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USE OF GIS FOR THE ASSESSMENT OF PHYSIOGRAPHIC CHARACTERISTICS OF THE WATERSHED OF OUISLANE, BOUFEKRANE AND TOULAL OUEDS

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ABSTRACT
This article presents the interest of the use of geographic information systems (GIS) for the characterization of the morphometric aspects, and the relief of the watershed of the three oueds studied (Ouislane, Boufekrane and Toulal), because these parameters play an important role in the flow of watersheds and in the risks of erosion. For this, we have realized several thematic maps from the SRTM images, namely: the hypsometric map, the slopes map and their exposures, the sub-basins map, the river system map and its classification. From these thematic maps produced for the watershed studied, several physical characteristics were extracted, such as the surface, the perimeter, the Gravelius compactness index, and the equivalent rectangle. These indices show that the sub-basins studied have an elongated shape which causes a delay in the delivery of water to the outlet during the flood period.

KEYWORDS: Watershed, Oued Ouislane, Oued Boufekrane, Oued Toulal, physical characteristics, GIS, SRTM images.

INTRODUCTION
Water as a vital resource and a factor of development, the importance of its protection leads us to evaluate the parameters that play an important role in the flow of superficial water.
These parameters have been the subject of several previous studies [1] [2] [3] [4]. They include the morphometric, topographic, and hydrographic characteristics of watersheds. The present work is the study of these characteristics at the level of the watershed of the three oueds of the region of Meknes namely Oued Ouislane, Oued Boufekrane, and Oued Toulal.

Geographical context

The city of Meknes is situated in the northern part of Morocco; it is the second largest city of the plain Sais after the city of Fez (Figure 1). The Oued Boufekrane is a permanent watercourse of the Middle Atlas; it rises to the west of El Hajeb, in the Middle-Atlas, 750 meters above the sea level. It takes first the name of Ain Maârouf, then that of Boufekrane to 10 km of the source, finally that of R'Dom after its confluence first with Oued Toulal which crosses the commune of Toulal, then with Oued Ouislane which belongs to the superficial river system of the region of Meknes starting from the south-east of the village of Boufekrane. Oued R'Dom flows towards the south to the north-west, with an average slope of 2 to 5 % to throw himself into the Merja El Jouab, north of Sidi Sliname, to join the Oued Sebou.

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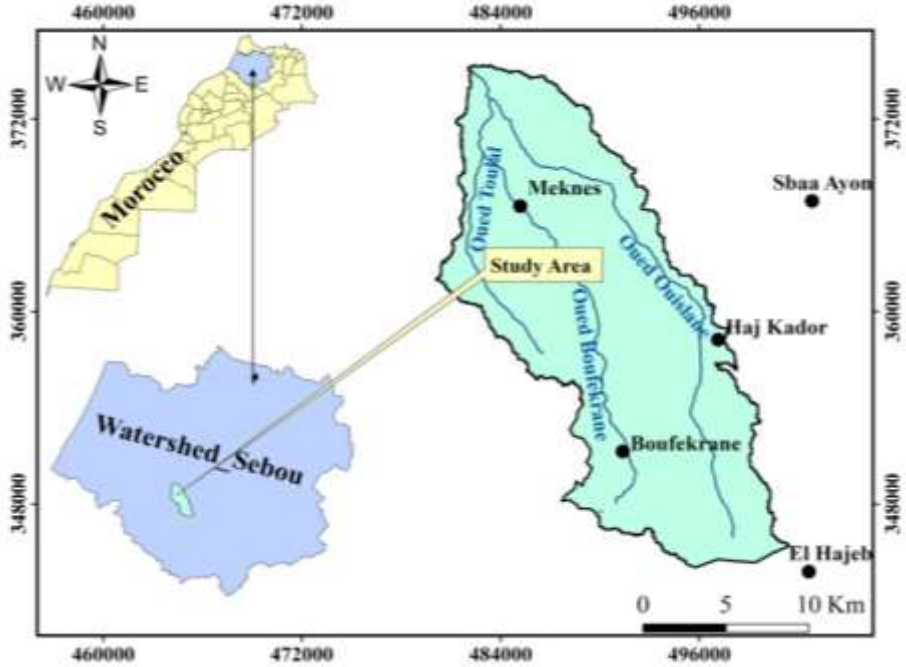

Figure 1: Location of the watershed of Ouislane, Boufekrane and Toulal oueds

Geological Context

From a geological point of view, the watershed of the three oueds studied is part of the Saïs basin, which occupies part of the Meknes-Fez lake basin which forms the northern part of the south Rifain. The plateau of Meknes represents about 2/3 of the Saïs; it extends 80 km from west to east, and 30 km from north to south [5]. The origin of this basin would be linked to the dislocation of the liasic substratum, which occurs underneath the neogene covering [6] [7].

At the level of the zone of the three oueds studied, predominate covers mainly tertiary and quaternary ages. They contain calcareous formations of Lias, and in the north of the clay-marly layers (Figure 2).

MATERIAL AND METHODS

In the case of this study, the geographic information systems (GIS), and the SRTM images (Shuttle Radar Topography Mission), with a resolution of 30*30 m, were used for the creation of thematic maps and the automatic extraction of a multitude of parameters and physiographic indices of the watershed studied.

GIS is a tool for storing, sharing, consulting and manipulating the objects represented on maps and plans with their geometric descriptions, as well as all the information attached to them [8].

RESULTS AND DISCUSSION

The use of geographic information systems (GIS) and SRTM images, allowed us to collect several results to fully understand the aspects of the watershed studied.

The digital elevation model (DEM) served us to realize thematic maps related to the slopes and their exposures, to the altitudes, and to the determination of sub-basins and river systems.

Extraction of contour lines

Many authors focus on contour lines production as Riegler [9] and Wang [10]. For our study the contours were extracted from the SRTM images.

In figure 3, we have presented the contour lines map relating to the watershed of the oueds studied. In the north of this map, the contours are close together and tighter, reflect the reliefs of the watershed.

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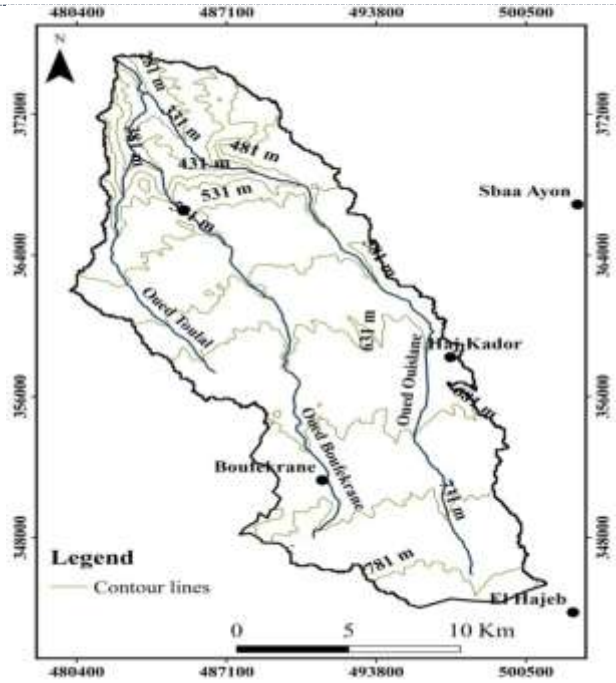

Figure 2: Contour lines map of the watershed of Ouislane, Boufekrane and Toulal oueds

DEM, hypsometric and TIN maps of the study area

The DEM (Digital Elevation Model) is a numerical representation of the terrain in terms of altitudes. It allows a representative space analysis, because it reflects information about the morphological structure throughout the watershed [11].

The hypsometric map and the TIN (Triangulated Irregular Network) map, obtained from the digital elevation model (DEM), present altitudes in the form of a succession of plateau stages throughout the basin studied, with an important drop between 256 and 852 m (Figure 4 and Figure 5).

The lowest altitudes of about 256 m are recorded downstream of the study area. As we move upstream, the altitudes become increasingly important from 750 to 852 m.

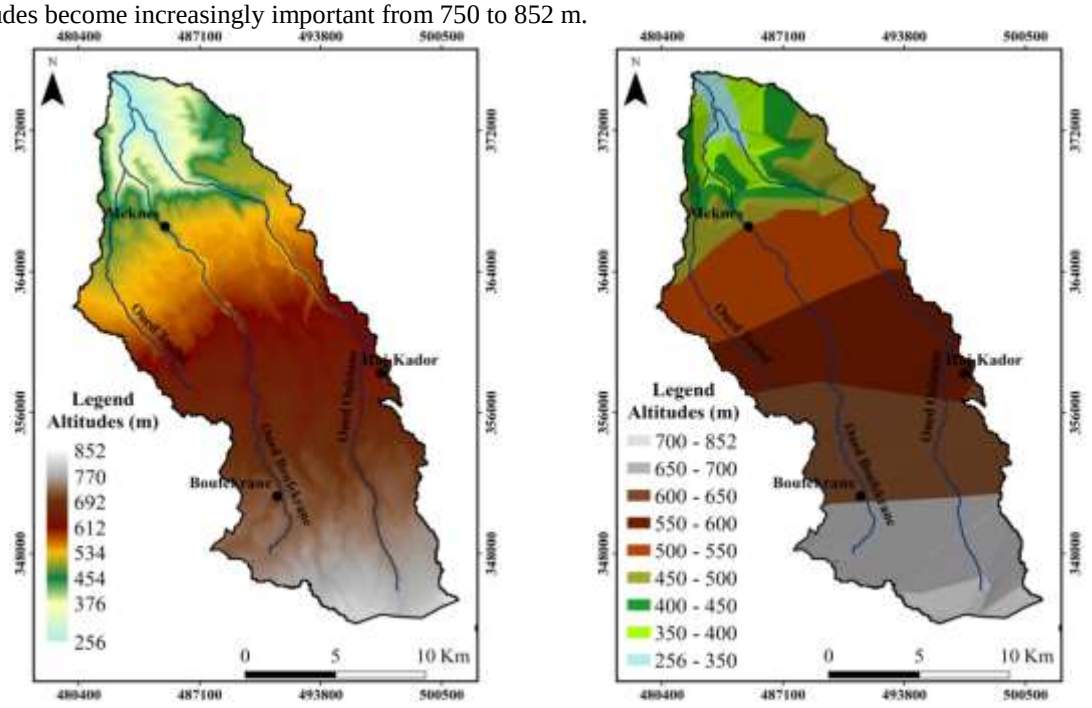

Figure 3: DEM map (left), and TIN map (right) of the watershed of Ouislane, Boufekrane and Toulal oueds

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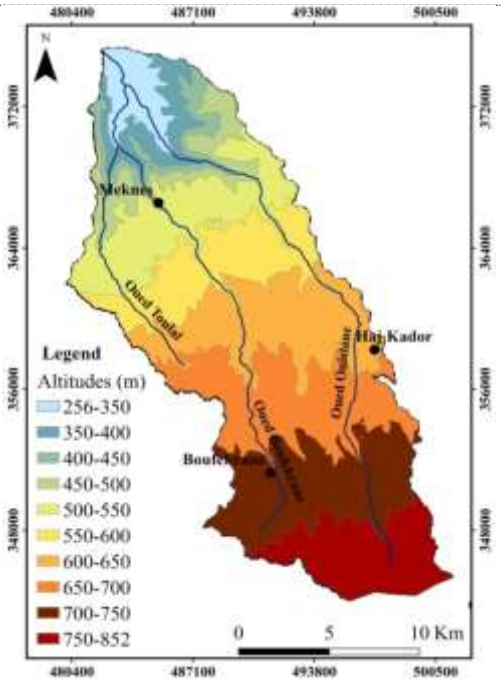

Figure 4: Hypsometric map from the DEM of the watershed of Ouislane, Boufekrane and Toulal oueds

Slopes map

The slope plays an essential role in the hydrological cycle, so the characterization of the slopes of the watersheds is an important criterion as the slope determines the flow rate and thus the erosion.

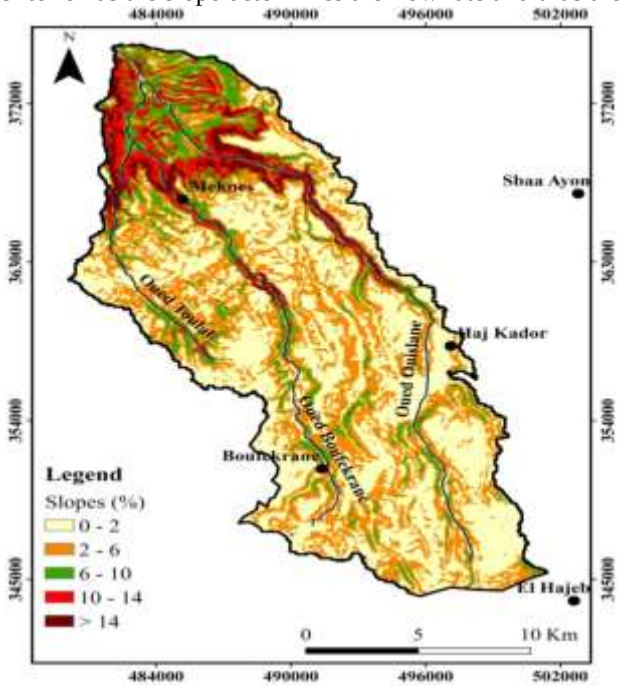

Figure 5: Slopes map of the watershed of Ouislane, Boufekrane and Toulal oueds

The slopes map analysis (Figure 6) shows that the watershed of the three oueds studied is characterized by a predominance of the classes of the low and average slopes of 0-2 % and 2-6 %, which extend over a large part of the total watershed area, against the steep slope classes which are located in a small area in the north and north-west of the watershed studied.

Slopes exposure map

The slopes exposure map is used to determine the orientation of slopes with their percentages and their exposure in the watershed. It is dominated mainly by the north, north-east, and north-west exposures (Figure 7; Table 1).

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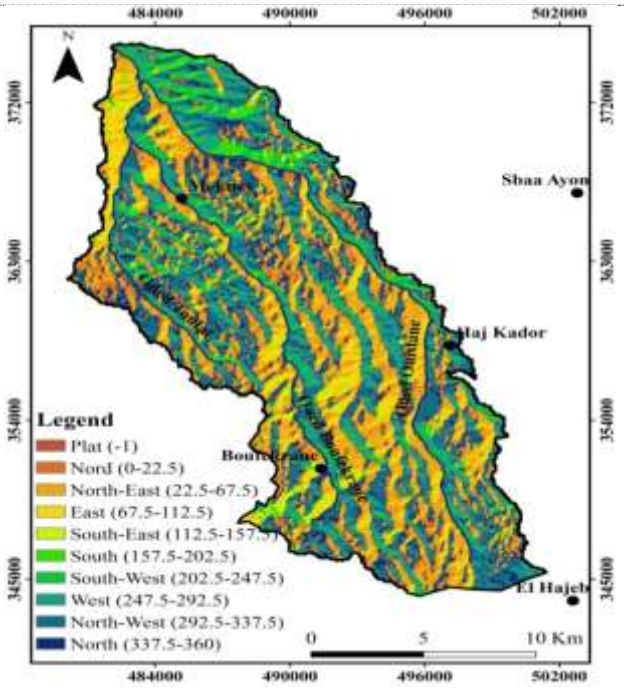

Figure 6: ***Slopes exposure map of the watershed of Ouislane, Boufekrane and Toulal oueds***

Table 1. ***Exposure of slopes of the watershed of Ouislane, Boufekrane and Toulal oueds***

Exposure	North	North-east	East	South-east	South	South-west	west	North-west
Percentage	21.14	20.45	9.40	2.12	2.49	7,73	16,24	20,28

River system

The river system is one of the most important characteristics of a watershed. It is defined as all natural or artificial streams, permanent or temporary, which participate in the flow [12].

The topology is useful in the description of the river system, notably by proposing a classification of it. This classification is facilitated by a system of numbering of the sections of watercourses (main and secondary streams).

The results illustrated in figure 8 and table 2, show that three oueds appear at the level of the main oueds, namely Oued Ouislane in the east with 20.16 %, Oued Boufekrane and Oued Toulal in the west with respectively 16.17 % and 7.65 %. For the secondary oueds, they represent 56.02 % of the total river system.

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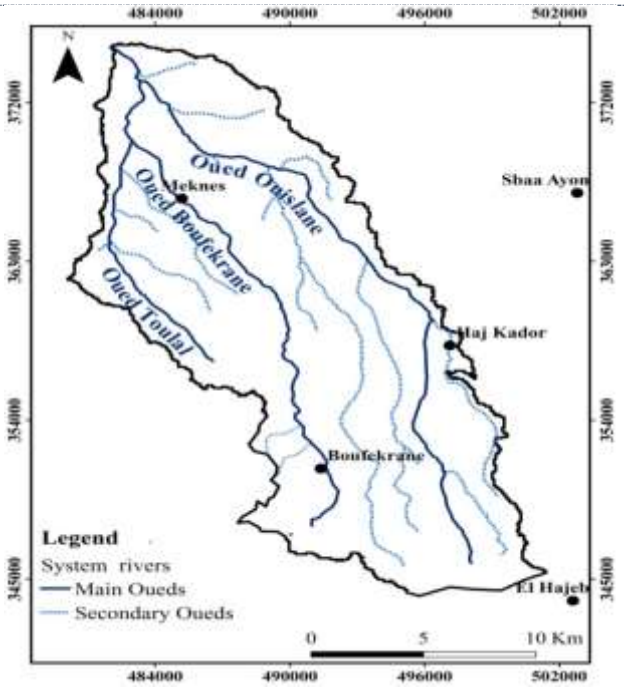

Figure 7: Classification of the river system of the watershed of Ouislane, Boufekrane and Toulal oueds

Table 2. Characteristics of the river system of the watershed of Ouislane, Boufekrane and Toulal oueds

River system type	Stream	Length (km)	Percentage (%)
Main rivers	Oued Ouislane	38.14	20.16
	Oued Boufekrane	30.58	16.17
	Oued Toulal	14.48	7.65
Secondary rivers	Secondary oueds	105.90	56.02

Determination of sub-basins

The watershed is the reception area for precipitations and feeding of watercourses; flows will be partly linked to its surface. The watershed of the three oueds studied extends over an area of 326.46 km^2, where there are three sub-basins.

- The sub-basin of Oued Ouislane that located in the east and characterized by the largest percentage which is of the order of 61.79 % of the total area.
- The sub-basin of Oued Boufekrane, which contains a surface of 19.64 % of the total area.
- The sub-basin of Oued Toulal, which is located in the west of the study area and participates with 18.57 % of the total area (Figure 9 and Table 3).

The perimeter is the length of the contour of the watershed, usually expressed in km. It is calculated by assimilating the basin to a regular geometric shape. The perimeter of the total watershed area is 266.06 km, of which 44.56 % corresponds to the Oued Ouislane sub-basin, and 35.21 % and 20.23 % respectively for the sub-basins of Boufekrane and Toulal oueds.

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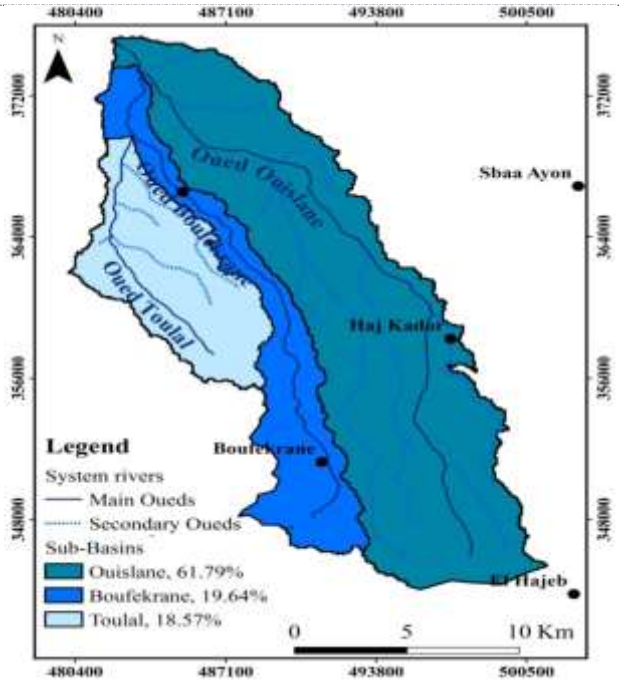

Figure 8: Sub-basins map of the watershed of Ouislane, Boufekrane and Toulal oueds

Table 3. Characteristics of the sub-basins of Ouislane, Boufekrane and Toulal oueds

Sub-basin	Surface (km^2)	% Surface	Perimeter (km)	% Perimeter
Oued Ouislane	201.72	61.79	118.55	44.56
Oued Boufekrane	64.11	19.64	93.69	35.21
Oued Toulal	60.63	18.57	53.82	20.23

Maps and hypsometric curves of sub-basins

Hypsometric maps

The relief is an important factor for a relevant cartographic representation, and for an analysis of the impact of geomorphological factors on flows. The hypsometric maps show the spatial distribution of the different altitude classes, with their frequency and abundance at the level of each sub-basin (Table 4 and Figure 10).

At the level of the Oued Ouislane sub-basin predominates the altitudes between 600 and 852 m, with 61.36 % and a surface of 123.54 km^2. Whereas, the altitudinal range between 256 and 500 m, is only 38.63 % of the total area of the sub-basin studied.

The sub-basin of Oued Boufekrane shows the predominance of the class of altitudes 650-700 m with 20.26 % and a surface of 12.92 km^2, and the class of altitudes 700-750 m with 30.14 % and an area of the order of 19.22 km^2.

In the sub-basin of Oued Toulal, the altitude classes 500-550, 550-600 and 600-650 m are relatively equivalent with a slight importance of the 500-550 m class, which occupies 31.79 % of the total area of the overall watershed. The lowest percentage in the order of 0.02 % is recorded at the level of 256-350 m class located downstream of the sub-basin.

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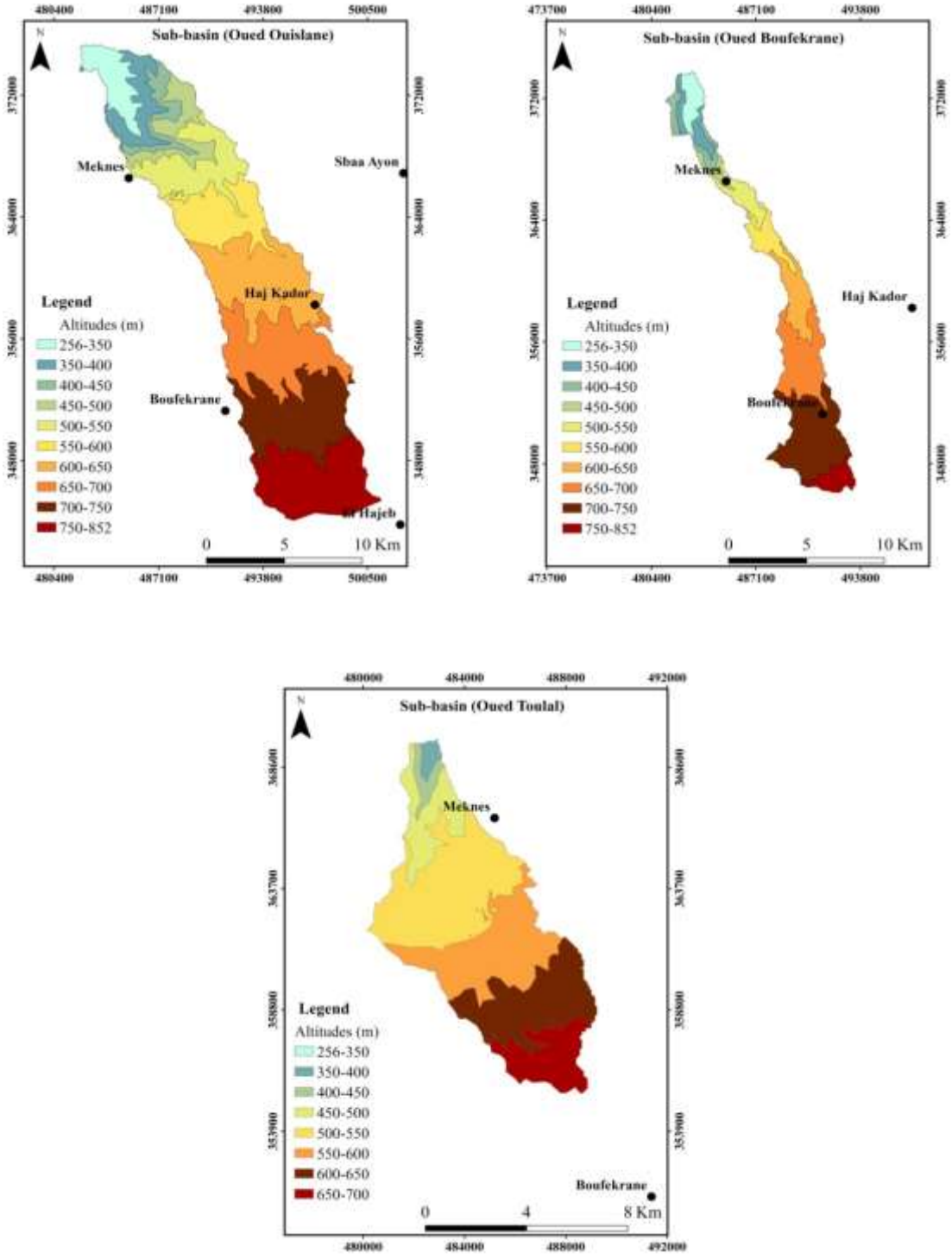

Figure 9: ***Hypsometric maps of the three sub-basins of Ouislane, Boufekrane and Toulal oueds***

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

Table 4. Repartition of the area according to the contours elevation

Sub-basin	Contour elevation (m)	Area between curves (km)	% Surface	% Cumulative Surface
Oued Ouislane	256-350	10.39	5.16	100.00
	350-400	10.14	5.04	94.84
	400-450	7.30	3.62	89.80
	450-500	10.73	5.33	86.18
	500-550	19.38	9.63	80.85
	550-600	19.82	9.85	71.22
	600-650	32.38	16.08	61.37
	650-700	29.92	14.86	45.29
	700-750	31.27	15.53	30.42
	750-852	29.97	14.89	14.89
Oued Boufekrane	256-350	3.87	6.06	100.00
	350-400	3.42	5.36	93.93
	400-450	2.95	4.63	88.57
	450-500	1.44	2.26	83.94
	500-550	4.29	6.73	81.68
	550-600	4.69	7.35	74.95
	600-650	7.18	11.26	67.60
	650-700	12.92	20.26	56.33
	700-750	19.22	30.14	36.08
	750-852	3.79	5.94	5.94
Oued Toulal	256-350	0.01	0.02	100.00
	350-400	0.89	1.47	99.98
	400-450	1.39	2.31	98.51
	450-500	5.74	9.52	96.21
	500-550	19.16	31.79	86.68
	550-600	14.10	23.40	54.89
	600-650	12.12	20.11	31.50
	650-700	6.86	11.39	11.39

Hypsometric curves of sub-basins studied

The hypsometric curve provides a synthetic view of the basin slope. This curve represents the repartition of the surface of the watershed according to its altitude. It carries on the abscissa the percentage of the basin area and the altitude on the ordinate [13].

According to Strahler [14], the shape of the hypsometric curve characterizes the cycle of erosion of the studied current relief (Figure 11). Indeed, a convex curve is a characteristic of a relief where erosion is still intense (immature relief), while a concave shape will reflect a stabilization of erosion processes (advanced relief) [15] [16].

The analysis of the hypsometric curves of the three sub-basins (Figure 12), and the comparison with the classification of figure 11, shows that the morphology of our three sub-basins tends toward an immature relief, which could be linked to the nature of the geological formations, inducing to a strong notch by the water erosion forces.

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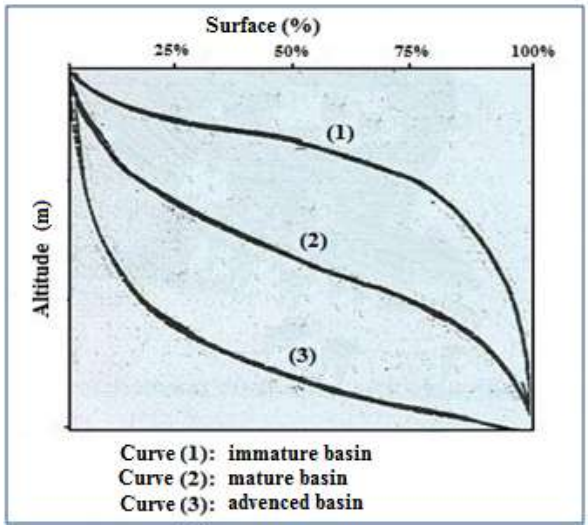

Figure 10: Shape of the hypsometric curve and state of the maturity of watersheds relief [14]

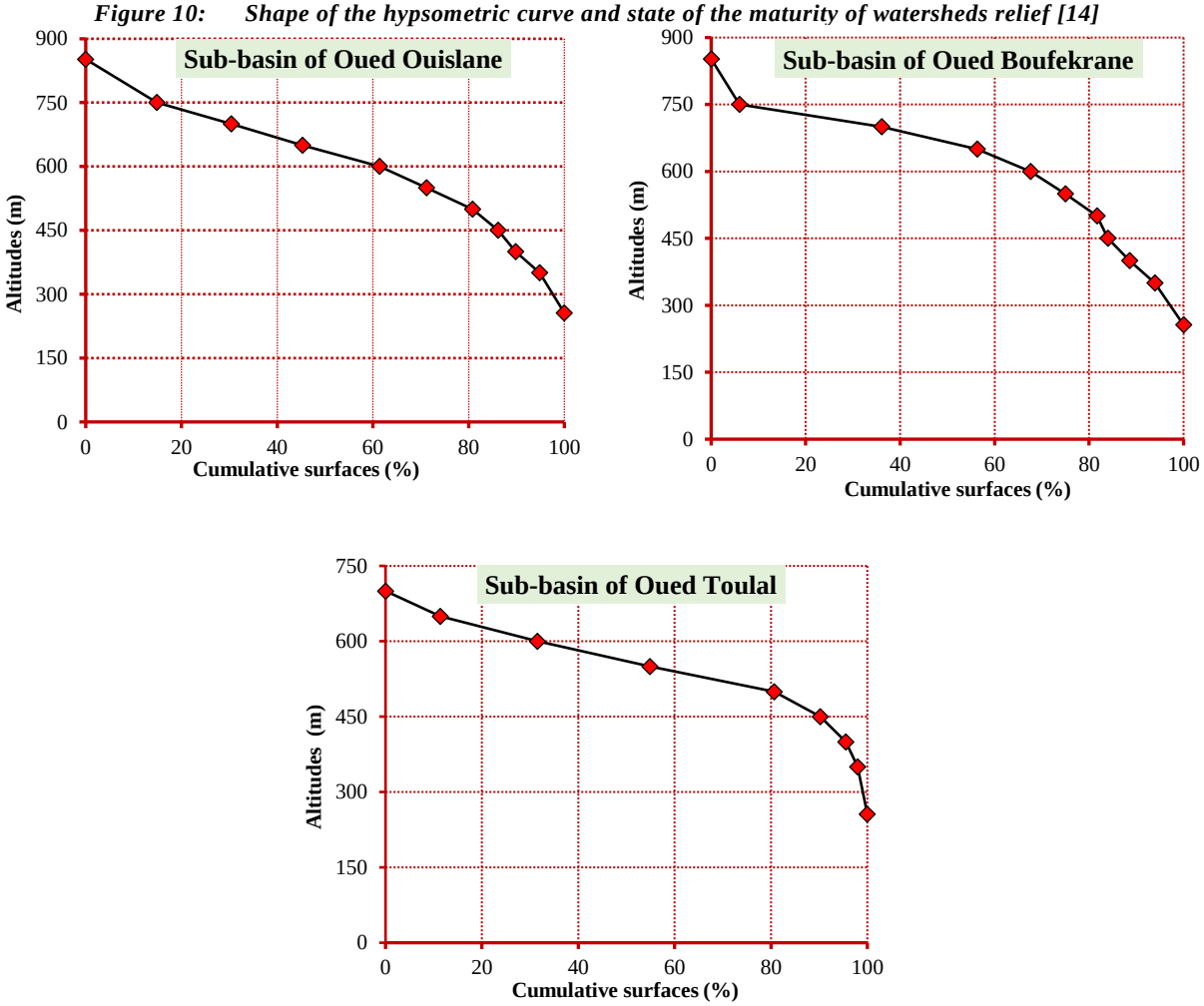

Figure 11: Hypsometric curves of the sub-basins of Ouislane, Boufekrane and Toulal oueds

Shape characteristics of sub-basins

A watershed is defined primarily by its contour, which has a certain shape and which extends over a certain area. This form will directly influence the overall flow of water.

Index of Compactness or Coefficient of Gravelius

The index most commonly used by hydrologists to characterize the geometry of a watershed is Gravelius's compactness index, which is defined as the ratio of the basin perimeter to that of a circle of the same surface

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[17]. It is close to 1 for a circular basin and greater than 1 if it is elongated. The formula used to calculate it is as follows [18]:

$$K_G = \frac{P}{2.\sqrt{\pi.A}} \approx 0.28.\frac{P}{\sqrt{A}}$$

With:

K_G: index of compactness of Gravelius;
A: surface of the watershed (km^2);
P: perimeter of the watershed (km).

For the three sub-basins studied, the compactness index calculated from the data presented above is greater than 1 (Table 5). So our three sub-basins have an elongated shape.

Table 5. Compactness index of the sub-basins of Ouislane, Boufekrane and Toulal oueds

Sub-basin	K_G : Gravelius coefficient
Oued Ouislane	2.33
Oued Boufekrane	3.45
Oued Toulal	1.94

The equivalent rectangle

The equivalent rectangle is a geometric representation of the contour of the basin transformed into a rectangle. It allows comparing watersheds with each other from the morphological point of view. This notion assumes that on a given basin, the flow is almost the same as on a rectangle of the same surface with the same Gravelius coefficient [19].

Knowing the compactness index of Gravelius K_G and the area of the watershed (A), we can deduce W and L which are respectively the width and the length of the equivalent rectangle, by the application of the following formulas: [17].

$$W = \frac{K_G \times \sqrt{A}}{1.12}\left[1 - \sqrt{1 - \left(\frac{1.12}{K_G}\right)^2}\right]$$

$$L = \frac{K_G \times \sqrt{A}}{1.12}\left[1 + \sqrt{1 - \left(\frac{1.12}{K_G}\right)^2}\right]$$

From the results of the calculations shown in table 6, we note that all sub-basins have an elongated shape, which will cause a delay in the flow of water to the outlet during a flood period [20]. This type of watershed should know very few cases of flooding of riparian communities even during high water.

Table 6. Characteristics of equivalent rectangles of sub-basins of Ouislane, Boufekrane and Toulal oueds

Sub-basin	Length (km)	Width (km)	Perimeter (km)	Surface (km^2)
Oued Ouislane	55.65	3.62	118.54	201.45
Oued Boufekrane	48.00	1.34	98.68	64.32
Oued Toulal	24.43	2.48	53.82	60.59

CONCLUSION

The topographic, morphological, and hydrographic characterization of the watershed studied was carried out by geographic information systems (GIS) from the SRTM images. The thematic maps produced allowed us to obtain information on our watershed of the three oueds studied.

The watershed studied covers an area of 326.46 km^2, where the large area is occupied by the sub-basin of Oued Ouislane with a percentage of 61.79 % of the total area, followed in second class of the Oued Boufekrane sub-basin, finally the one of Oued Toulal which occupies respectively 19.64 % and 18.57 % of the total area.

The hypsometric map and the TIN elevations map, obtained from the digital elevation model (DEM), present altitudes in the form of stairs, where the high altitudes of about 850 m are registered upstream of the watershed of the three oueds studied. As one moves downstream, the altitudes become increasingly low to about 256 m. The low slopes (0 to 2 %) and the medium slopes (2-5 %) extend over a large part of the watershed, while the steep slopes are located on a small area in the north and north-west of the watershed studied.

The physical study of the sub-basins studied shows that the three sub-basins have an elongated form which favors low flows, an important delivery time and therefore the risk of erosion.

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