm on the coast and more than 1500 mm in Aïn Draham. Agricultural region by tradition, the region is experiencing a spectacular development of tourism (the region of Tabarka and Aïn Draham). The rains are often violent and have serious consequences on the natural environment especially on the soils since they increase the aggressiveness of the flows and consequently the water erosion and the flood. Winter is the rainiest season with 45.65% of precipitations, spring has reached 34.55%, autumn with 17.3% and summer remains very dry with only 2.6% (DGRE, 2012). This area has strong local climatic contrasts due to the rugged relief nature and the topographical complexes perpendicular to the dominant humid flux.

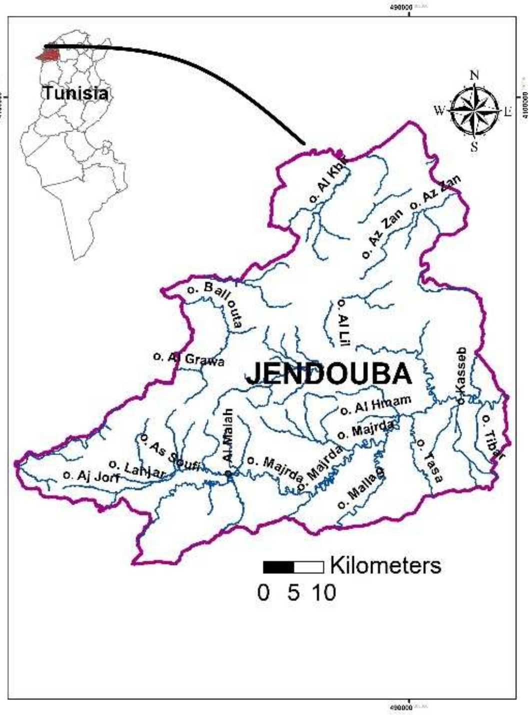


Fig 1: Study area location.

Data and processing

Several types of data layers were used in order to map flooding risk in Jendouba. These data were extracted from the thematic maps (topographical, soil types, geological), satellite images and rainfall stations of Jendouba.

Topographic maps (1:50 000 scale) covering the entire governorate, provided by the Office of Topography and Cartography (OTC), were used to calibrate satellite images. The 2016 Landsat 8 (OLI) (Operational Land Imager) satellite imagery of the 2010 RADAR images (SRTM) was used to extract: 1) the land use map (2016), 2) the Digital Elevation Model (DEM) of the study area, 3) the slope map, 4) the slope management map and 5) the hydrographic network map. Daily, monthly and annual rainfall time series, were collected from 2005 to 2015 of the governorate and 46 surrounding rainfall stations were also used. Geological maps at 1: 50,000 scales allowed identifying the geology of the terrain (Table 1).

Table1: List of data sets used in the study.

Data type	Scale and observation	Source
Soil map	1/200000	DGS/MARH
Rainfall	Monthly rainfall, 46 stations during 10 yea	DGRE/INM
Topographic map	1/25000	OTC & SRTM (USGS)
Drainage Network	1/25000	SRTM (USGS)
Geological maps	1/50000	ONM
Image LandSat 8 OLI	Cell size 30 m	USGS
Image SRTM	Cell size 30 m	USGS

USGS = United States Geological Survey,
SRTM =Shuttle Radar Topography Mission,
ONM = National Office of Mines,
DGS =General Direction of soil,
INM = National institute of Meteorology.

Annual precipitation

Climatic data were provided from 46 rainfall stations located in and around the study area (Fig 2). Average annual rainfall has been calculated for each station. Rainfall interpolation surface was created based on the inverse-weighting method using ArcGIS. The Inverse Distance Weighting Interpolation (IDW) determines cell values through the linearly weighted combination of a set of sample points. Unlike other more complex methods such as kriging, this method is widely used to map isohyets, because kriging involve interactively analyzing the spatial behavior of the phenomenon represented by the rainfall before selecting the best estimation method for the generation of the output surface.

The analysis of the rainfall time series of the different meteorological stations has shown that the annual rainfall averages sometimes exceed 1000 mm and can reach 1500 mm in the governorate of Jendouba. The most important quantities fall on the reliefs, best exposed to moist air masses, especially in the Ain-Draham area. The highest rainfall was recorded in Ain Draham with a total of 2502 mm / year (Atlas Jendouba and INS, 2016), in Beni M'tir with 1570.7 mm / year and in Fernana with 1313.5 mm / year (DGRE, 2012).

Drainage network

Hydrographic network data was digitized from topographic maps (1/50 000 scale) using ArcGIS. The governorate of Jendouba has a high hydrographic density. The major part of Medjerda wadi is located at the Governorate of Jendouba. Indeed, 85% of its hydrographic network belong to the southern part of this Governorate, and the remaining to the northern part, drained by Barbara and Kebir Wadis.

In Tunisia, the Medjerda wadi starts from Ghardimaou plain, and it has several meanders and confluences. These meanders become increasingly tight when it gets closer to Jendouba city. In this Governorate, Medjerda wadi has several tributaries, such as Mellegue, Raghai, Meliz and Melah, Khalled and Tessa. These two latter wadis directly follow into Bou Salem city plain (Fig 3).

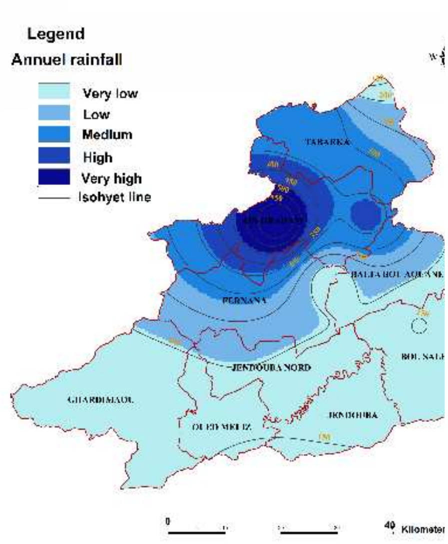


Fig 2: Rainfall interpolation surface.

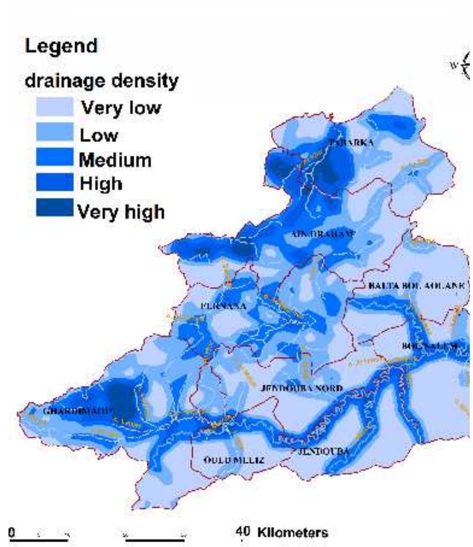


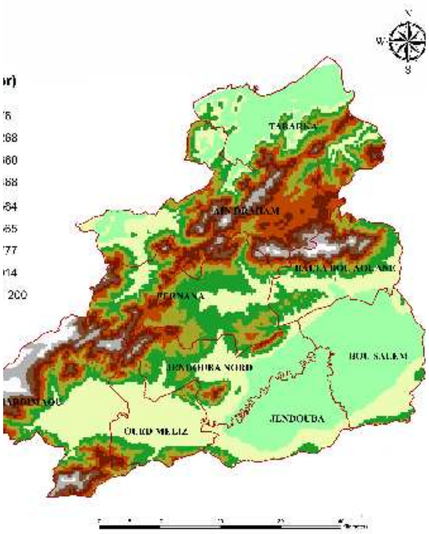
Fig 3: Drainage network density.

Topographic criteria

The Digital Elevation Model (DEM) (Fig 4) characterizing the topography of the area was made from topographic maps of Tunisia (1: 50,000) with equidistance of 10 meters. This resolution appears largely sufficient for our study since it is superior to that of SRTM images (30 m) (Schuttle Radar Topography Mission). The slope of the ground is one of the essential parameters used to evaluate water flow and especially gravity flow in watercourses.

Areas with low slopes are those at high flooding risk, such as Bou Salem, Wadi Mliz, Jendouba and Ghardimaou regions. This could be explained by the relatively flat topography of the plain, as well as by the high-water inflow from Medjerda wadi, giving rise to vast areas submerged by floodwaters.

Jendouba governorate seems to be particularly exposed to flooding because of its topographic features. In particular, Bou Salem city is among the most exposed area to flooding (Gharbi et al., 2014), because it is an in-land valley, surrounded by mountains in both the northwest and southeast sides, and because it is flowed by several wadi tributaries. In the extreme north-west, from Ghardimaou to Aïn Drahem, the slope is steep, while further south, from Wadi Mliz to Bou Salem, the topography is gently sloping (Fig 5).



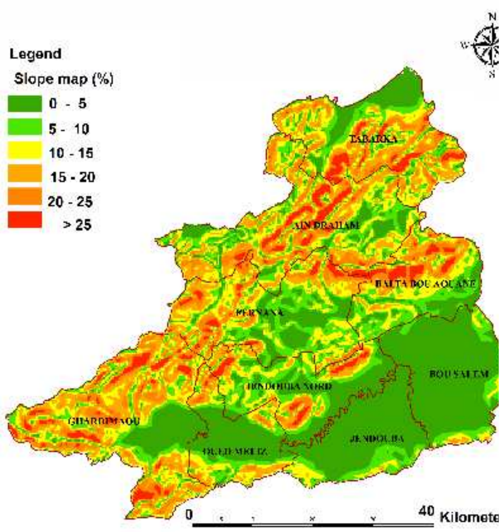


Fig 4: The Digital Elevation Model (DEM) of Jen governorate.

Fig 5: The slope of Jendouba governorate.

Soil type criteria

In the governorate of Jendouba, with a climate characterized by heavy winter precipitation, the Oligocene parent rock gave rise to brown soils more or less leached, depending on the nature and the degradation of the vegetal cover. Advanced brown forest soils generally occur under oak forests; in case of excessive cutting, overgrazing or fire, these brown forest soils become leached Podzolic soils. Hydromorphic soils locally exist, due to the high rainfall leading to waterlogging due to insufficient drainage of rainwater. A result, peat deposits in herbaceous marshes or small peat bogs maintained by springs occurs. Slightly developed soils occur on coastal dune formations of Aeolian origin (Belkhoudja and Bortoli, 1973).

Land use map criteria

The land use map was established by processing Landsat-8 images, of July and August 2015, using ENVI 4.7 software. The used methodology in this study combined both satellite image processing techniques and field observations.

Image pre-processing started with geometric correction of satellite images covering the study area. Landsat-8 images were geometrically rectified, with a residual error of about 4 m. The nearest-neighbor resampling method that retains the original radiometric values of the image (Caloz et al., 1993) was used. Radiometric correction was subsequently performed to reduce the atmosphere disruptive effects (Foody, 2002). Digital processing was first used in order to establish unsupervised land-use classes, (Fig 6), serving as a basis for field observations. Color combination of the OLI (6-5-4) raw bands and of the neo-channels of the principal component analysis (PCA 1-2-3) allow to discriminate the different types of land occupation and to select Region of Supervised Interest (training sites) (Fig 7). Four classes were discriminated: forests, farms, water surface and bare soil.

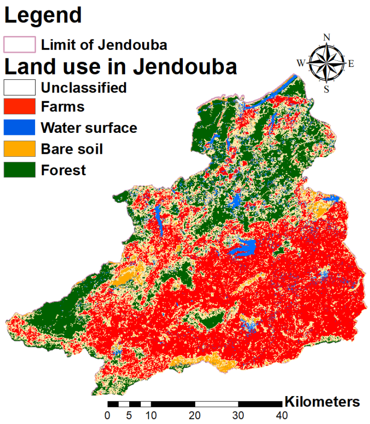


Fig 6: Unsupervised land-use classes.

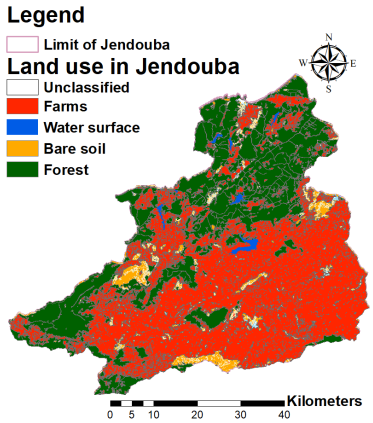


Fig 7: Supervised land-use classes.

Geological criteria

The substratum of the study region is a clay and sandstone "Numidian" flysch evolved in the Oligocene age and establishing a geological formation from the extreme north-west of Tunisia to Bizerte. In addition to these dominant sandstone and clay formations, secondary lands, and Paleocene and Eocene deposits outcrop at the surface in different places between Cape Serrat and Jendouba: clays and Triassic sandstones; Jurassic limestones; Cretaceous marls, clays, sandstones and limestones; Paleocene clays and marls; limestone and marl from the Eocene. Two substrata respectively formed in the Miocene and in the Mio-Pliocene were located in wadi Medjerda furrow. The first one is a molassic and lagoon series whereas the second one is a continental red sandy series. The Quaternary period is represented by dune systems at the seaside and by continental fluvial deposits. Peat deposits in the substratum, which has low permeability, seems to be enhanced by the humid climate of the region.

Spatial multi-criteria analysis and mapping

The method used to establish flooding risk map of Jendouba Gouvernorate by overflow of Medjerda wadi was the Analytic Hierarchy Process (AHP). The use of this method in assessing a territory's vulnerability (Florent, 2016) to flooding is justified by the fact that planning problems for flood protection schemes are complex spatial decision-making problems and of multi-criteria nature. These problems involve multiple stakeholders in the space and generally combine conflicting objectives that reflect the diversity of interests and concerns of stakeholders in the territory. The resolution of these problems requires a considerable amount of both quantitative and qualitative data that does not have the same importance (Malczewski, 2006).

AHP method is based on five main steps leading to the establishment of a risk map (Fig 8). These steps are as follows:

1) Define the problem and Structure the decision hierarchy. It consists of defining the problem by specifying the assumptions, and then breaking down the decision into identify different hierarchical levels (Saaty, 1991) goal, criteria and sub-criteria.

2) Determine the weights of the criteria and sub-criteria. The decision maker sets the priorities by comparing the criteria pairwise (Tables 2 and 3). The ranking method was latter used to generate criterion weight values for each evaluation unit, with values varying between 1 and 9; 9 indicating a higher vulnerability and 1 indicating a low vulnerability according to the class values of the evaluation unit criterion.

3) Normalize the weights of the criteria. First, in each column of the comparison matrix, the criterion weight has to be normalized so that the sum per column is equal to one. Then, the row sum is calculated for each criterion; the criterion weight is obtained by dividing the row sum by the number of criteria (Table 4).

4) Evaluate the consistency of the judgments. Each column of the non-normalized comparison matrix was multiplied by the weight of the associated criterion (Table 5).

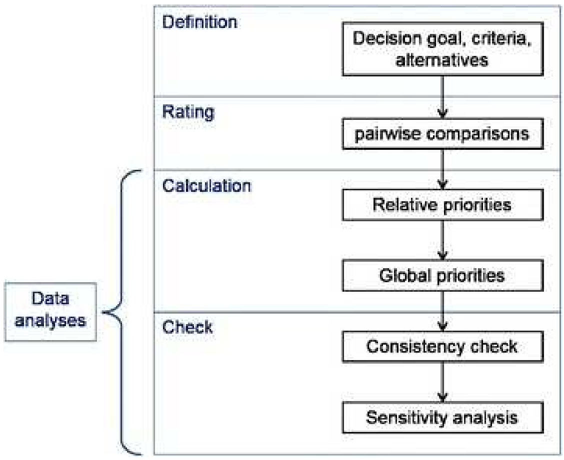


Fig 8: Steps of AHP model.

Once the weights were calculated, their coherence should be evaluated in order to validate the obtained priorities. This coherence was assessed using Consistency Ratio (CR), calculated using (CI) (Consistency index) and (RI) (Random Index or Consistency index of a random-like matrix; see Table 6) according to the following formula:

$$CR = CI/RI \qquad \text{(eq. 1)}$$

where:

$CI = (\lambda_{max} - n)/(n - 1)$;

λ_{max} = priority vector multiplied by each column total;

n = Number of criteria.

CR has to be less than or equal to 10% in order to consider the assessment consistent, and when it exceeds 10%, the assessment should be reviewed.

The flood risk map is obtained by calculating the following index:

$$Risk = \prod_{i=1}^{6} \omega_i C_i \qquad \text{(eq. 2)}$$

where: ω_i is the weigh of the Criterion C_i (C_1= Rainfall; C_2= Drainage network of the river basin; C_3= Slope of the basin; C_4= Soil type; C_5= Land cover; C_6= hydrogeological map).

The validation of the established flood risk map was based on bibliographical references, and documents describing flooding during crisis period. These documents were provided mainly by the DGRE (General Department of Water Resources under the supervision of the Ministry of Agriculture, Hydraulic Resources and Fisheries), ONPC (National Office of Civil Protection), INS (National Statistical Institute) and the National Committee Fighting Natural Disasters. These records described in detail: 1) limits of certain flooded areas, 2) nature of the floods (overflow, rising water, runoff), 3) duration and frequency of the submersions, and 4) influence of structures (roads, bridges) on flooding. In addition, field observations were conducted to locate flooded areas and flood markers, and to identify recent changes in wadi bed or land use.

Table 2: Binary comparison scale used to assess territorial vulnerability (adapted from Saaty, 1991).

Appreciation	Level of importance
Equal importance of the two criteria	1
Low importance of one criterion to another	3
Average importance of one criterion compared to another	4
Strong importance of one criterion over another	5
Very strong importance of one criterion compared to another	7
Extremely importance of one criterion over another	9

Table 3: Square pairwise comparison matrix of the criteria (C1= Rainfall; C2= Drainage network of the river basin; C3= Slope of the basin; C4= Soil type; C5= Land cover; C6= hydrogeological map) used to assess flooding risk.

Criterion	C1	C2	C3	C4	C5	C6	Priority vector
C1	1.00	2.00	2.00	2.00	4.0	2.0	0.307
C2	0.50	1.00	2.00	2.00	4.0	2.0	0.210
C3	0.50	0.50	1.00	2.00	4.0	2.0	0.160
C4	0.50	0.50	0.50	1.00	4.0	2.0	0.129
C5	0.25	0.25	0.25	0.25	1.0	2.0	0.057
C6	0.50	0.50	0.50	0.50	0.5	1.0	0.090
Sum	3.25	4.75	6.25	7.75	17.5	11.0	1.000

Table 4: Normalized weights of the different criteria (C1= Rainfall; C2= Drainage network of the river basin; C3= Slope of the basin; C4= Soil type; C5= Land cove; C6= hydrogeological map) used to assess flooding risk.

Criterio	C1	C2	C3	C4	C5	C6	Row total	Criterion weight
C1	0.31	0.421	0.32	0.258	0.228	0.182	1.719	1.719/6 = 0.2868
C2	0.154	0.210	0.32	0.258	0.228	0.182	1.352	1.352/6 = 0.2253
C3	0.154	0.105	0.16	0.258	0.228	0.182	1.087	1.087/6 = 0.1810
C4	0.154	0.105	0.08	0.129	0.228	0.182	0.878	0.878/6 = 0.1463
C5	0.074	0.054	0.04	0.0325	0.057	0.182	0.4395	0.439/6 = 0.0732
C6	0.154	0.105	0.08	0.0645	0.031	0.090	0.5245	0.524/6 = 0.0874
Sum	1	1	1	1	1	1		1

Table 5: Consistency assessment for the different criteria (C1= Rainfall; C2= Drainage network of the river basin; C3= Slope of the basin; C4= Soil type; C5= Land cover; C6= hydrogeological map) used to evaluate flooding risk.

Criterion	C1	C2	C3	C4	C5	C6	Row sum	Coherence ratio
C1	0.2868	0.380	0.362	0.2926	0.2928	0.1748	1.8596	6.483
C2	0.1434	0.2253	0.362	0.2926	0.2928	0.1748	1.4909	6.617
C3	0.1434	0.11265	0.181	0.2926	0.2928	0.1748	1.1972	6.614
C4	0.1434	0.11265	0.0905	0.1463	0.2928	0.1748	0.9604	6.564
C5	0.0717	0.056325	0.04525	0.036575	0.0732	0.1748	0.4578	6.254
C6	0.1434	0.11265	0.0905	0.07315	0.0366	0.0874	0.5437	6.220

Table 6: Random Indices for matrices of various sizes (Saaty, 1991).

n	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
RI	**0**	**0**	**0.58**	**0.90**	**1.12**	**1.24**	**1.32**	**1.41**	**1.45**	**1.49**	**1.51**	**1.48**	**1.56**	**1.57**	

In this study Random Indices" n" is equal to 6.

RESULTS AND DISCUSSIONS

Sensitivity analyses of the criteria

Calculated CI and RI of the AHP approach used to assess flooding risk in Jendouba Gouvernate were equal to 0.123 and 1.24, respectively. The Consistency Ratio (CR) was around 0.099, below the threshold value of 0.1, indicating a reasonable level of consistency. Hence, the calculated criterion weights would be accepted. The criteria contributing the most to flooding risk in Jendouba Gouvernate were mainly annual rainfall (C1), Drainage network of the river basin (C2) and Slope of the basin (C3), with weights of 0.2868 0.2253 and 0.1810, respectively.

Flood risk map

The flood risk map (Fig 9), established using multi-criteria assessment methods with GIS, delineated five levels of risk, ranging from very low to very high. Regions with very low and low flooding risk cover respectively 26.60% and 22.60% of Jendouba Gouvernate. They are located in the centre, particularly between Balta Bouaouane, Ain Draham and Fernana delegations, characterized by high elevation and rugged (hilly) terrain.

On the other hand, regions with medium, high and very high flooding risk cover 31.40%, 12.0% and 7.60% respectively, with a total of 51% representing areas potentially affected by flooding. These regions are located in riparian zones, particularly in the meanders and in zones with tight hydrographic network. In addition, the hydrographic network in these regions has many short and steep tributaries, coming from mountains and hills, and flowing into the wadi Medjerda mainstream; the water flow from these tributaries is simultaneously concentrated in the flat areas of the main wadi and causes floods.

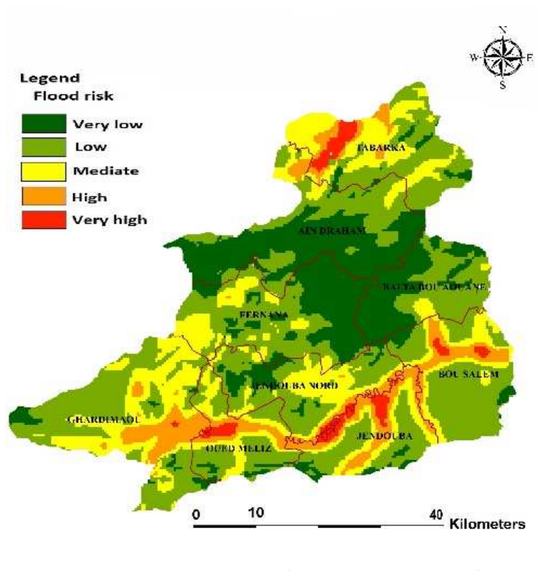


Fig 9: Flood risk map.

According to several sources (Gharbi, 2014, Ben Hassine et al., 2003), the major bed of hydrographic network Medjerda has a tendency of sedimentation superior to the scour. Thus, these deposits produce a decrease in flow capacity, considered as one of the major problems of the Medjerda watershed. Finally, it should also be noted that the problems encountered in the hydrographic network Medjerda come as a result of the behavior of certain citizens, which consists in planting trees or cultivating crops or even building constructions in the major bed of the Wadi, contributes directly to the modification of the geometry of the hydrographic network. Moreover, areas between Oued Mliz, Jendouba and Bousselem cities have a shallow groundwater table (BIRH et DGRE, 2010), increasing flood risk. In these areas, flood would happen when soils are saturated and the water table rises to the surface.

With the engravement of wadi Bouhertma bed between the Bouhertma's dam and the wadi Mejerda confluence, the stretch was unable to withstand the volume of discharged water, which resulted in overflows on both sides of the wadi causing flooding on farm lands and nearby settlements (Ben Hassine et al., 2003; CRDA, 2012; Ben Rjeb et al., 2015). In addition, the MC59 road connecting Bou Salem city and the northern zone of Balta-Bouaouène delegation (Gharbi, 2014), rehabilitated in 2003, had played unfortunately the role of a barrier blocking the Wadi, accentuating the flow of flood waters toward Diamenta neighbourhood, located in southern of the railway in Bou Salem city. As a result of torrential rains in Wadi Rarai basin, a rapid rise in the Medjerda wadi and a major flooding was signalled by the control station located upstream at the confluence between Rarai affluent and Mejerda wadi, near Chemtou city.

CONCLUSION

In this research, a flood risk map was developed based on the multi-criteria decision-making approach (MCDA) using different geospatial data, such as rainfall, elevation, slope, distance to the river, and land use / land cover. Field observations had showed that MCDA and GIS techniques are very powerful approaches for flood risk analysis and mapping. The MCDA approach used, in this study, remains flexible through either the change of the evaluation criteria or the integration of new criteria such as permeability, surface runoff, river flow, morphology, urban areas, the channel of the Wadi. This study also showed the role of this approach based mainly on GIS and remote sensing on the one hand and multicriteria analysis on the other hand in the qualitative risk zoning and the quantitative evaluation of the vulnerability of the criteria to flood risk.

This editorial also highlights the need for an integrated approach to risk that combines both qualitative risk zoning and quantitative vulnerability assessment of the criteria. The result is a series of digital maps, whose diagnosis of information makes it possible to visualize areas of risk according to criteria and their importance. Indeed, the knowledge of these criteria represents an important contribution to reduce and control the consequences of a flood on this specific Governorate. The resulting prototype can be used for flood preparedness and mitigation activities in any similar region.

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