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Evaluation of morphometric parameters and prioritization of the Oued Joumouaa watershed

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ABSTRACT

This paper aims to evaluate the adequacy of morphometric parameters (linear, shape and relief) for watershed management. The main objectives of this study include the estimation and prioritization of the sub-watersheds of the Oued Joumouaa basin using reliable methods. The morphometry of the watershed gives an apparent picture of the basin and its evolution. A morphometric analysis attempts to prioritize twelve sub-watersheds of the Oued Joumouaa which is a tributary of theoued Ouergha. The hydrographic network was divided into twelve sub-basins which were delimited from a DTM based on the open-source software. The following parameters were calculated for each sub-watersheds: the length of stream (lu), the mean length of stream (Lsm), the ratio of length of flow (Rl), the constant of maintenance of the channel (C), the ratio of biffurcation, the texture of drainage (Dd), the density of drainage (T), the frequency of stream (Fs), the ratio of elongation (Re), the ratio of circularity (Rc), the factor of form (Ff), the relief and the relief ratio. By combining the values of these parameters, we have classified the sub-watersheds into three prioritization classes: the high class in sub-watersheds (02, 03, 05, 07, 08, 10 and 12) are susceptible to maximum soil erosion, the medium class in sub-watersheds(04, 06 and 09) and the low class in sub-watersheds (01 and 11).

Key words: *Erosion, Watershed, Oued Joumouaa, Prioritization, Morphometric parameters.*

Introduction

The watershed is an ideal entity for planning and management of land and water resources (Gajbhiye *et al*., 2013). It is a natural hydrological entity that allows surface runoff to a defined channel, drain, stream or river at a particular point (Chopra *et al.,* 2005). Physiography, drainage, geomorphology, soil, land use and land cover are some parameters that play an important role in watershed planning (Javed *et al*., 2011).

Watershed management involves the proper use of land, water, forest and soil resources. Thus, a realistic assessment of the hydrological behavior of a watershed is important for developing effective management. The study of natural hazards in a watershed requires a good hydrological, climatic, geological, ecological, and geomorphological understanding to determine the factors that influence the occurrence of natural hazards (land use, slope, vegetation cover, and drainage network). These factors are necessary to determine the prioritization of watersheds and thus figure out a program to combat natural hazards (Benzougagh *et al.,* 2016 and 2017).

The proper management of a watershed and the study of the prioritization of sub-watersheds requires the use of geographic information system techniques (GIS) the digital terrain models (DTM) of type SRTM, for a better evaluation of the study area in terms of slope, drainage system, topography, geomorphology and lithology from geological maps. These data are used in the analysis of morphometric parameters of the watershed and sub-basins, which allowed a prioritization of the watersheds for possible protection against flooding and landslide risks.

Presentation of the study area

Physical characteristics of the study area

The watershed of the Oued Joumouaa is located in the north of the large watershed of Sebou. It is a sub-basin of the Oued Ouergha basin, which is the first sub-watershed of the Sebou. It covers an area of 59 km² and a perimeter of 60 km (Fig. 1).

The watershed of oued Joumouaa shows a topography with a drop ranging from 760 m to 94m. The bedrock of the basin is essentially formed by impermeable Cretaceous clays and marls (Boukrim, 2011). Its climate is of the Mediterranean type with a dry season in summer and rain in winter following each other. This geographical situation in the south of the Rif mountains, on which the Ouergha watershed extends over most of its area offers a rich flora (olive trees, oaks, cereals, cedars). The basin contains four dams, from upstream to downstream: Asfalou, Bouhouda, Sahla, and El ouahda neighboring.

Climatic data

The average annual temperature recorded is around 19 °c (from 1982/1983). The highest humidity values are recorded in December and January (80%); however, they do not exceed 55% in July and August. The average annual humidity is 71.7%, which classifies the climate of the Ouergha basin as humid. The potential evapotranspiration varies from 22 mm (January) to 162 mm (August). The monthly evapotranspiration takes its maximum values from June to September, and its lowest values in December and January (Boukrim, 2011).

The Martonne rainfall index is about 31 and the Moral rainfall index is about 1.87 which qualifies the Ouergha basin as a subhumid to humid area. The xerothermic index of Gaussen (Fig. 2) shows that the wet period extends from November to March. The wettest month is December when the difference between the two peaks is maximum (Boukrim, 2011)

Methodology adopted

The methodology adopted in this work is expressed in (Fig. 3). The formulas used for the quantitative

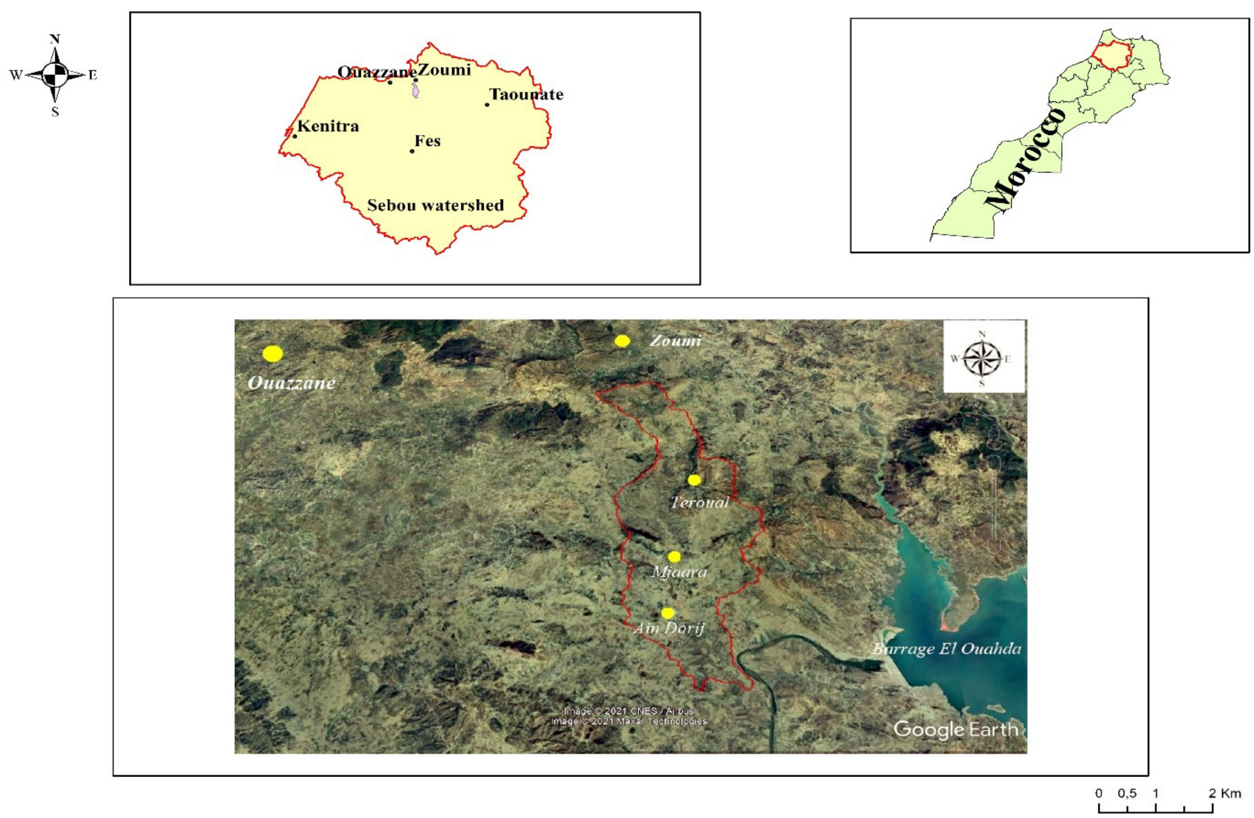

Fig. 1. Geographical location of the oued Joumouaa watershed.

Morphometricparameters	Formula	References
	Shapeparameters	
Drainage density (Dd) (Km/km²)	Dd=Lu /A Lu=total length of the flow orders (Km), A=basin area in km².	Horton (1945)
Frequency of stream(Fs)	Fu = Nu /A Nu = total number of different orders, A = basin area	Horton (1945)
Meanbiffurcation ratio (Rbm)	Average biffurcation ratio of all orders	Strahler, 1964
Drainage texture (T) (no/km²)	T = Nu/P Nu: total number of order flows p: perimeter (km)	Horton (1945)
Flow length (lo) (km)	Lo = 1/Dd Dd drainage density	Horton (1945)
Form factor (Ff)	Ff =A /Lb² A= basin area (km²) square of basin length	Horton (1945)
Basin shape (Bs)	Bs = Lb² / A	Nooka Ratnam *et al.*, (2005)
Elongation ratio (Re)	$Re = 1{,}128\sqrt{A/Lb}$ A= basin area Lb= basin length (Km)	Schumm (1956)
Channel maintenance constant ©	$C=A / \sum_{i=n}^{i=1} Lu$ A= area of the basin(Km²) Lu = total length of all flow orders in km	Horton (1945)
Compactness coefficient (Cc)	$P/\ 2\sqrt{\pi A}$	Horton (1945)
Number of infiltration (If)	f = Fu * Dd Fu: Flow frequency Dd = drainage density	Faniran (1968)
Circularity ratio (Rc)	Rc = 4*π *A/ P²	Miller (1953)
	Relief parameters	
Basin relief (Bh)	Bh = H -h1 H = maximum altitude H1 = minimum altitude	Horton (1945)
Relief ratio (Re)	R/L	Schumm (1963)
Relative relief (Rh)	Rh = Bh / LbBh = basin relief Lb = basin length	Schumm (1956)
Robustness number (Rn)	Rn = Dd * (Bh / 1000) Bh = basin relief, Dd = drainage density	Moore *et al.*, 1991

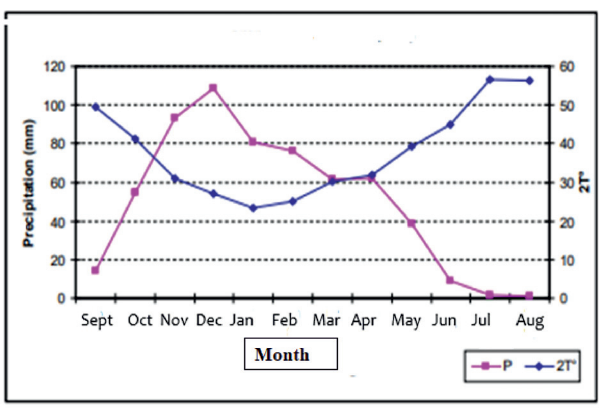

Fig. 2. Umbrothermal diagram of the Ouergha watershed (Boukrim, 2011).

determination of morphometric parameters are presented in Table 1. All analyses were performed using the open-source software Quantium GIS (QGis) and from the digital terrain model (DTM) type SRTM with a resolution of 30 m, as well as the topographic map 1/50000 of the study area to confirm the hydrographic network. The DTM data are available and can be downloaded from (https://earthesplorer.usgs.gov/). It was used for the extraction and estimation of morphometric parameters (area, perimeter, altitude, length and width of the basin, number and length of flows of each order), these parameters are used to calculate other things such as drainage density, bifurcation ratio, drainage frequency, circulatory ratio, and the shape factor etc., (Fig. 3). The classification of the 12 sub-watersheds of the study area is done by classifying the calculated morphological parameters into three classes: linear, shape and relief parameters (Table 1).

Results and Discussion

The linear, shape and relief parameters were deter-

Table 1. Method of calculation of morphometric parameters.

Morphometric parameters	Formula	References
Basic parameters		
Watershed area (A)	Calculatedthrough gis environnement	Horton (1945)
Watershed perimeter (P)	Calculatedthrough gis environnement	Horton (1945)
Linear parameters		
Stream order (U)	Hierarchicalorder of flow	Horton (1945)
number of stream (Nu)	Total number of the stream	Strahler (1957)
length of the basin (Lb)	Length of stream	Nooka Ratnam *et al.*, (2005)
Length of stream (Lu)	gissoftoware	Horton (1945)
Mean length of stream(LSM)	Lsm=Lu/Nu	Horton (1945)
biffurcation ratio (Rb)	Rb=Nu/Nu+1 Nu+1=Number of higher order flow segments	Schumm (1956)

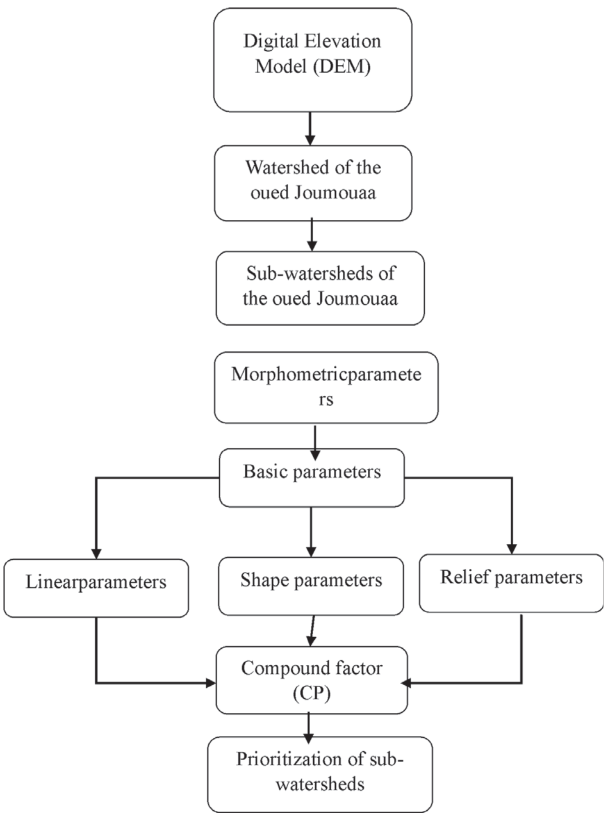

Fig. 3. Methodology of morphometric analysis of the Oued Joumouaa watershed.

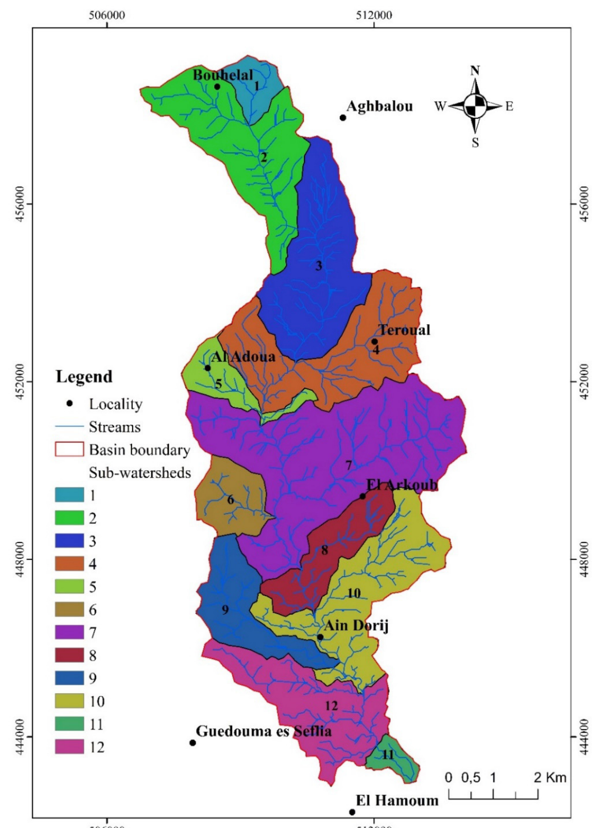

Fig. 4. Map of the sub-watersheds areas of the Oued Joumoua.

mined and calculated by subdividing the Joumouaa watershed into twelve sub-basins in order to prioritize them (Fig. 4).

The basic parameters

The basic parameters of the morphometric analysis are essential for the calculation of other parameters, namely: basin area (A), basin perimeter (P) and basin length (Lb) (Table 2). The calculation of these parameters is based on the digital terrain model (DTM) type SRTM of 30 m of resolution and the software (Quantum Gis) (open-source software).

Area and perimeter

The watershed of Oued Joumouaa covers an area of 59km² and a perimeter of 60 km (Fig. 5).

Table 2. Number of watercourses, length of the watercourse and ratio of the lengths of the twelve sub-watersheds.

Sub-watersheds	Area watershed km²	Basin perimeter km	Length of the basin in km	Lengths of the stream (Lu) in Km 1	2	3	4	5	Length of the stream in Km (ΣLu)
1	1,27	4,78	1,59	1,83	1,30	0,02	0,00	0,00	3,15
2	6,95	15,56	5,19	12,10	6,02	2,09	2,69	0,00	22,89
3	7,06	13,47	5,15	16,46	5,51	1,06	4,85	0,17	28,06
4	7,26	16,68	4,70	13,48	6,87	2,26	2,04	1,73	26,38
5	1,80	9,41	3,13	3,74	1,19	1,93	0,00	0,39	7,25
6	2,24	6,23	2,10	2,40	1,62	1,64	0,00	0,45	6,12
7	14,01	22,71	6,39	24,33	11,98	2,99	3,67	4,85	47,81
8	3,23	10,08	3,89	7,14	2,36	2,34	0,42	1,43	13,70
9	3,50	11,08	3,98	5,00	2,39	4,16	0,00	0,32	11,87
10	6,81	18,38	4,85	11,89	7,13	1,81	2,16	2,97	25,96
11	0,69	3,80	1,27	1,43	0,00	0,00	0,00	1,31	1,31
12	5,55	14,04	4,60	11,48	6,34	0,69	0,00	1,90	20,42

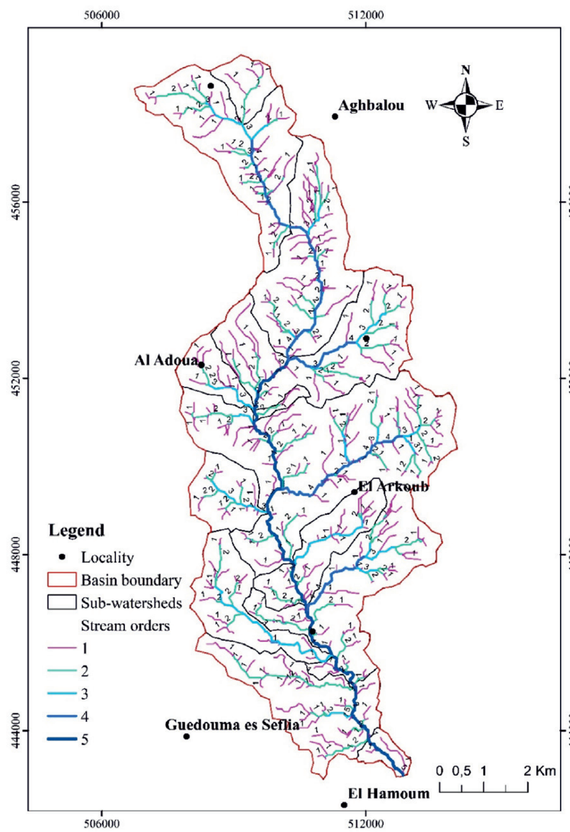

Fig. 5. Detailed hydrographic network of the oued Joumoua watershed.

The linear parameters

The linear parameters of the drainage system of the watershed are: the stream order (u), the number of streams of each order (Nu), the stream length, the mean length of stream (Lsm), the stream length ratio (Rl), the bifurcation ratio (Rb) and the flow ratio (Lo) (Table 3 and Table 4).

Stream order (u)

Stream ordering is the first step performed for any basin drainage analysis. In this study, stream order was performed using the method proposed by Strahler (1964). Stream order is defined as a measure of the subdivision of water lines in watersheds. It represents the organized relationship between the flow parts. According to Horton's Law (1945). The unsubdivided stream is designated as first-order stream. The second-order stream is the joinder of the two first-order streams. The third order stream is the joining of two second order stream. ect...

The study area contains 1621 streams (Fig. 5): 856 first-order, 363 second-order, 149 third-order, 120 fourth-order and 133 fifth-order. This large number of gullies results in water erosion of the soil.

Number of stream (Nu)

The number of streams is defined as the total number of stream segments of order (U) (Horton, 1945) and (Strahler, 1964). The analysis of hierarchical hydrographic network of the watershed of ouedJoumouaa shows that the total number of streams is of order 1621.

Length of stream (Lu)

According to Horton (1945) the calculation of stream lengths is done by measuring the total length of stream segments of different orders of the stream. stream length is the most important factor in a basin drainage, based on the law proposed by Horton

Table 3. Analysis of the stream of the twelve sub-watersheds of the Oued Joumouaa.

Sub-watersheds	Number the of stream (Σu)	Stream the number of different order (u)							Bifurcation ratio (Rb)		
		1 (Nu)	2	3	4	5	Rb1	Rb2	Rb3	Rb4	Average Rb (Rbm)
1	13	6	5	2	0	0	1,20	2,50	0,00	0,00	1,85
2	211	127	45	13	26	0	2,82	3,46	0,50	0,00	2,26
3	260	146	55	10	48	1	2,65	5,50	0,21	48,00	14,09
4	131	62	25	19	12	13	2,48	1,32	1,58	0,92	1,58
5	49	31	6	9	0	3	5,17	0,67	0,00	0,00	1,94
6	44	18	13	11	0	2	1,38	1,18	0,00	0,00	0,86
7	388	207	87	29	23	42	2,38	3,00	1,26	0,55	1,80
8	106	51	16	19	1	19	3,19	0,84	19,00	0,05	5,77
9	83	39	18	24	0	2	2,17	0,75	0,00	0,00	0,97
10	192	100	44	10	10	28	2,27	4,40	1,00	0,36	2,01
11	8	3	0	0	0	5	0,00	0,00	0,00	0,00	0,00
12	136	66	49	3	0	18	1,35	16,33	0,00	0,00	5,89

Table 4. Order length ratio and average order ratio

Sub-watersheds	Mean Lu (Lsm in km) in the different stream orders u (Lu/Nu)					Order length ratio (RLm)				Average order ratio (RL)
	1	2	3	4	5	2/1	3/2	4/3	5/4	
1	0,30	0,26	0,01	0,00	0,00	0,71	0,01	0,00	0,00	0,36
2	0,10	0,13	0,16	0,10	0,00	0,50	0,35	1,29	0,00	0,71
3	0,11	0,10	0,11	0,10	0,17	0,34	0,19	4,57	0,04	1,28
4	0,22	0,27	0,12	0,17	0,13	0,51	0,33	0,90	0,85	0,65
5	0,12	0,20	0,21	0,00	0,13	0,32	1,62	0,00	0,00	0,97
6	0,13	0,12	0,15	0,00	0,23	0,68	1,01	0,00	0,00	0,84
7	0,12	0,14	0,10	0,16	0,12	0,49	0,25	1,23	1,32	0,82
8	0,14	0,15	0,12	0,42	0,08	0,33	0,99	0,18	3,42	1,23
9	0,13	0,13	0,17	0,00	0,16	0,48	1,74	0,00	0,00	1,11
10	0,12	0,16	0,18	0,22	0,11	0,60	0,25	1,19	1,38	0,86
11	0,48	0,00	0,00	0,00	0,26	0,00	0,00	0,00	0,00	0,00
12	0,17	0,13	0,23	0,00	0,11	0,55	0,11	0,00	0,00	0,33

(1945). Here, we calculated the stream lengths of the two sub-watersheds. According to the second law of Horton (1945) which suggested that as the order of stream decreases the length increases. This means that the length of the first order stream is maximum. In our study area the total length of the streams is 216.34 km. The total of the numbers and length of the stream of each order decrease for the orders 1 to

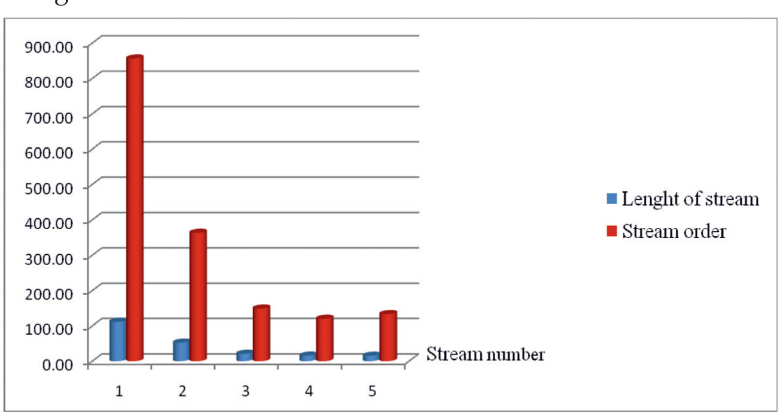

Fig. 6. Number and length of stream of each order in the Joumoua watershed.

5 and remain almost the same for the orders 4 and 5 (Fig. 6).

Stream Length Ratio (LR)

The stream length ratio is the ratio between the average stream length (Lu) of any given order (u), and the average stream length of next lower order (Lu-1), (Horton, 1945) which indicates the difference between slope and topography. The length ratio (LR) has a significant control of discharge capacity and different stages of erosion, it is useful to determine the stream rate and erosion stage of the basin (Horton, 1945; Sreedevi *et al.*, 004; Magesh *et al.*, 2013). The calculated values of RL (Table 4) range from 00 in (sub-watershed-11) to 1.28 in (sub-watershed-3). The later shows a degree of drainage development. The LR between successive orders generally varies with topographic variation, so there is a strong relationship between surface runoff and erosion stages of sub-watersheds.

Bifurcation ratio (Rb)

The bifurcation ratio is determined by the number of streams from one order to the next (Schumm, 1956), According to Horton (1945), the bifurcation ratio is considered an index of relief and dissection. It is an important parameter that articulates the degree of drainage branching and an indicator of the complexity and degree of dissection of a watershed (Bharadwaj *et al.*, 2014). Strahler (1957) has shown that in areas that have different environments, the bifurcation ratio exhibits little variation except in geologically resistant sites. The low values of the bifurcation ratio are the characteristics of structurally less disturbed watersheds without any distortion of the drainage network (Nag, 1998).

The bifurcation ratio for a given density of drainage lines is strongly controlled by the shape of the basin and shows very little variation (between 3 and 5) in homogeneous bedrock from one region to another (Chorley *et al.*, 1984). Generally, the average value of Rb varies between 3.0 to 5.0 for a watershed where the influence of geological structures on the drainage system is negligible (Yestappen, 1983).

The values of the bifurcation ratio of the study area vary from 0 to 14.09 (Table 3). The sub-watersheds of theouedJoumouaa which present low bifurcation ratios (2, 4, 5, 6, 7, 9, 10, 11) (Table 5) are more stable and not affected by structural disturbances. On the other hand, the other sub-watersheds (3, 8, 12) (Fig. 7) having high Rb values, they show a resistant structural control on the drainage network. The drainage network ofouedJoumouaa has 1621 (Table 2). The high number of streams is found in sub-watershed-7 (388) and the less numberis in sub-watershed-11 (8). Thus, the length of the stream follows the number of orders of the rivers in the hierarchy of the sub-watersheds, the sub-watershed-7 is the first with a length of 47.81 km and the last sub-watershed is 11 with 2.73 km. It is also noted that the dimensions of the sub-watershed and the variation of the order are related to the lithological conditions, in fact the sub-watershed-7 has marl formations against the sub-watershed-11 which covers limestone formations. It should also be noted that the

Table 5. Bifurcation ratio classification in the Joumouaa watershed

Bifurcation ratio	Classes	Sub-watershed
<3	low	2;4;5; 6;7;9;10;11
[3-5]	Medium	————
>5	high	3 ; 8 ;12

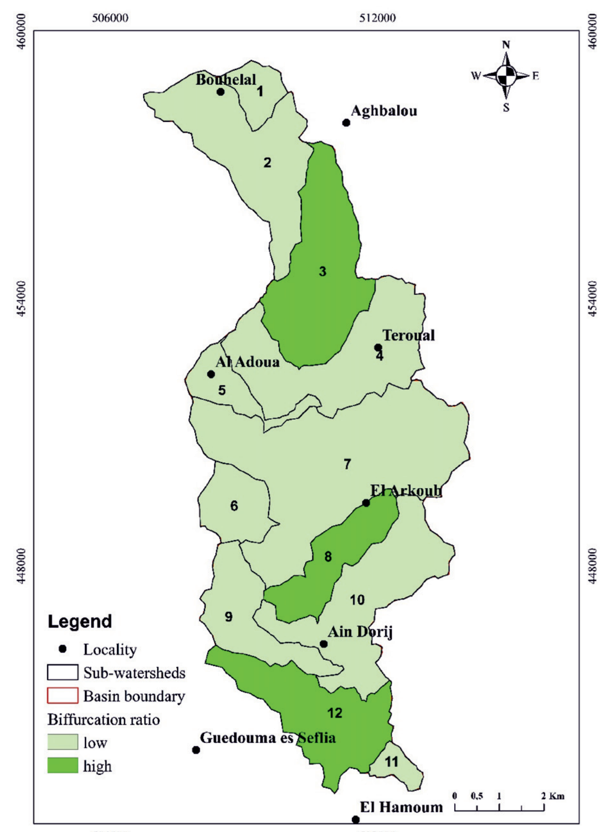

Fig. 7. Classification of the bifurcation ratio of the sub-watersheds of the Oued Joumouaa

study area is characterized by significant slopes that increase the speed of runoff and severe climatic conditions. This favors the process of water erosion and the formation of Badlands.

Shape parameter

The shape parameters of a watershed are a very important morphometric attribute, as they are related to the spatial distribution of several factors (Table 6) including density (Dd) and drainage texture (Td), frequency of stream (Fs), form factor (Ff), circularity ratio (Rc), elongation ratio (Re), length overland flow (Lo), compactness coefficient (Cc), constant channel maintenance (C) and infiltration number (In).

Drainage Density (Dd)

According to Horton (1932), drainage density is the total length of the drainage system per unit the area of a watershed. This density is controlled by vegetation, climate, the nature of the soil and subsoil, and the geological nature of the land (Humbert, 1990).

The work of (Melton, 1957; Strahler, 1964; Nag, 1998; Mesa 2006; Thomas *et al.*, 2011 and Benzougagh *et al.*, 2016 & 2017) has shown that high values of drainage density (Dd>3.50) correspond to impermeable soils. Moderate values of drainage density [1.75-3.50] show that the soil and subsoil occupy a highly permeable vegetation cover. Low values of drainage density [0-1.75] designate that the soil and the subsoil are very permeable.

The drainage density of theouedJoumouaa subwatersheds varies from 1.89 to 4.25. The sets 1, 2, 6, 7, 9, and 11 have drainage density values between 1.75-3.50. (Table 6). This can be explained by the presence of a highly permeable vegetation cover. On

Table 6. Results of the shape parameters in the basin of ouedJoumouaa

Sub-wtersheds	Drainage density (Dd)	Stream frequency (Fs)	Drainage texture (Td)	Length of flow (Lo)	Infiltration (In)	Drainage intensity (Din)	Channel maintenance constant (C)
1	2,47	10,22	0,66	1,24	25,30	4,13	0,40
2	3,29	30,36	1,47	1,65	100,03	9,22	0,30
3	3,97	36,82	2,08	1,99	146,27	9,27	0,25
4	3,63	18,04	1,58	1,82	65,52	4,96	0,28
5	4,04	27,27	0,77	2,02	110,10	6,76	0,25
6	2,73	19,62	0,98	1,36	53,52	7,19	0,37
7	3,41	27,70	2,11	1,71	94,55	8,12	0,29
8	4,25	32,86	1,36	2,12	139,60	7,74	0,24
9	3,40	23,74	1,07	1,70	80,63	6,99	0,29
10	3,81	28,18	1,41	1,90	107,34	7,40	0,26
11	1,89	11,61	0,34	0,95	22,00	6,13	0,53
12	3,68	24,51	1,45	1,84	90,20	6,66	0,27

Table 7. Circularity ratio, compactness coefficient, elongation ratio and form factor in the Joumouaa basin.

Sub-watersheds	Basin shape (Bs)	Circularity ratio (Rc)	Compactness coefficient (Cc)	Elongation ratio (Re)	Formfactor (Ff)
1	1,99	0,70	1,20	0,25	0,50
2	3,88	0,36	1,66	0,43	0,26
3	3,76	0,49	1,43	0,44	0,27
4	3,04	0,33	1,75	0,49	0,33
5	5,45	0,26	1,98	0,18	0,18
6	1,97	0,73	1,17	0,34	0,51
7	2,92	0,34	1,71	0,70	0,34
8	4,69	0,40	1,58	0,26	0,21
9	4,53	0,36	1,67	0,28	0,22
10	3,45	0,25	1,99	0,45	0,29
11	2,34	0,60	1,29	0,17	0,43
12	3,81	0,35	1,68	0,38	0,26

the other hand, the sub-watersheds 3, 4, 5, 8, 10, and 12 have a drainage density higher than 3.50 (Fig. 8), they are characterized by impermeable marl soils and a low vegetation cover, the erosion rate of the land is thus high.

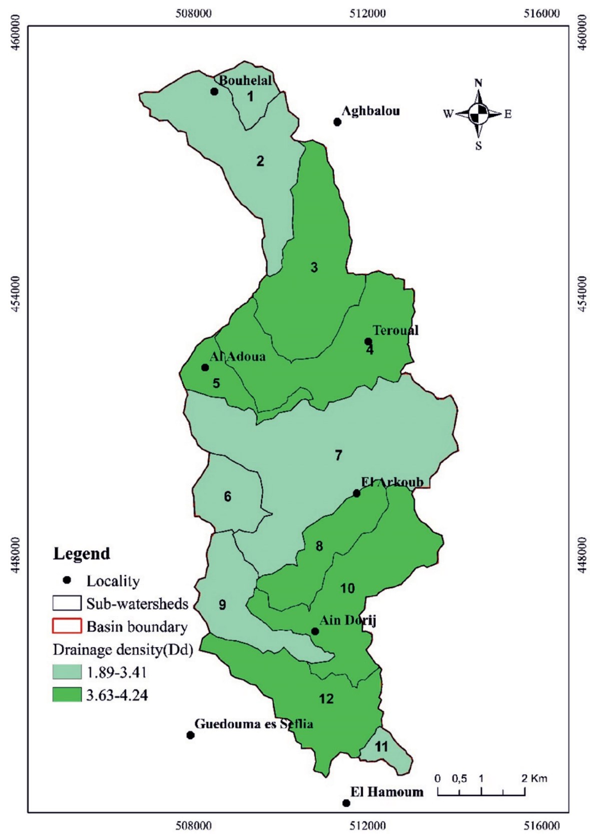

Fig. 8. Density of drainage in the Joumouaa watershed

Stream frequency (Fs)

The drainage stream is defined as the total number of segments of all orders of the stream per unit in the area (Horton, 1932). In the watershed of oued Joumouaa, the value of the flow frequency is maximum in the sub-watershed-3 and reaches 36.82, while in sub-watershed-01 the stream frequency is minimal and covers 10.22. In general, the study area has high values of stream frequency this is related to impermeable formations.

Drainage texture (Td)

Drainage texture is the total number of stream segments of all orders within the perimeter of the area (Horton, 1945). It presents the spacing of channels in a divided riverine terrain and depends on many natural factors such as climate, vegetation, precipitation, soil type, lithology, relief and infiltration capacity (Smith, 1950; Vincy *et al.*, 2012). According to Smith (1950) five classes of drainage texture were designated (Table 8).

Table 8. Drainage texture classification.

Classe	Drainage texture value	Type of texture
01	<2	Very high
02	[2-4]	High
03	[4-6]	Moderate
04	[6-8]	Fine
05	>8	Very fine

The sub-watershed of oued Joumouaa has a drainage texture that varies from 0.34 to 2.11 (Table 6). Two categories of drainage texture are recognized, very high for all sub-watersheds (<2) except sub-watershed-03 (2.08), and sub-watershed-07 (2.11) which have a high drainage texture (Fig. 9).

Drainage Intensity (Din)

Drainage intensity (Din) is the ratio of stream fre-

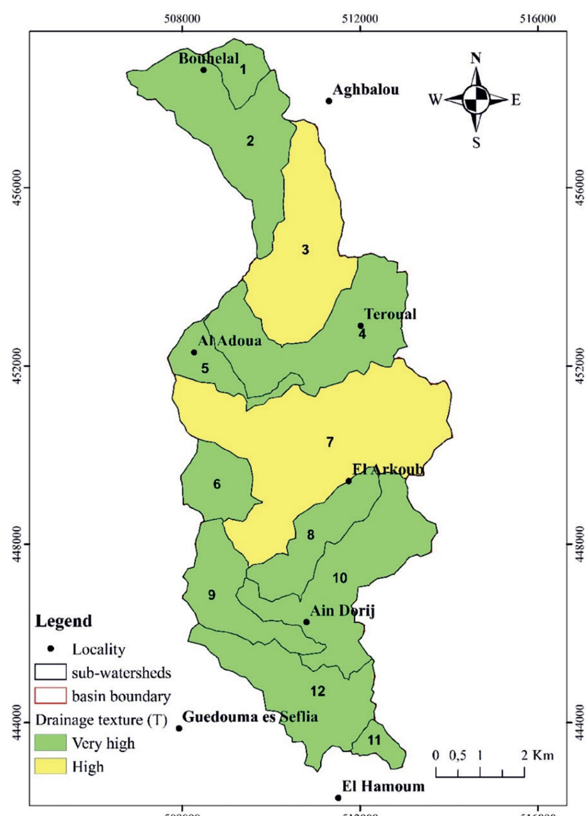

Fig. 9. Drainage texture map of the oued Joumouaa sub-watersheds

quency to drainage density (Faniran, 1968). The low value of drainage density means low impact of density and stream frequency on soil erosion agents and vice versa (Faniran, 1968). Drainage intensity values range from 4.13 (sub-watershed-01) to 9.27 (sub-watershed-03) (Table 6). Generally, the drainage density values in the study area are higher which reveal that the stream frequency (Fs) and drainage density (Dd) have a significant impact on the extent to which the surface runoff is high and the soil surface has been eroded making the basin susceptible to gully erosion as well as flooding.

Length of overland flow (Lo)

Surface runoff length (Lo) is defined as the length of water at the soil surface before it collects in the channels of defined water lines (Horton, 1945). This index is half the drainage density Dd, Lo=1/2Dd. It is inversely proportional to the average channel slope (Sunil *et al.,* 2010; Shiva and Dharanirajan, 2014; Umair and Syed, 2014; Waikar and Nilawar, 2014), (Fig. 10).

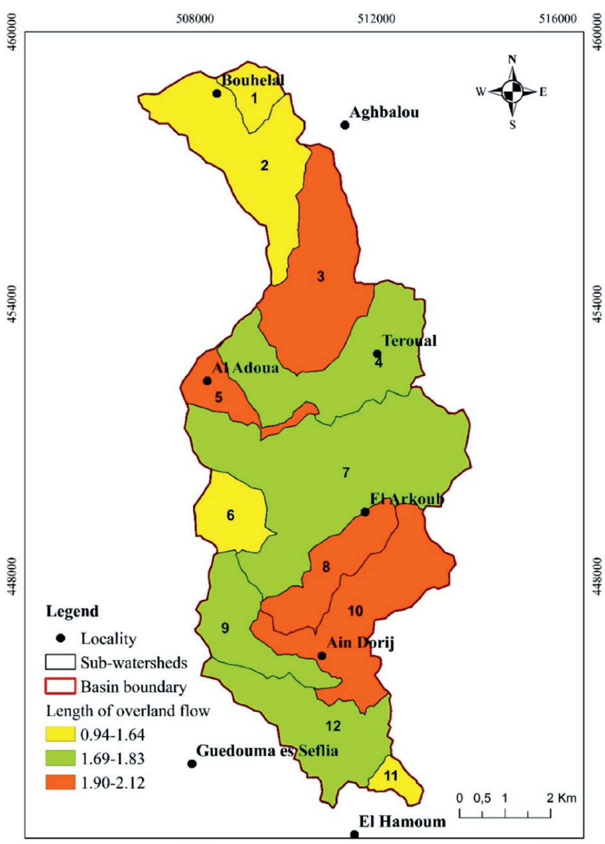

Fig. 10. Map of flow length of the ouedjoumouaa watershed

It depends on relief, rock type, permeability, climatic factors, vegetation cover and water erosion. Generally, a slow flow means that the value of Lo is higher. It is found in areas with low slopes or low erosion. The length of flow in flat terrain is higher compared to rougher terrain (Kumar, 2017). This index is related to the development period of a basin. As such, it affects the hydrologic, topographic, and physiographic evolution of a watershed.

The length of the surface runoff of the sub-watersheds of oued Joumouaa varies from 0.95 to 2.12. The low value of the runoff is marked in sub-watershed-11 (0.95) which indicates a rapid runoff movement. While the highest value of the flow length is recorded in sub-watershed-8 which shows a slow runoff process.

Form factor (Ff)

Form factor(Ff) indicates the flow intensity of a basin in a defined area. Horton (1932-1945) has presented the form factor as the ratio of basin area to the square of the basin length. Its value varies from 0 to 1, the smaller the value is more elongated the shape of the watershed. The high form factor in a basin corresponds to a shorter duration flow, as well as the average form factor value in an elongated sub-basin whichcorresponds to a low flow with a long duration (Umak *et al.,* 2017). In the study area the form factor varies from 0.18 to 0.51 (Table 3). Only elongated study sub-watersheds with longer drainage duration are found.

Elongation ratio (Re)

The aspect ratio is defined as the ratio of the circular diameter of the same area as the drainage basin to the maximum length of the basin (Schumm, 1956). In general, according to Strahler (1964), values near 1 are typical of areas of very low relief, while values in the range of 06 to 0.8 are generally associated with high relief and steep slopes. The varying slopes of the watershed can be classified according to the aspect ratio, i.e., more elongated (<0.5), elongated (0.5-0.7), less elongated (0.7-0.8), oval (0.8-0.9) and circular (0.9-1). The values of the elongation ratio in the twelve sub-watersheds of ouedJoumouaa vary from 0.17 to 0.7. (Table 7). This shows that all sub-basins have a more elongated shape except sub-watershed-07 which is elongated.

Coefficient of Compactness (Cc)

The coefficient of compactness (Cc) is defined as the ratio of the length of basin perimeter and perimeter of a cercle with same area (Gravelius, 1914). It is useful for expressing the relationship of a circular basin and the hydrological basin. This index is directly related to the estimation of erosion risk, that is large values indicate an increase and high vulnerability of erosion risk and show the need for anti-erosion conservation measures. However, low values indicate low erosion (Umak *et al.*, 2017). In the study area the value of compactness coefficient varies between 1.17 and 1.99. The lowest value is marked in sub-wtershed-06 while the highest value is noted in sub-watershed-10 (Cc=1.99). According to this coefficient, sub-watershed-05 and sub-wtershed-10 are the most exposed to erosion risk.

Channel maintenance constant (C)

Channel maintenance constant (C) (Fig. 11) is represented as the inverse of drainage density (Dd) (Schumm, 1956). In fact, it is a measurement of required drainagearea to maintain a unit length of channel or consistency of channel (Ritter *et al.*, 1995). This parameter is controlled by several factors such as relief factor, geology, climate, ect....

In this study the channel maintenance constant values varybetween 0.24 (sub-watershed-08) and 0.53 (Sub-watershed-11) (Table 6). This designates that the sub-watershed-08 contains less permeable rock formations, less maturity, lower structural disturbance and higher runoffthan sub-watershed 11.

Infiltration (In)

The infiltration index is the combined result of drainage density, flow frequency and inversely proportional to the infiltration capacity of the basin (Romshoo *et al.*, 2012). That is, the higher the infiltration number, the lower the infiltration capacity and therefore the surface runoff will be higher (Umrikar, 2017). In the study area the infiltration number values range from 22 (sub-watershed-11) to 146 (sub-watershed-3). Generally, the infiltration number is high in all sub-watersheds. This means that the infiltration capacity is lower at the watershed level (Fig. 12).

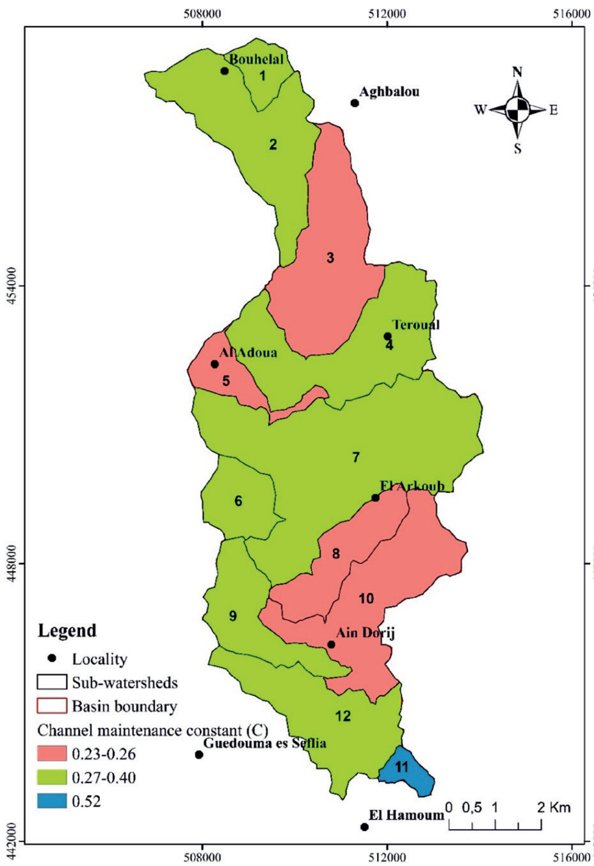

Fig. 11. Canal maintenance map of the Joumoua watershed

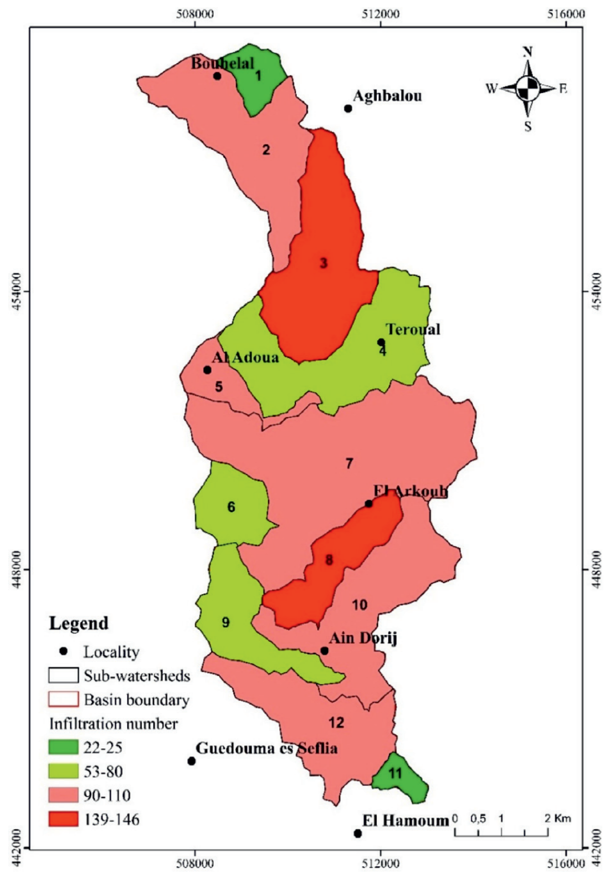

Fig. 12. Infiltration value in the oued Joumouaa watershed.

Table 9. Correlation between Rc and cycle stage of the ouedJoumouaa watershed.

Rc value	Life cycle stage of the watershed
Low	Young
Medium	Mature
High	Old

Circularity ratio (Rc)

The circularity ratio is defined as the ratio of the basin area to the area of a circle that has the same circumference as the basin perimeter (Miller, 1953). This ratio is controlled by several factors mainly Tectonic, lithology, slope, climate, land use, flow frequency, length and vegetation cover of the basin. The table shows the correlation of circularity ratio values with basin life stages (John Wilson *et al.,* 2012; Magesh and Chandrasekar, 2012).

in the study area, the values of the circularity ratio of theouedJoumouaa sub-watershed vary from 0.26 to 0.73 (Table 4). The lowest stage corresponds to the young sub-basin while the highest correspond to the final stage of maturity of the watershed.

Conclusion

The shape parameters namely the compactness coefficient, the shape factor and the circularity ratio are inversely correlated to soil erosion. This means that the shape parameter remains a good indicator of erosion risk with its lowest.

Relief parameters

These parameters include basin relief (Rb), relative relief; robustness number (Rn) (Umair Ali and Syed Ahmad Ali, 2014) or slope (Table 10).

Basin relief (H)

Basin relief is expressed as the difference between the highest point and the lowest point (drainage division) (outlet) (Schumm, 1963; Kartic and Jatisankar, 2013). This factor is important not only for the evolution of landforms, surface and groundwater flow, drainage, permeability, and erosion properties of the land but also for understanding the denudation characteristics of the basin (Magesh and Chandrasekar, 2012). The values of the relief of subbasins of ouedJoumouaa (Table 10) vary between 102m for (sub-watershed-11) and 437m for (subwatershed-3). It is concluded that sub-watersheds (1,11and 12) have low values of basin relief while the other sub-basins (2,3,4, 5, 6, 7, 8, 9 and 10) have an important basin relief, therefore they will be exposed to an important drainage and a low infiltration.

Relief Ratio (Re)

The relief ratio is the ratio of maximum relief to horizontal distance along the longest dimension of a basin parallel to the main drainage line. It is a measure of the overall slope of the watershed (Schumm, 1956; Strahler, 1964). This measurement is an index of the increase in erosion being created on the watershed slope. The rate of relief normally increases with the drainage area and size of a given drainage basin (Gottschalk, 1964). The high value of Rh corresponds to the characteristics of mountainous regions. Rh, as well as the Robustness Number (Rn), directly correlates with watershed erodibility (Ameri *et al.*, 2018). The values of the relief ratio of

Table 10. Results of relief parameters in the ouedJoumouaa watershed.

Sub-watersheds	Basin relief in m	Robustness number (Rn)	Relative relief (Rr)	Relief ratio (Re)
1	145	0,36	3.03	0,09
2	397	1,31	2.55	0,08
3	437	1,74	3.24	0,08
4	390	1,42	2.33	0,08
5	225	0,91	2.39	0,07
6	294	0,80	4.72	0,14
7	376	1,28	1.65	0,06
8	307	1,30	3.04	0,08
9	230	0,78	2.07	0,06
10	338	1,29	1.83	0,07
11	102	0,19	2.68	0,08
12	147	0,54	1.04	0,03

the sub-watersheds of ouedJoumouaa vary from 0.03 to 0.14 (Table 6). The highest value is noted in sub-watershed-6 which shows a steep slope, on the other hand the lowest value is marked in sub-watershed-12 this is explained by a low slope (Fig. 13).

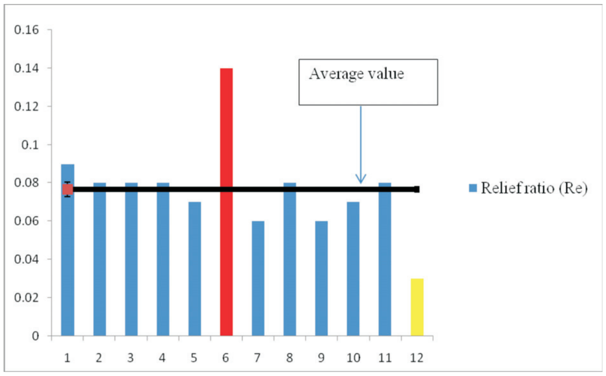

Fig. 13. Relief ratio of the sub-basins of the oued Joumouaa.

Relative Relief (Rr)

Relative relief presents the ratio of maximum basin relief (H) to watershed perimeter (Melton, 1958). It is an important indicator for assessing general morphological parameters of the terrain (Umair and Syed, 2014). The high relative relief value of a sub-basin designates that the runoff potential is higher than the others (Umair and Syed, 2014). The relative relief value ofouedJoumouaa sub-watersheds varies from 1.05 for (sub-watershed-12) to 4.72 for (sub-watershed-7) (Table 7). It can be seen that most of the sub-basins have a high runoff potential.

Robustness number (Rn)

According to (Strahler, 1957; Melton, 1958) the robustness number (Rn) is the product of drainage density (Dd) and that of the basin (H) in the same unit. In the study area the values of the robustness number vary between 0.19 and 1.74 (Table 10). The lowest value is noted in sub-watershed-11 (0.19) and the highest is marked in sub-watershed-3 (1.74), (Fig. 14).

Conclusion

The analysis of the basin relief parameters such as basin relief (Rb), Relative Relief (Rr), relief ratio (Rh) and robustness number (Rn) show the following results: Most sub-watersheds have high runoff potential.

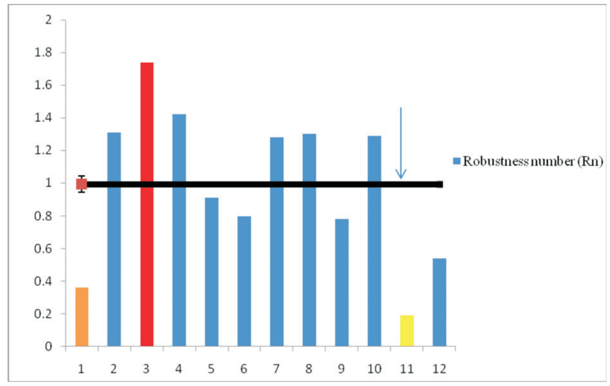

Fig. 14. Number of robustness of the sub-watersheds of oued Joumouaa

Ranking and prioritization of sub-watersheds based on morphometric analysis

According to (Biswas *et al.*, 1999), morphometric parameters are considered as erosion assessment parameters used to prioritize sub-watersheds. Linear parameters have a direct and proportional relationship with erodibility, the higher the value the higher the erodibility. Based on the average value of these parameters, the sub-watersheds with the low value are considered to be the highest priority, and the sub-watershed with the highest value of compound factor is the lowest priority. The sub-watersheds are classified (Table 11) based on the range of values of the compound factor which vary between 4.8 and 8, into three prioritization categories: high, medium and low (Fig.15), (Benzougagh, 2016 and 2017).

Prioritization of sub-watersheds

Morphometric parameters allow the evaluation of erosion risks. They have been used to prioritize sub-watersheds (Biswas *et al.*, 1999). Linear parameters have a direct and imperfect relationship with erodibility, that is the higher the value the higher the erodibility. Based on this rule we have classified the linear parameters (Table 11).

The shape parameters have an inverse relationship with erodibility, the lower the value, the higher the erodibility. The values of these parameters are ranked in an ascending order in the form of a ranking (Nooka Rtnam *et al.*, 2005; akram *et al.*, 2009). The following table (Table 12) shows the ranking of shape parameters of the study area based on the previous rule.

Table 11. Classification of the shape parameters in the watershed of Oued Joumouaa

Sub-water-sheds	Dd	Class	Fs	Class	Td	Class	Rbm	Class	Lo	Class	In	Class	Din	Class	Ce	Class
1	2,47	11,00	10,22	12,00	0,66	11,00	1,85	6,00	1,24	11,00	25,30	11,00	4,13	12,00	0,40	2,00
2	3,29	9,00	30,36	3,00	1,47	4,00	2,26	4,00	1,65	9,00	100,03	5,00	9,22	2,00	0,30	4,00
3	3,97	3,00	36,82	1,00	2,08	2,00	14,09	1,00	1,99	3,00	146,27	1,00	9,27	1,00	0,25	10,00
4	3,63	6,00	18,04	10,00	1,58	3,00	1,58	9,00	1,82	6,00	65,52	9,00	4,96	11,00	0,28	7,00
5	4,04	2,00	27,27	6,00	0,77	10,00	1,94	7,00	2,02	2,00	110,10	3,00	6,76	8,00	0,25	11,00
6	2,73	10,00	19,62	9,00	0,98	9,00	0,86	10,00	1,36	10,00	53,52	10,00	7,19	6,00	0,37	3,00
7	3,41	7,00	27,70	5,00	2,11	1,00	1,80	8,00	1,71	7,00	94,55	6,00	8,12	3,00	0,29	6,00
8	4,25	1,00	32,86	2,00	1,36	7,00	5,77	3,00	2,12	1,00	139,60	2,00	7,74	4,00	0,24	12,00
9	3,40	8,00	23,74	8,00	1,07	8,00	0,97	11,00	1,70	8,00	80,63	8,00	6,99	7,00	0,29	5,00
10	3,81	4,00	28,18	4,00	1,41	6,00	2,01	5,00	1,90	4,00	107,34	4,00	7,40	5,00	0,26	9,00
11	1,89	12,00	11,61	11,00	0,34	12,00	0,00	12,00	0,95	12,00	22,00	12,00	6,13	10,00	0,53	1,00
12	3,68	5,00	24,51	7,00	1,45	5,00	5,89	2,00	1,84	5,00	90,20	7,00	6,66	9,00	0,27	8,00

Table 12. Classification of shape parameters in the basin of Oued Joumoua.

Sub-watersheds	Bs	Class	Rc	Class	Cc	Class	Re	Class	Ff	Class
1	1,99	2	0,70	11	1,20	2	0,25	3	0,50	11
2	3,88	9	0,36	7	1,66	6	0,43	8	0,26	4
3	3,76	7	0,49	9	1,43	4	0,44	9	0,27	6
4	3,04	5	0,33	3	1,75	10	0,49	11	0,33	8
5	5,45	12	0,26	2	1,98	11	0,18	2	0,18	1
6	1,97	1	0,73	12	1,17	1	0,34	6	0,51	12
7	2,92	4	0,34	4	1,71	9	0,70	12	0,34	9
8	4,69	11	0,40	8	1,58	5	0,26	4	0,21	2
9	4,53	10	0,36	6	1,67	7	0,28	5	0,22	3
10	3,45	6	0,25	1	1,99	12	0,45	10	0,29	7
11	2,34	3	0,60	10	1,29	3	0,17	1	0,43	10
12	3,81	8	0,35	5	1,68	8	0,38	7	0,26	5

Table 13. Prioritization results of the morphometric analysis of the Oued Joumouaa sub-watersheds

Morphometric parameters																
Sub-water sheds			Linearparameters							Shape parameters				Sum	cp	Final
	Dd	Fs	Td	Rbm	Lo	Din	In	Ce	Re	Ff	Rc	Bs	Cc	*****	value ******	priority ******
1	11	12	11	6	11	12	11	2	3	11	11	2	2	105	8,08	Low
2	9	3	4	4	9	2	5	4	8	4	7	9	6	74	5,69	High
3	3	1	2	1	3	1	1	10	9	6	9	7	4	57	4,38	High
4	6	10	3	9	6	11	9	7	11	8	3	5	10	98	7,54	Medium
5	2	6	10	7	2	8	3	11	2	1	2	12	11	77	5,92	High
6	10	9	9	10	10	6	10	3	6	12	12	1	1	99	7,62	Medium
7	7	5	1	8	7	3	6	6	12	9	4	4	9	81	6,23	High
8	1	2	7	3	1	4	2	12	4	2	8	11	5	62	4,77	High
9	8	8	8	11	8	7	8	5	5	3	6	10	7	94	7,23	Medium
10	4	4	6	5	4	5	4	9	10	7	1	6	12	77	5,92	High
11	12	11	12	12	12	10	12	1	1	10	10	3	3	109	8,38	Low
12	5	7	5	2	5	9	7	8	7	5	5	8	8	81	6,23	High

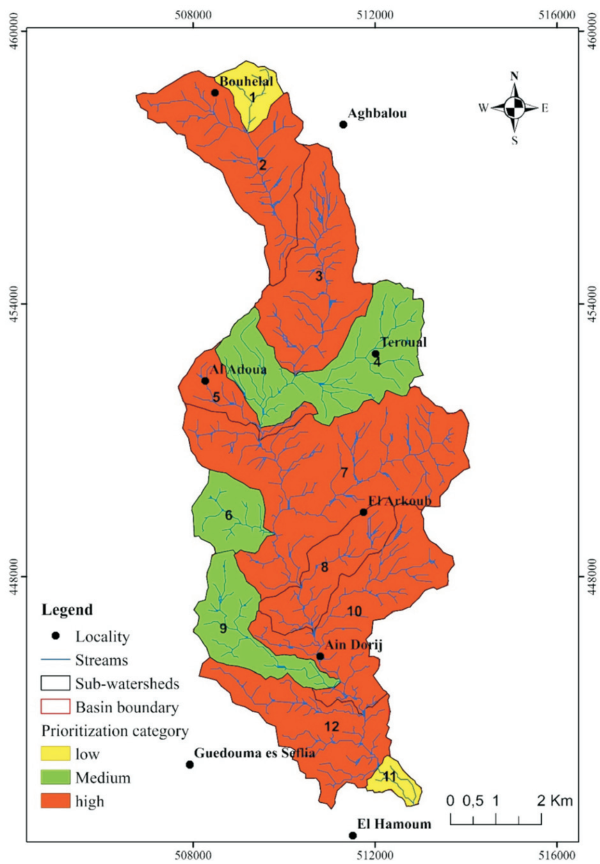

Fig. 15. Prioritization map of the Oued Joumouaa watershed.

Conclusion

The prioritization of watersheds is one of the most relevant approaches in planning, natural risk management and implementation of sustainable development programs. The morphometric parameters of the different sub-watersheds obtained in this study show the hydrological response and their relative characteristics. They allow a prioritization of the sub-watersheds in terms of prioritization (Table 13).

They show that the sub-watersheds 2, 3, 5, 7, 8, 10 and 12 have a high priority (Fig. 15) and are more sensitive to soil erosion and require the greatest attention because of the greatest susceptibility to soil erosion, the sub-watersheds, 1, 11 require a less of attention in the sense of management and maintenance due to a very minimal vulnerability to soil erosion The sub-basins 4, 6, 9, require moderate attention to protection against erosion. So, it can be concluded that in order to minimize the rate of soil erosion and preserve the land surface as well as maintain the natural quality, some of the successful measures should be carefully formulated and implemented taking into account the geomorphology and morphometric parameters of the basin.

Through the example of *O. Joumouaa*, we believe that we have proposed a method that can be generalized in the whole prefecture area. Moreover, the latter, of which ouedJoumouaa is a part, shows the same natural characteristics (geological and climatic...). The approach can therefore be extrapolated to the rest of the areas below the Rif mountains, several thousand km².

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