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A MULTI-CRITERIA ANALYTICAL HIERARCHY PROCESS (AHP) TO FLOOD VULNERABILITY ASSESSMENT IN BATNA WATERSHED (ALGERIA)

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Abstract: A multi-criteria Analytical Hierarchy Process (AHP) analysis was carried under a geographic information system (GIS) integrating several factors, namely slope, maximum daily precipitation, for a 100-year return period, drainage density, permeability and vegetation cover whose purpose is to better understanding, evaluate and mapping the vulnerability to flooding in Batna watershed. This analysis assesses the level of this phenomenon according to several criteria of different nature; these criteria were recorded and weighted on the same scale. The results show that several areas are extremely vulnerable requiring the implementation of priority actions to address this risk.

Key words: AHP, Batna, flood, GIS, vulnerability, watershed

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INTRODUCTION

Hydrological risks pose a threat to people and property in most parts of the world. The optimal management of floods requires prior knowledge of the cause of the phenomenon and a good mapping of its extent (Wade et al., 2008; Herman, 2009, 2010).The methodology adopted for

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the characterization and delimitation of flood vulnerability in the Batna watershed is based on multi-criteria analysis by integrating several factors where each one has a weight depending on their importance and their influence on the gravity of the phenomenon.

Multicriteria analysis is a decision support tool developed to solve complex multi-criteria problems that include qualitative and/or quantitative aspects in a decision-making process (Mendozaet al., 2000). This method makes it possible to provide answers to several difficulties posed by the evaluation (Grivault et al., 2007). We chose T. Saaty's method, which has the advantage of proposing an easily comprehensible model of data organization reflecting the natural tendency of the mind to sort the elements of a system into different levels and to group similar elements on one level to solve unstructured problems (Barczak et al., 2007).

The factors involved in the analysis depend on the availability of data. The slope is the major factor that influencing flooding; the areas of low to very low slope are areas prone to flooding and submersion. The precipitation is the factor that generates flow and triggers flooding. Rainwater accumulates in low-lying areas and converges towards the downstream; these areas represent the drainage network which can take third place in the weighting.

Permeability is explained by the lithological nature and by the land cover, waterproofing of the soil is one of the factors that favours surface flows. When water infiltration into soil is permanently reduced, the risk of surface runoff is increased (Montoroi, 2012).

Finally, the vegetation cover exerts an important limiting effect on surface runoff. It regulates stream flow and dampens low- and medium-amplitude floods. However, its effect on extreme flows caused by catastrophic floods can be reduced (Saley et al., 2005). Degraded vegetation cover is a favourable factor for surface flows and promotes the watershed's hydrological response. Runoff is strongly accentuated for soils with scattered vegetation cover (Montoroi, 2012).

We used an index parameterized approach where each parameter is in fact a numerical index translated by a code used for modeling.

STUDY AREA

The catchment area of Batna figure 1, located in eastern Algeria, covers an area of 802.68 km², between latitudes 35°25' and 35°47' North and between longitudes 6°5' and 6°29' East.

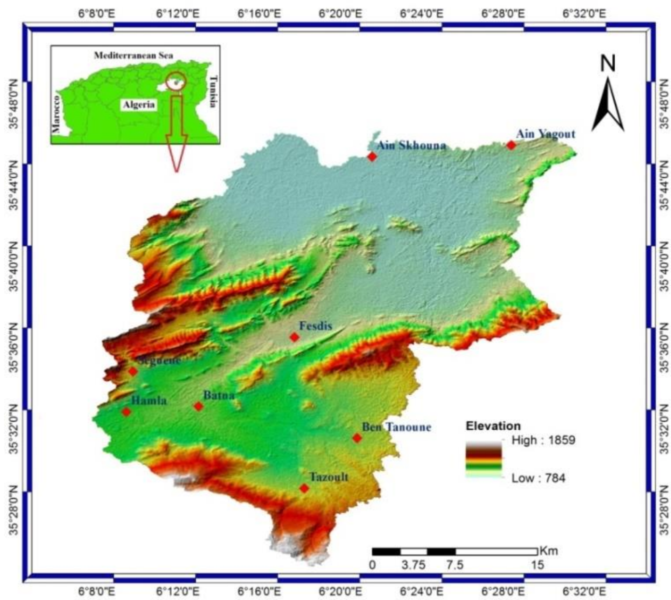


Figure 1. Study area
(Source: Guellouh Sami)

The climate of the region is classified as semi-arid, characterized by irregular rainfall. (Sami et al., 2016). Its geography makes it possible to identify several categories of land use, each characterized by strong specificities and great diversity.

MATERIALS AND METHODS

To map the vulnerability to flooding in the Batna watershed, several thematic maps have been drawn up beforehand. The factors involved in the analysis, their sources and the method of acquisition are summarised in order of priority in the table below.

Table 1. Data Sources and Acquisition Method

Parameters	Data Sources	Acquisition Method
Slope	DEM	Extraction
rainfall	Rainfall National Water Resources Agency (ANRH)	Interpolation
Drainage density	DEM	Extraction
Permeability	Geological map of Algeria 1/ 500,000	Scan
vegetation cover	Satellite image 30 m	Supervised classification

The adopted method is AHP. It's i a popular method used as a tool for multi-criteria decision making (MCDM) or as a technical estimation (Taibi and Atmani, 2017). This method has mathematical properties and allows total ranking, it requires a hierarchy of the decision problem and a pairwise comparisons of entities in every node of the hierarchy (Saaty, 1991). AHP involves the following steps: (1) structuring possible factors for the problem into a hierarchy; (2) arranging the factors for each alternative; (3) developing the criteria for alternatives; (4) evaluating the importance of alternatives; and (5) analyzing the weight of each factor (Chen et al., 2011).

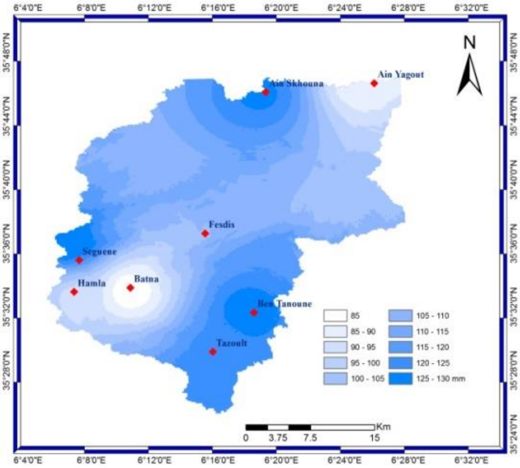
Table 2. Fundamental AHP judgment scale with integers 1 to 9 and their definition

Jugement	Definition	Comment
1	Equal importance	Two activities contribute equally to the objective
3	Moderate importance	Experience and judgment slightly favor one activity over another
5	Strong importance	Experience and judgment strongly favor one activity over another.
7	Very strong or demo-started importance	An activity is favored very strongly over another; its dominance demonstrated in practice.
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation..
2, 4 ,6 et 8	Values associated with intermediate judgments	Where a compromise is necessary.

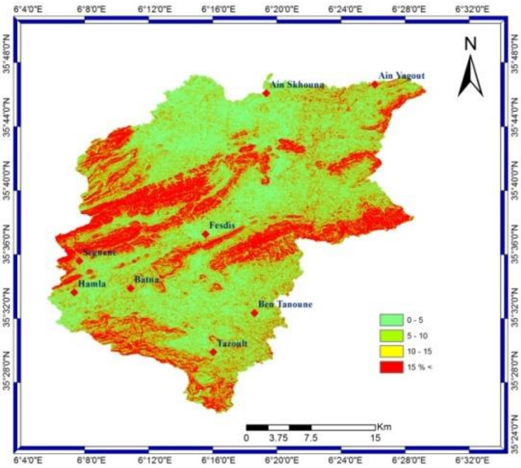
Table 3. Pair Comparison Matrix (Judgment Matrix)

	Slope	rainfall	Drainage density	Permeability	vegetation cover
Slope C1	1	2	4	5	7
Rainfall C2	½	1	3	5	6
Drainage density C3	¼	1/3	1	3	4
Permeability C4	1/5	1/5	1/3	1	3
vegetation cover C5	1/7	1/6	¼	1/3	1
Total	2.09	3.7	8.58	14.33	21

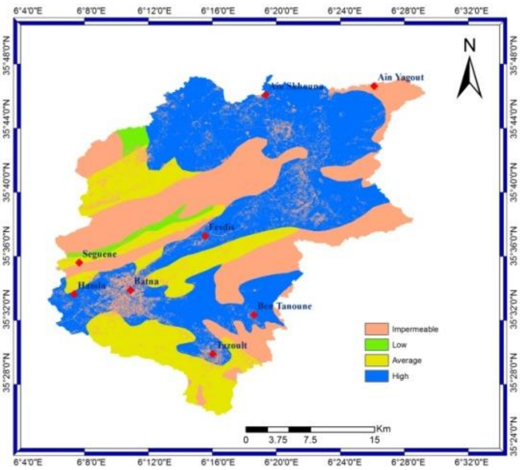
We divided each element of the matrix by the column total by the total value of the column and we calculated the average of the elements of each row.



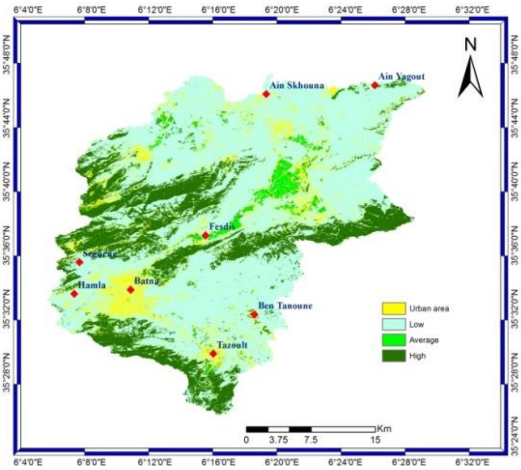
(A) Rainfall



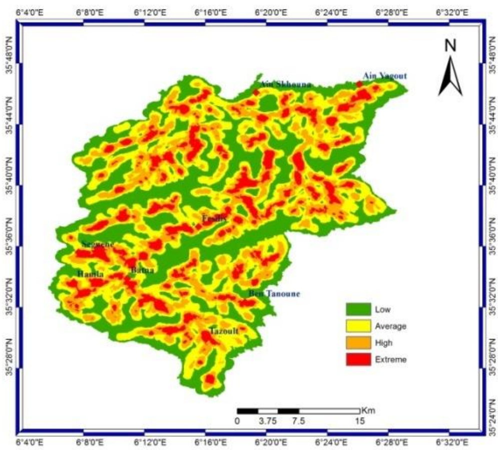
B) Slope



(C) Permeability



(D) vegetation cover



(E) Drainage Density

Figure 2. Thematic maps

Table 4. Determination of the weight of each criterion

	C1	C2	C3	C4	C5	The weight
C1	0.47	0.54	0.46	0.35	0.33	0.437
C2	0.24	0.27	0.34	0.35	0.28	0.302
C3	0.12	0.09	0.11	0.20	0.19	0.142
C4	0.095	0.054	0.038	0.07	0.14	0.075
C5	0.068	0.045	0.029	0.023	0.047	0.041
Total	1	1	1	1	1	1

The results from AHP are scores equal to 1 (Griot, 2007).After calculating the relative importance and determining the weight of each factor in the hierarchy, the vulnerability is calculated using the following formula:

Vulnerability = 0.437 Slope + 0.302 rainfall + 0.142 Drainage density + 0.075 Permeability + 0.041 vegetation cover.

We note that the weighting for the different classes of the same criterion is based on the following principle:

Table 5. Weighting for different classes of the same criterion

Parameters of Classes	**C1**	**C2**	**C3**	**C4**	**C5**
Classe 1	Weight C1 X 1	Weight C2 X 1	Weight C3 X 1	Weight C4 X 1	Weight C5 X 1
Classe 2	Weight C1 X ½	Weight C2 X ½	Weight C3 X 1/2	Weight C4 X 1/2	Weight C5 X 1/2
Classe 3	Weight C1 X 1/3	Weight C2 X 1/3	Weight C3 X 1/3	Weight C4 X 1/3	Weight C5 X 1/3
Classe 4	Weight C1 X ¼	Weight C2 X ¼	Weight C3 X 1/4	Weight C4 X 1/4	Weight C5 X 1/4

RESULTS AND DISCUSSIONS

With Arc GIS software and its extensions, we were able to attach weights to the different thematic maps and to create the map of vulnerability to floods in Batna watershed.

To verify the level of consistency of judgments and to ensure that the data are logically related to each other, a consistency ratio R below 0.10 is considered permissible, the higher ratio of 0.10 indicates a higher level of inconsistency. In our case R = 0.048 (figure 3, 4).

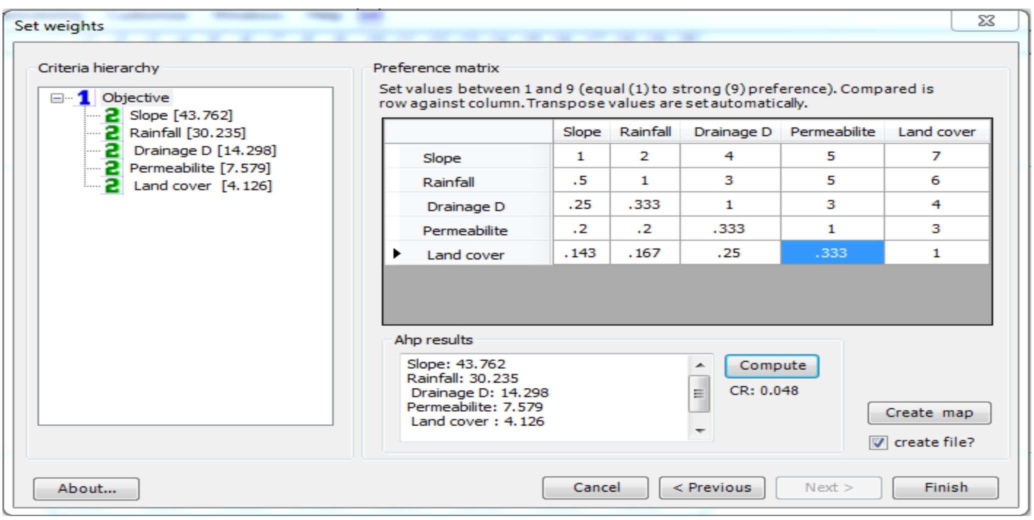


Figure 3. AHP extension under Arc Gis

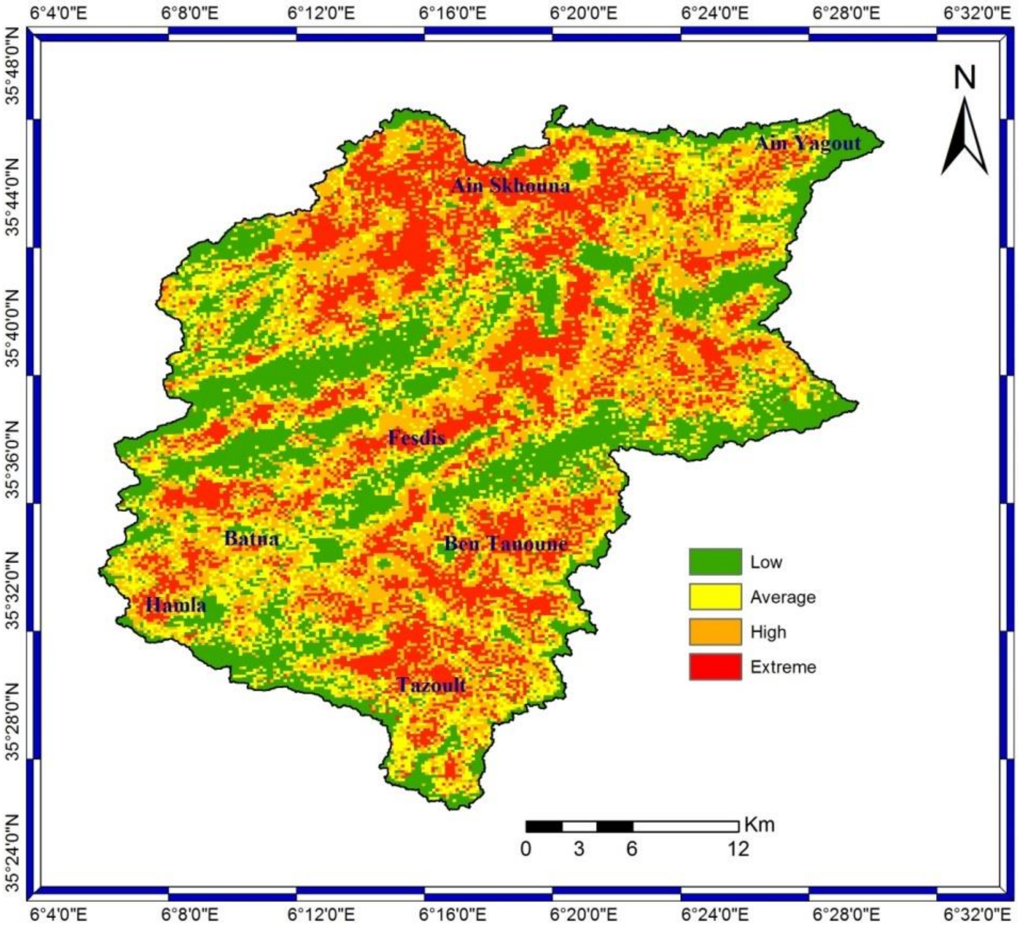


Figure 4. Vulnerability to flooding in the Batna watershed

The vulnerability to flooding in the Batna watershed is classified into four levels, from low to very strong going through the medium and the strong.

The map shows that several areas are listed in a strong and very strong vulnerability, notably Tazoult, Batna, the plain of Fesdis and Ain Skhouna, and this essentially comes back to the very low slope (less than 5%). The use of multi-criteria analysis under a GIS can be a useful tool for the spatialization of this vulnerability.

CONCLUSION

Accurate and prior knowledge of the physical characteristics of the study area is an essential step in the study of flood vulnerability.

The hierarchical multi-criteria analysis method provided reliability in delineating flood vulnerability by weighting each criterion involved in the analysis several areas are in significant vulnerability (Batna, Tazoult, Fesdis Plain and Ain Skhouna Plain) and its mainly due to the nature and form of the physical characteristics which have a significant influence on the flows, particularly the very low slope (0-5%) and the characteristics of the river system related to the drainage density which strongly favor the duration of submersion.

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