Prioritising the sub-watersheds of the Oued El Abid basin upstream of Oum Er-Rbia using Fuzzy Analytic Hierarchy Process (FAHP) and geographic information systems (GIS)

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Abstract. Studying watersheds is essential for understanding their morphological and hydrological dynamics, especially those located in mountainous areas with significant elevations and steep slopes, such as the Oued El Abid, one of the secondary watersheds in the Upstream Oum Er-Rbia basin. The study area includes 45 sub-watersheds. The aim of this study is to identify their priorities based on processing their morphometric characteristics using Geographic Information Systems (GIS) and the Fuzzy Analytic Hierarchy Process (FAHP). To prioritise the sub-watersheds, 18 morphometric indicators were analysed, including cadastral, geometric, and linear indicators. The (FAHP) approach enabled us to categorise these sub-watersheds according to their need for intervention. The study results revealed that 6 sub-watersheds were of high priority, 9 were of medium priority, 11 were of medium priority, and 19 sub-watersheds were of weak or very weak priority. These results confirm the benefits of using Geographic Information Systems and the Fuzzy Analytic Hierarchy Process to determine their priorities for implementing interventions, in order to protect them from risks and enhance their sustainability.
Keywords: prioritisation of watersheds - fuzzy analytic hierarchy process - morphometric characteristics.

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1 Introduction

Watershed management lies at the heart of sustainable environmental practice because it achieves the integrated management of water, soil, and plant resources within a specific area. This approach helps to maintain ecological balance while integrating environmental, social, and economic objectives [1]. Recent studies have shown that the most effective solutions combine natural and engineered approaches to minimise soil degradation, increase vegetation cover and support local family income. A participatory management approach has also emerged as an effective tool for addressing the complex challenges in these diverse and fragile areas, since the involvement of local communities is key to ensuring long-term management success .

The natural characteristics of watersheds, such as terrain topography, climate, soil, and vegetation, are crucial factors in determining their hydrological dynamics. The geographical features of the land, particularly steepness, accelerate surface water runoff and increase erosion rates, while flat lands increase water infiltration rates for groundwater recharge [2]. Soil properties such as texture and water retention capacity vary from sandy soil that promotes infiltration to clay soil that increases surface runoff. Vegetative cover, especially forests, acts as a regulating factor by intercepting rainfall, reducing runoff velocity, and increasing water absorption and plant evaporation, which improves water quality and controls streamflow. The nature of climate, including the amount and temporal distribution of precipitation, directly determines water availability, flood frequency, and periods of drought .

Human activities within watersheds, such as agriculture, urbanisation, and industrialisation, exert significant pressure on water resources by affecting hydrological processes and water quality. Transformations in land use, especially urban expansion and land reclamation, lead to changes in components of the water balance such as surface runoff, infiltration, and evaporation, which exacerbate the problems of groundwater loss and increase the risk of flooding [2]. These activities also cause significant changes in water quality. Urbanisation transports pollutants such as metals through sewers, while agriculture contributes to water saturation with fertilisers and pesticides that lead to pollution.

Understanding the morphometric characteristics of watersheds is key to grasping their composition, as well as the dynamics and volume of runoff, including seasonal variations and flash flood probabilities. Studies indicate that watersheds with a low degree of elongation and a tendency towards circularity are more susceptible to surface runoff, which increases the probability of flash floods.

Compared to the classical methods of morphometric analysis that were adopted by Hurton (1932, 1945) [3, 4], and Strahler (1964) [5], the modern techniques associated with Geographic Information Systems possess excellent tools that reduce effort and time. There have been many studies that have adopted (GIS) in the morphometric analysis of watersheds, including [6]

Technological developments, including Geographic Information Systems (GIS), provide powerful and effective tools for studying watersheds, that facilitate the collection and analysis of high-resolution spatial data and contribute to supporting sound environmental decision-making processes. Besides, morphometric analysis is essential in geomorphological studies to understand the natural characteristics of watersheds and evaluate their impact on hydrological and geographical processes. Combining these two tools enables researchers and planners to adopt comprehensive and integrated methodologies to improve water resource management and enhance environmental sustainability. Studying morphometric analysis and understanding how the watershed responds to heavy rainfall is crucial for analysing flood risks.

The integration of morphometric analysis with (GIS) in risk mapping has emerged as an effective tool for assessing the hydrological characteristics of watersheds. This approach allows researchers and decision-makers to understand potential risks and plan containment strategies more accurately [7]. It also enables the prioritisation of watersheds based on their various characteristics and attributes to determine their importance and susceptibility to influence. This, in turn, helps prioritise them for improved resource management. Furthermore, morphometric characteristics can be used to quickly and efficiently classify sub-watersheds without incurring high costs or taking up excessive time .

The prioritisation of watersheds is considered one of the most important pillars of their coordinated and effective management, as it contributes to reducing sediments, floods, and erosion, thereby positively impacting the achievement of sustainable development . At a global level, numerous studies have centred on developing tools and methodologies for prioritising sub-watersheds based on morphometric analysis. This approach has been successfully applied in studies in multiple regions, including Ethiopia by Bogale et al. (2023), and India by Shekar and Mathew (2022),) [8, 9]. Significant research has been conducted at the Mediterranean level, focusing on watershed classification and morphometric analysis to inform environmental management strategies. This research has been carried out in countries such as Greece, as outlined in the work of Kouli et al. (2006) [10]. In Morocco, pioneering studies have emerged such as El Abbassi et al. (2024) [11], that have evaluated the morphometric characteristics of sub-watersheds and classified them according to environmental and hydrological priority.

It should be noted that most of the aforementioned studies used (FAHP) techniques to determine the priority of watersheds with greater accuracy.

2 Field of study

2.1 Location

The Oued El Abidis one of the secondary watersheds of the Upstream Oum Er-Rbia basin and an important part of its hydrological system. It is bordered to the north by the Upstream Oum Er-Rbia basin; to the south, by the Asif N Ohansal watershed; to the east, by the Ziz-Ghris watershed and the Moulouya basin, and to the west by the Bine El Ouidane dam, which is the main outlet of the watershed. Administratively, this watershed belongs to Beni Mellal-Khenifra and Draa-Tafilalet regions, specifically the provinces of Beni Mellal and Midelt. It encompasses parts of 25 territorial communities, with an estimated area of 3,177 km², equivalent to 9% of the Oum Er-Rbia basin's area (Figure. 1).

This area was chosen because of its location at the top of the Bine El Ouidane dam, which increases the importance of studying it and identifying the various dynamics it experiences. The aim is to provide a scientific basis that can be used to manage natural resources on the one hand, and to protect the area from the various hydrogeomorphological hazards that threaten it on the other. First and foremost among these are the dangers of flooding and erosion, which lead to an increase in the volume of sediment reaching the dam and threaten its capacity.

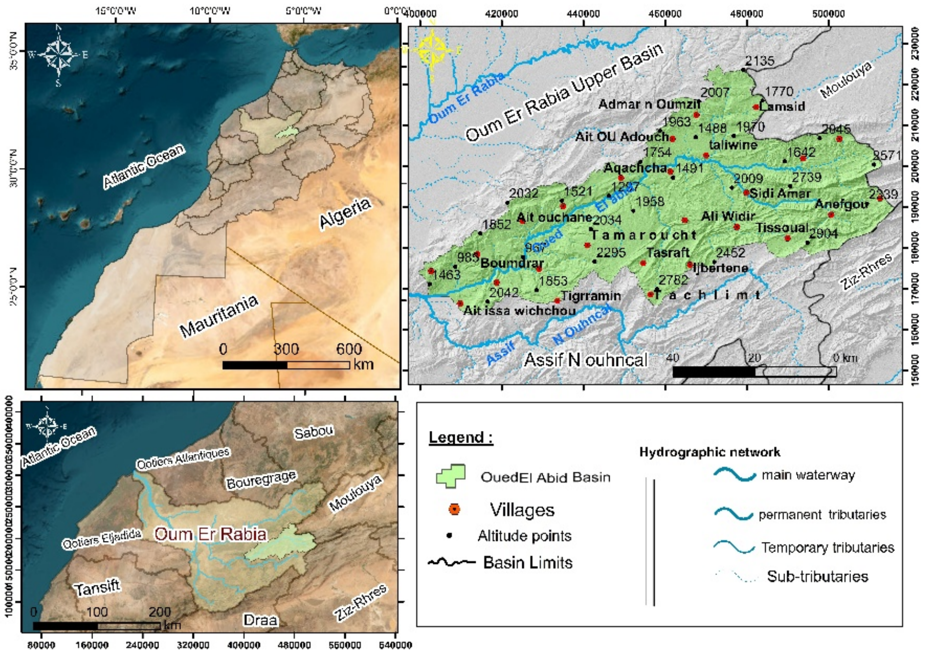
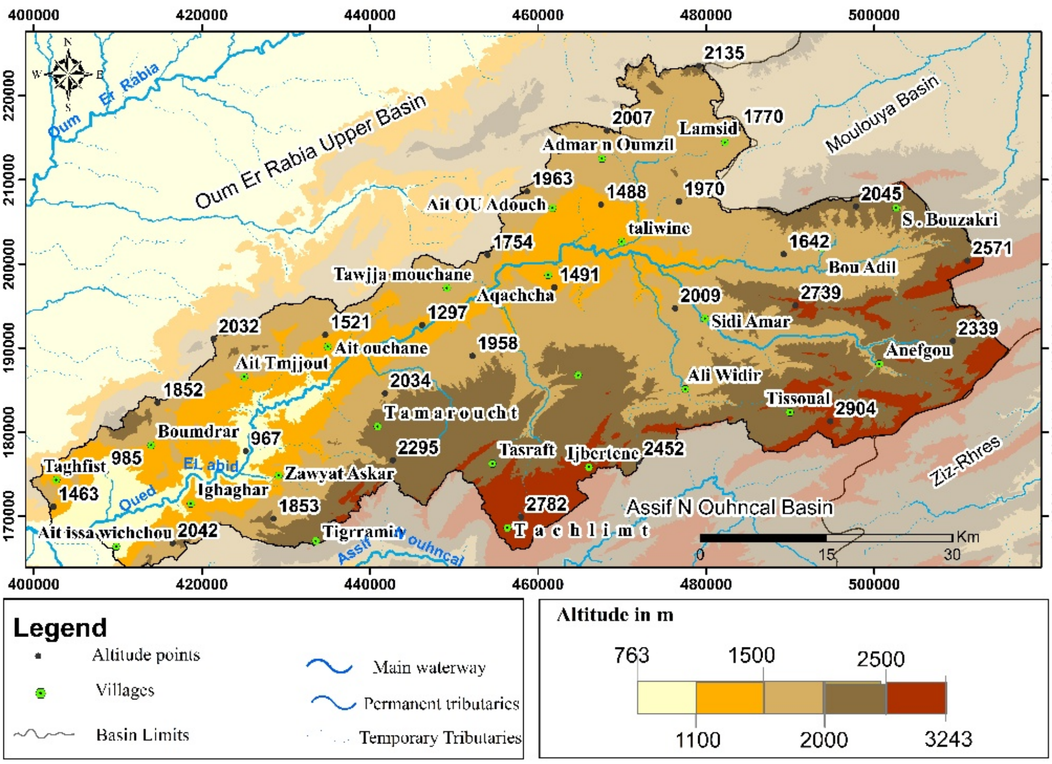


Figure. 1. Location of the Study Area

2.2 Topography of the Oued El Abid watershed

2.2.1 Elevation distribution in the Oued El Abid watershed

The Oued El Abid watershed is distinguished by its heterogeneous elevations, which range from a minimum of 763 m at the mouth of the watershed to a maximum of 3242 m at its summit. As illustrated by the elevation distribution map, the predominant elevations range between 1500 m and 2000 m at a rate of 42%, followed by elevations between 2000 m and 2500 m at a rate of 28% (Figure. 2).



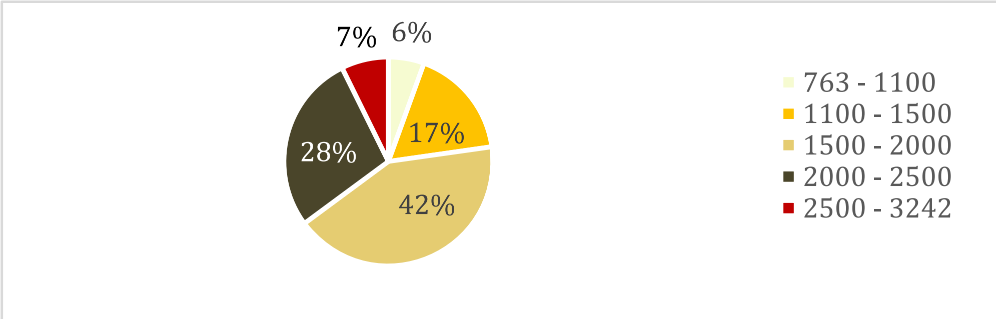


Fig. 2. Elevation Distribution in the Oued El Abid watershed

2.2.2 Slopes distribution in the Oued El Abid watershed

The Oued El Abid watershed is distinguished by its distinct distribution of slopes, with strong and very strong slopes accounting for approximately 11%, primarily concentrated in the southern, southeastern, and lower regions of the watershed. The moderate slopes represent approximately 21%, while the weak and very weak slopes comprise about 68%, and are distributed across various regions (Figure 3).

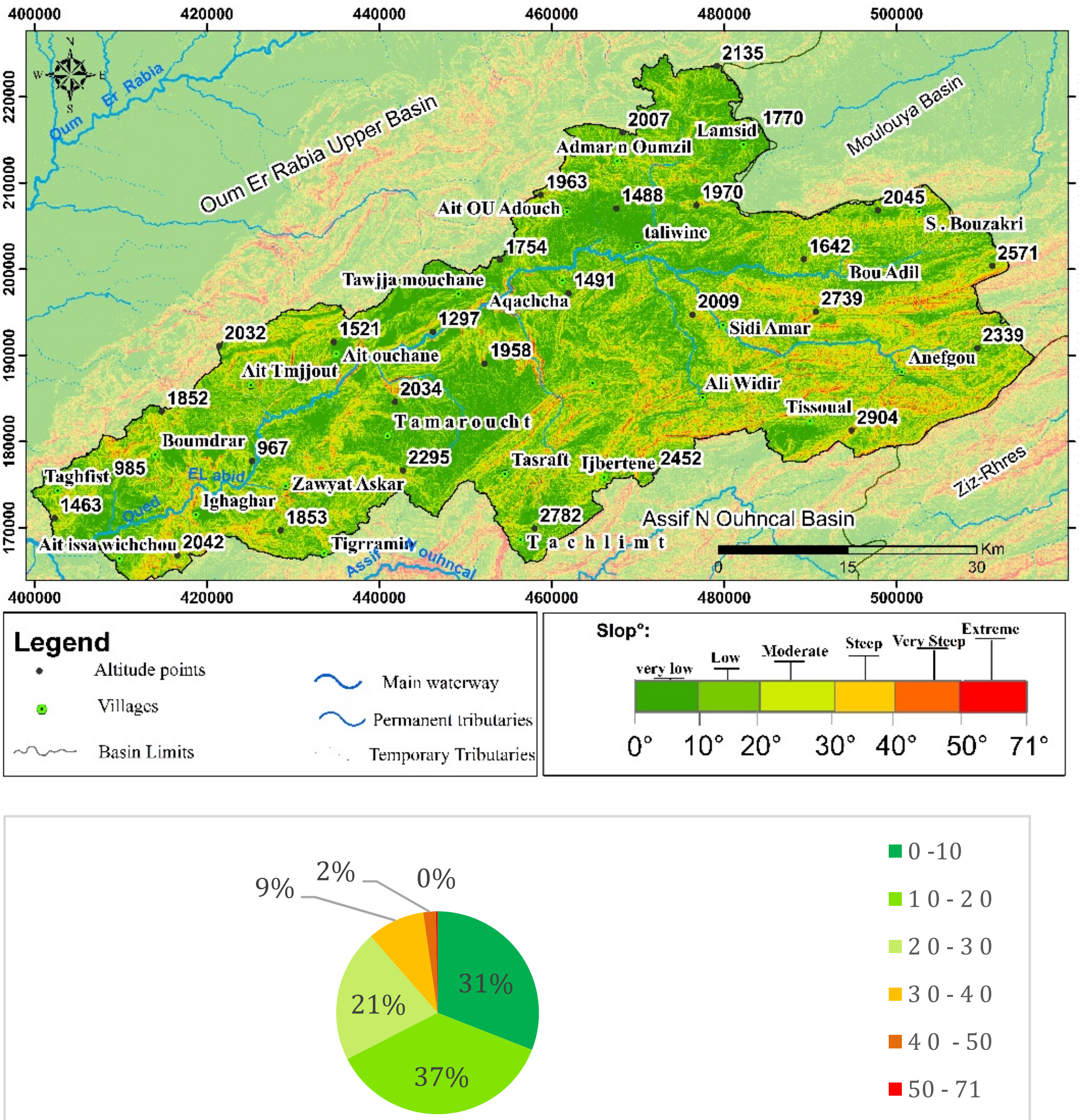


Fig. 3. Slopes distribution in the Oued El Abid watershed

2.2.3 Slopes orientation in the Oued El Abid Watershed

Slope orientation is considered one of the fundamental factors contributing to the dynamism of watersheds, as slopes directed towards the north and west are characterised by reduced direct solar radiation in comparison to those directed towards the south and east [12]. Accordingly, the Oued El Abid watershed is characterised by the dominance of slopes directed towards the north, which account for 28% of the total, while slopes directed towards the south account for 27%. As demonstrated in the accompanying map and diagram (Figure 4).

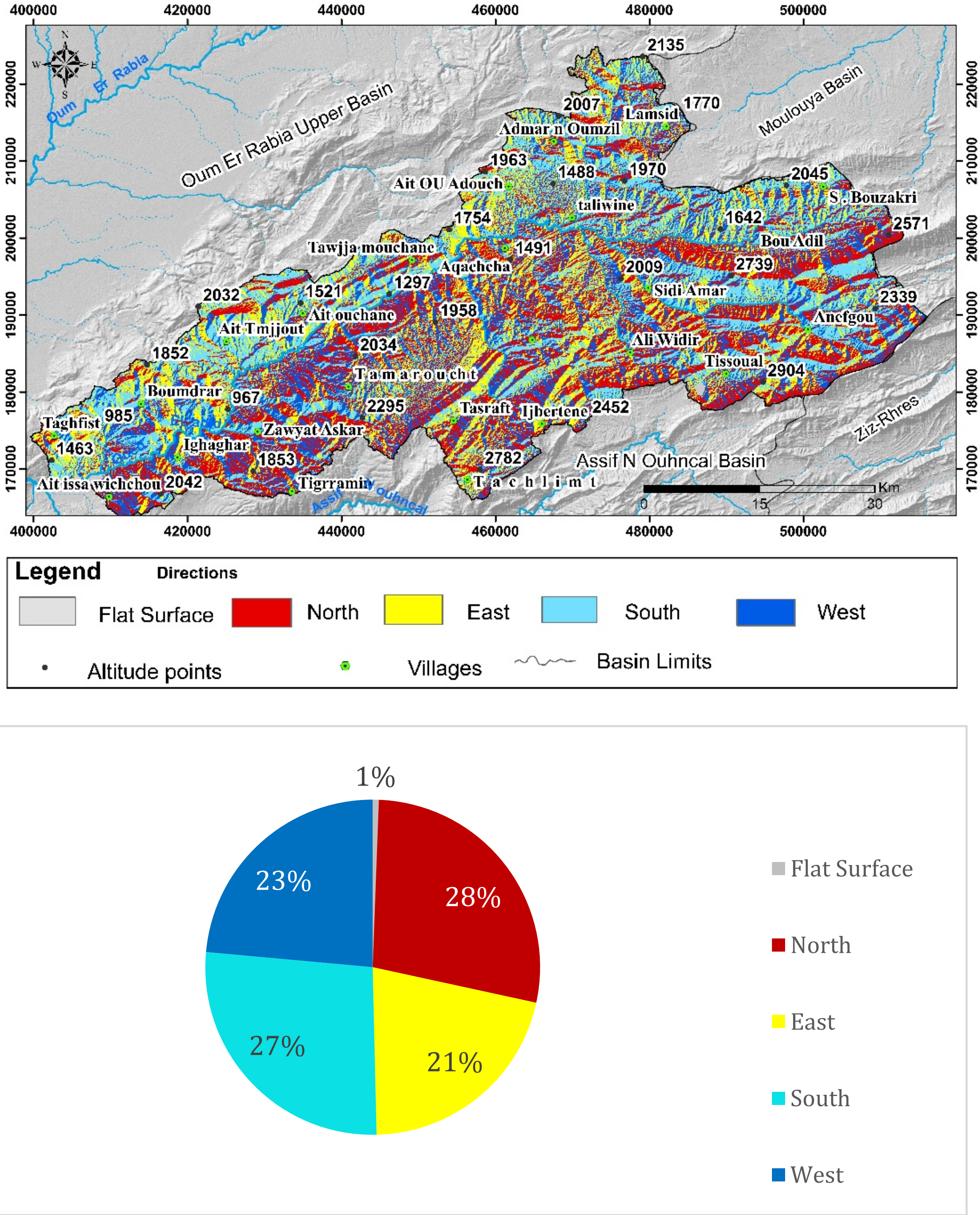


Fig. 4. Slopes orientation in the Oued El Abid watershed

2.2.4 Hydrographic network in the Oued El Abid watershed

The hydrographic network of the Oued El Abid watershed is notable for its high degree of density, marked by a diversity of features. The network is predominantly characterised by human activity and streams that flow into seasonal secondary streams, which in turn flow into the main stream of Oued El Abid watershed. This stream meanders northeast and southwest, ultimately emptying into the Bine El Ouidane dam. The watershed's most notable tributaries include Asif Agdo, Asif Werin, and Oued Attash (Figure 5).

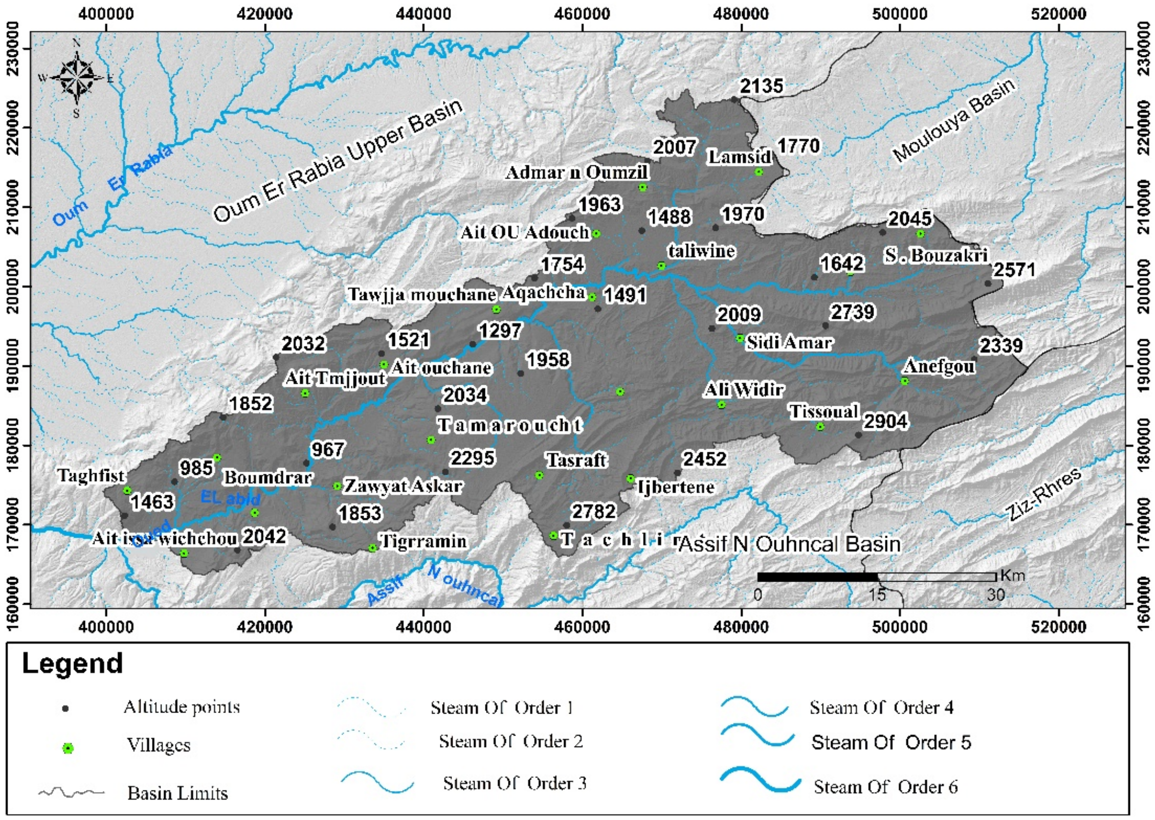


Fig. 5. Hydrographic network in the Oued El Abid Watershed

3 Methodology and tools

Prioritising sub-watersheds based on morphometric analysis using the Fuzzy Analytic Hierarchy Process (FAHP) and Geographic Information Systems (GIS) is an important practical step in collecting accurate geometric, topographical, and hydrographic network data on the study area. In this context, we used a set of topographical maps at a scale of 1/50,000, including maps of the following areas: Ouaizghat, Beni Mellal, Takzirt, Telkouite, Tizi Nesli, Anfkou, Aghbala, Emelchil, Otrebat, and Anarki Ou Tounfit.

We also used a digital elevation model with an accuracy of 30 m to extract terrain data with high precision. Additionally, we used GIS to extract linear, areal, and formal morphometric characteristics (Figure 6).

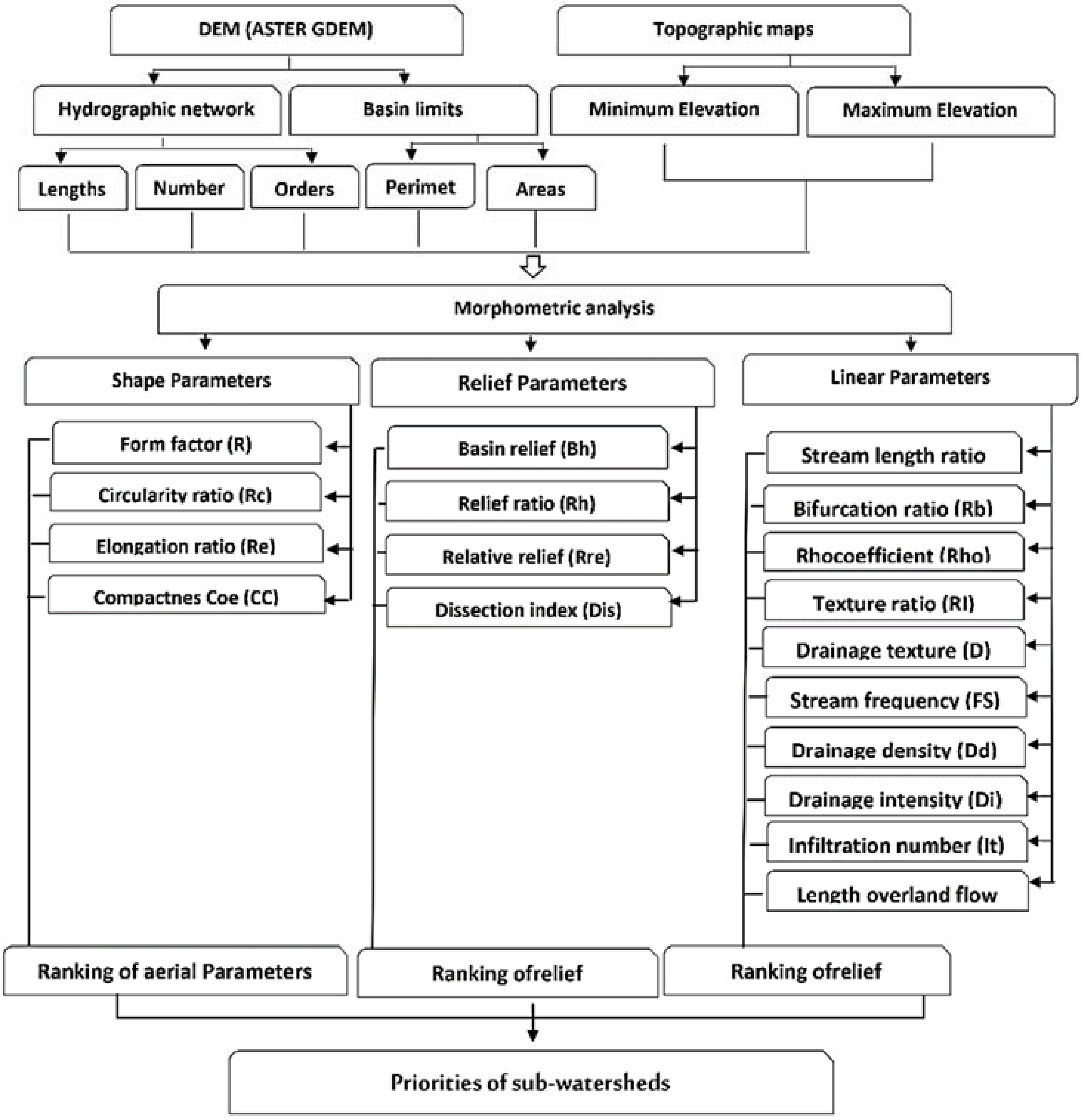


Fig. 6. Flowchart of the study methodology

These indicators were organised in Microsoft Excel tables, and the (FAHP) methodology was applied to prioritise and classify the sub-watersheds according to their importance for sustainable resource management.

Table 1. Empirical formulas used in the Morphometric Analysis

Morphometric Aspects	Morphometric Index	Formulas	Symbols meaning	References
Aerial Aspects	Form factor (R)	$Rf = A / L^2$	A : area of the watershed (km²)	Horton 1932
	Circularity ratio (Rc)	Rc = 4 x Π / (P^2	P. Perimeter of watershed (km)	Strahler 1964
	Elongation ratio (Re)	$Re = 1.128\times\sqrt{A/L}$	Lb : watershed length (km)	Schumm 1956
	Compactnes Coe (CC)	$CC = 0.28 \times P/\sqrt{A}$		Strahler 1964
	Shape factor (Bs)	$Bs = Lb^2/ A$		Horton 1932
Linear Aspects	Stream length ratio (RI)	Ri = Lu / Lu - 1	U : stream order	Horton 1945
	Bifurcation ratio (Rb)	Rb = Nu / Nu + 1	Nu : number of stream order	Schumm 1956
	Rhocoefficient (Rho)	Rho= Ri/Rb	Lu : Stream order length « u »	Strahler 1952
	Texture ratio (RI)	$Rt=N_1/p$	Lu-1 : Length of previous order parts km	Schumm 1956
	Drainage texture (D)	Dt= Ns/p		Horton 1945
	Stream frequency (FS)	Fs=Ns/A	Nu+1 : number of segments of the next	Horton 1932
	Drainage density (Dd)	Dd=Ls/p		Horton 1932
	Drainage intensity (Di)	Di=Fs/Dd		Faniran 1968
	Infiltration number (It)	It= F5 x Dd	Ns : total number of streams of all orders	Faniran 1968
	Length overland flow (Lo)	Lo = 1/2 x Dd	Ls : total stream length of all orders (km)	Horton 1945
Relief Aspects	Relief ratio (Rh)	Rh=Bh/Ls		Schumm 1963
	Ruggednes number (R)	Rn = Rre x Dd	H=Hmax - Hmin	Schumm 1963
	Dissection index (Dis)	Dis = H/Rn	Hmax : maximum elevation in meter	Singh 1994
	Relative relief (Rre)	Rre = Bh/P	Hmin : minimum elevation in meter	Schumm 1963

4 Results and discussion

4.1 Morphometric Analysis

Studying morphometric analysis of watersheds requires an understanding of three fundamental aspects:

The first is geometric characteristics, which focus largely on the overall shape of the watershed. In terms of its degree of roundness or elongation, these are extremely important factors in interpreting the hydrological behaviour of watersheds. The most important of these are the form factor (Rf), the circularity ratio (Rc), the elongation ratio (Re). They are therefore used to measure how close the shape of the watershed is to a circle or rectangle. It should be noted that circular watersheds are characterised by rapid water drainage, which increases the likelihood of sudden flooding, unlike elongated ones. Secondly, the topographic characteristics of a watershed are related to its elevation and slope. They are used to analyse the relationship between topography, surface runoff, and erosion. The most important of which are the relief ratio (Rh), the ruggedness (Rn) and the dissection index (Dis). It is important to note that watersheds with significant elevations and steep slopes are more susceptible to erosion than those with low slopes. Thirdly, linear characteristics are those related to the hydrographic network within the watershed in terms of its drainage density and branching ratio. Studying these characteristics provides a clear picture of the hydrographic network and the nature of the rock structure that this network cuts through. They also contribute to explaining the speed of surface runoff and the watershed's response to precipitation.

In this context, it should be noted that the Oued El Abid watershed consists of 45 sub-watersheds. The most important of these are Asif Ogdou, Asif Nirine, and Oued Attash. The Taghrout, Ait Sidi Aziz, and Ait Terwalt sub-watersheds are among the smallest, as shown on the map below (Figure 7).

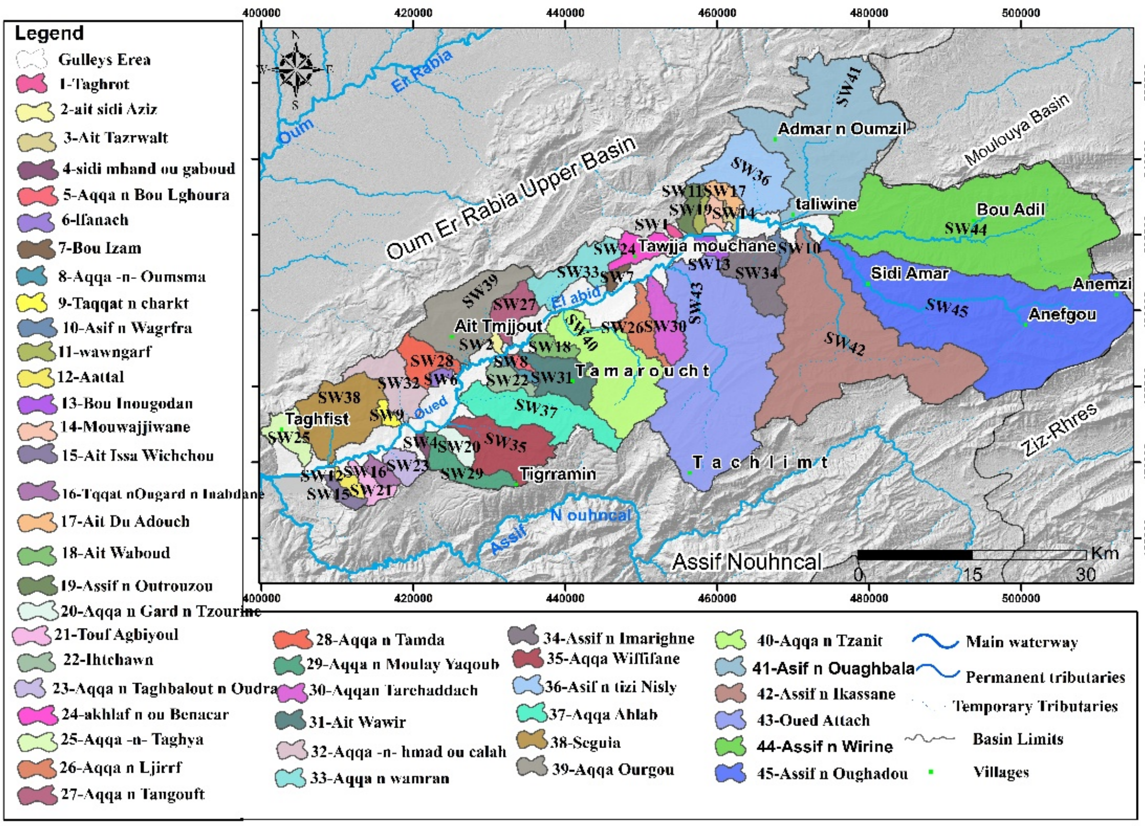


Figure 7. Sub-watersheds of the Assif Oued El Abid watershed

4.2 Form characteristics

As part of our study of the Oued El Abid watershed, we focused on five basic indicators that reflect its form characteristics:

First: Form factor (Rf)

This indicator enables us to determine the form of the watershed. According to Horton (1932) [3], the watershed tends to be circular in form as its factor approaches 1, and rectangular in form as the factor approaches 0.

Following the classification of the 45 sub-watersheds based on the values of this factor (Rf), we found that the high category (Rf > 0.45) includes only 6 sub-watersheds. These are with a form close to circular, such as SW1 with a value of 0.526 and SW2 with a value of 0.488. These reflect rapid watersheds where rainwater is able to reach the outlet quickly, increasing the possibility of flash floods. In terms of the medium category (ranging from 0.35 to 0.45), there are 15 sub-watersheds included, such as SW7 with a value of 0.454 and SW15 with a value of 0.426. These are distinguished by their more elongated form compared to the high category, which results in relatively balanced surface runoff and a moderate hydrological distribution that reduces the severity of floods. In terms of the low category, which is defined as Rf < 0.35, the majority is represented by 24 sub-watersheds. These include SW35, which has a value of 0.325, and SW45, which has a value of 0.256. These sub-watersheds are distinguished by their elongated shape, which results in a prolonged duration for water to reach the outlet. This effect reduces the velocity of surface runoff, thereby mitigating the risk of flash floods. The wide range of formfactor values reflects the presence of diverse terrain, characterised by varying slopes and geological features.

Second: Circularity ratio (Rc)

Based on the circularity coefficient (Rc) values for the 45 sub-watersheds, they can be divided into three main categories.

The high category, in which the value exceeds 0.50, which includes 8 sub-watersheds, such as SW1 and SW23, which have values of 0.590 and 0.640 respectively. These values indicate that the form is closer to circular and that the ability to drain water is faster, which increases the possibility of flooding. The medium category includes 25 sub-watersheds, such as SW7 with a value of 0.432 and SW8 with a value of 0.455, with (Rc) values falling between 0.35 and 0.50. These are characterised by an average form that reflects a balance in water flow, thus reducing the severity of flash floods. The low category includes 12 sub-watersheds with values of less than 0.35. These have more irregular or elongated shapes, which slow the flow of water, leading to a lower risk of severe flooding, but contributing to water retention over longer periods.

Third: Compactness coefficient Cc

As Strahler stated in 1964 [5], this indicator is used to measure the regularity of the watershed's form and reflects the form of its merging. Therefore, sub-watersheds can be classified into three categories based on the values of this parameter.

The first category comprises those with low consolidation, which includes 14, such as SW23 and SW1, with values less than 1.5, indicating less consolidation. The second category includes sub-watersheds with moderate consolidation, whose values range between 1.5 and 1.75, such as SW2 and SW4, representing 21 in total. The third category includes those with high consolidation, whose values exceed 1.75 and include 10 examples, such as SW37 and SW33, as these values reflect significant consolidation, which leads to faster water accumulation.

This classification accurately reflects the nature of the sub-watersheds, as the logical distribution of these values reflects the different hydrological and geomorphological characteristics of each category.

Fourth: Elongation ratio (Re)

It's one of the morphometric indicators proposed by Schumm in 1956 [13], and it is used to determine the extent of elongation in the form of the watershed. The closer the coefficient is to zero, the more is elongated. Accordingly, (Re) values for the 45 sub-watersheds indicate a clear distribution between high, medium, and low elongation.

The high category, where the value exceeds 0.75, includes 11 sub-watersheds, such as SW1 (0.819) and SW2 (0.788). These are characterised by a more circular form and close to a balanced shape, which indicates a lower distribution of sub-watershed elongation, with the possibility of faster and direct flow. The medium category, ranging from 0.65 to 0.75, encompasses 26, including SW31 with a value of 0.668 and SW20 with a value of 0.719. These sub-watersheds exhibit moderate shapes, characterised by moderate elongation, and demonstrate moderate water drainage speed and distribution. In the low category, which includes those with values less than 0.65, there are 8 examples. These include SW41, which has a value of 0.589, and SW43, which has a value of 0.579. These are more elongated in shape, with water flowing more slowly and in a more complex manner. This reduces the risk of flash flooding but increases the period for which water remains within the sub-watershed.

Fifth: Shape factor (Bs)

As identified by Horton in 1932 [3], this is an important tool for morphometric analysis, reflecting the extent of watershed elongation. The (Bs) factor can be classified into three main categories based on the recorded values:

The first category with low values (between 1.90 and 2.50) includes 20 sub-watersheds, such as SW1 and SW6. These values reflect soil with less permeability and relatively less slope, which leads to slower drainage for water. The second category includes medium values (ranging from 2.51 to 3.30) and has 18 sub-watersheds, such as SW22 and SW33. This category is characterised by areas where there is a balance between permeability and slope, enabling effective and balanced drainage of water. The third category, which has high values (above 3.30), includes 7, such as SW40, SW41, and SW44. These indicate the presence of soil with high permeability and a steep slope, leading to rapid water drainage and increased surface runoff speed.

Table 2. Areal and morphometric variables of the Oued El Abid watershed

N	Name SW	Form factor (Rf)	Circularity ratio (Rc)	Elongation ratio (Re)	Compactness Coe Cc
SW1	Taghrot	0.526	0.590	0.819	1.352
SW 2	Ait Sidi Aziz	0.488	0.439	0.788	1.508
SW 3	Ait Tazrwalt	0.483	0.367	0.784	1.649
SW 4	Sidi Mhand Ou Gaboud	0.481	0.361	0.783	1.665
SW 5	Aqqa n Bou Lghoura	0.469	0.413	0.773	1.555
SW 6	lfanach	0.459	0.260	0.765	1.961
SW 7	Bou Izam	0.454	0.432	0.761	1.521
SW 8	Aqqa -n- Oumsma	0.451	0.455	0.758	1.482
SW 9	Taqqat n charkt	0.447	0.361	0.754	1.664
SW 10	Asif n Wagrfra	0.447	0.360	0.754	1.666
SW 11	wawngarf	0.440	0.461	0.749	1.472

SW 12	Aattal	0.436	0.382	0.745	1.619
SW 13	Bou Inougodan	0.435	0.537	0.744	1.365
SW 14	Mouwajjiwane	0.334	0.404	0.741	1.573
SW 15	Ait Issa Wichchou	0.426	0.360	0.737	1.666
SW 16	Tqqat n Ougard n Inabdane	0.422	0.541	0.733	1.359
SW 17	Ait Du Adouch	0.421	0.358	0.732	1.670
SW 18	Ait Waboud	0.409	0.453	0.722	1.486
SW 19	Assif n Outrouzou	0.408	0.380	0.721	1.621
SW 20	Aqqa n Gard n Tzourine	0.406	0.552	0.719	1.345
SW 21	Touf Agbiyoul	0.404	0.371	0.718	1.641
SW 22	Ihtchawn	0.395	0.435	0.709	1.516
SW 23	Aqqa n Taghbalout n Oudra	0.392	0.640	0.707	1.250
SW 24	akhlaf n ou Benacar	0.378	0.377	0.694	1.628
SW 25	Aqqa -n- Taghya	0.376	0.312	0.692	1.789
SW 26	Aqqa n Ljirrf	0.368	0.252	0.684	1.990
SW 27	Aqqa n Tangouft	0.367	0.533	0.684	1.370
SW 28	Aqqa n Tamda	0.366	0.419	0.683	1.545
SW 29	Aqqa n Moulay Yaqoub	0.361	0.294	0.678	1.845
SW 30	Aqqan Tarehaddach	0.360	0.373	0.677	1.637
SW 31	Ait Wawir	0.350	0.344	0.668	1.706
SW 32	Aqqa -n- hmad ou calah	0.348	0.324	0.665	1.755
SW 33	Aqqa n wamran	0.343	0.305	0.661	1.811
SW 34	Assif n Imarighne	0.335	0.434	0.653	1.518
SW 35	Aqqa Wiffifane	0.325	0.366	0.643	1.653
SW 36	Asif n tizi Nisly	0.319	0.385	0.638	1.612
SW 37	Aqqa Ahlab	0.318	0.244	0.636	2.023
SW 38	Seguia	0.315	0.514	0.634	1.395
SW 39	Aqqa Ourgou	0.312	0.445	0.630	1.498
SW 40	Aqqa n Tzanit	0.300	0.346	0.618	1.699
SW 41	Asif n Ouaghbala	0.272	0.273	0.589	1.913
SW 42	Assif n Ikassane	0.265	0.268	0.581	1.932

SW 43	Oued Attach	0.263	0.363	0.579	1.658
SW 44	Assif n Wirine	0.257	0.403	0.572	1.575
SW 45	Assif n Oughadou	0.256	0.337	0.572	1.721

4.3 Linear characteristics

It refers to a set of coefficients associated with the hydrographic network. In this study, 9 were focused on:

First: Stream Length Ratio (Ri)

Horton (1932) [3] defined it as the average length of streams on a river scale. Based on the analysis of (Ri) ratio for the 45 sub-watersheds, the values were classified into three main categories:

Low values (less than 0.4), which include 14 sub-watersheds, indicate a highly elongated form. These are often characterised by slow surface runoff and a delayed hydrological response to floods. Examples include SW10 with a value of 0.007 and SW3 with a value of 0.129, reflecting a long, narrow morphology associated with rugged terrain and limited drainage streams. The medium category (between 0.4 and 0.9) includes 24 sub-watersheds, representing the largest percentage. These have average characteristics in terms of form and respond moderately to precipitation. Examples include SW1 with a value of 0.453, and SW21 with a value of 0.731. These values are considered realistic and represent the area's diverse topography. Thoughtful. The high category (more than 0.9) includes 7 and indicates sub-watersheds that are closer to a circular form. This means they can collect water faster and are more likely to experience sudden floods due to the convergence of flow arrival times from different parts of the sub-watershed. This category is represented by SW2 (value: 1.453) and SW8 (value: 1.487).

Second: Bifurcation ratio (Rb)

This coefficient represents the sum of the outlets spread throughout the watershed area. Based on analysis of the (Rb) values for the 45 watersheds, these values were classified into three categories.

Low values (less than 3). This category includes 12 watersheds and indicates a slight degree of branching in the watershed network. This reflects high geological cohesion or low slopes, which reduce drainage intensity and lead to more regular flow. The most prominent examples are SW10 and SW13, which have values of 1.000 and 1.500, respectively, indicating a relatively stable geomorphological environment. The medium category (values from 3 to less than 5) includes 20 watersheds. This indicates moderate branching of the drainage network and a relative balance between geological, structural, and topographical influences. Examples of this category include SW7 with a value of 3.000 and SW22 with a value of 3.33. The high category (5 and above) includes 13 watersheds and is characterised by high values of the bifurcation ratio, indicating dense branching in the stream network. This is linked to weak rocks, highly fragmented soil, or high stream density due to steep slopes. Watersheds in this category are considered to be more sensitive to surface runoff; the most prominent examples are SW18 with a value of 7.000 and SW43 with a value of 7.079.

Third: Rhocoefficient (Rho)

According to Strahler (1952) [14], it's a synthetic index used to evaluate the relationship between the bifurcation ratio (Rb) and the average length of the drainage network.

Based on the analysis of (Rho) coefficient values for 45 sub-watersheds, we were able to classify them into three categories, one of which was low (less than 0.1). This category includes 16 sub-watersheds and indicates low-density drainage networks. This reflects the presence of relatively flat terrain or high soil permeability, which reduces the number of small streams. Examples include SW10 with a value of 0.007 and SW18 with a value of 0.032. As for the medium category (from 0.1 to less than 0.5), which includes 27 sub-watersheds, it is characterised by medium drainage density, which indicates a balance between terrain, soil type, and erosion rates, and a moderately dense watershed network, such as SW8 with a value of 0.372 and SW16 with a value of 0.337. While the high category (0.5 and above) includes only 3 sub-watersheds, showing a very high drainage density, and indicating the presence of a dense watershed network as a result of steep slopes, examples of which include SW5 with a value of 1.570 and SW13 with a value of 0.525.

Fourth: Drainage texture (Dt)

The drainage texture coefficient (Dt) is a measure of the spacing of streams within a watershed. Horton's proposal in 1945 [4] sought to facilitate comprehension of the interplay between drainage, geology, and terrain. The (Dt) coefficient for the 45 sub-watersheds can be classified into three categories, reflecting the complexity of the drainage network within each one.

The first category includes 20 with low values (less than 0.7), expressing relatively simple and regular drainage networks. For instance, the values assigned to SW10 are 0.129 and 0.247 for SW5. The second category includes sub-watersheds with average values between 0.7 and 1.5. The drainage networks in this area are of medium complexity, with a balanced distribution of streams. For instance, SW31 has a value of 1.415, and SW33 has a value of 0.849, totalling 17. The third category comprises sub-watersheds with values above 1.5, reflecting complex, densely branched drainage networks. Examples of such measurements include SW44 (4.285) and SW45 (4.165). This classification reflects the diversity of drainage texture complexity among the studied sub-watersheds.

Fifth: Stream Frequency coefficient (Fs)

According to Horton's 1932 study [3], the (Fs) coefficient is a measure of the density of stream distribution within the watershed. About this, the 45 sub-watersheds can be divided into three categories, which reflect the following:

The first category includes sub-watersheds with low values (less than 0.7), which indicate low-branching and low-density watershed networks, such as SW10 with a value of 0.290, and SW19 with a value of 0.370, and the number of them is 19. The second category is made up of 18 watersheds with average values between 0.7 and 1.3, representing watershed networks with moderate density and medium branches. Examples of this include SW1 with a value of 1.446 and SW14 with a value of 1.123. The third category, which reflects high values (above 1.3), displays dense and highly branched watershed networks. These include SW40, with a value of 1.477, and SW44, with a value of 1.185, and there is a total of 8 sub-watersheds in this category.

This classification reflects the diversity of the sub-watershed density among the sub-watersheds that have been studied and demonstrates the influence of terrain and geological factors on the distribution of surface runoff. High values indicate rugged terrain and a greater density of flow channels, whereas lower values indicate more balanced terrain or higher permeability.

Sixth: Drainage density (Dd)

As Shekar et al. (2022) [9] define it, the coefficient in question is indicative of the total length of the water field in the watershed, expressed as a proportion of the watershed's total area.

The factors that influence this include terrain, the nature of rocks, climate, and vegetation. The discharge density factor (Dd) for the 45 sub-watersheds can be divided into three categories that reflect the extent of sewage concentration and water discharge.

The initial category encompasses 12 sub-watersheds with low values (less than 1.0), which collectively represent low drainage density. Examples of this phenomenon include SW19, which has a value of 0.761, and SW5, which has a value of 0.916. The second category is comprised of 26, which exhibit average values ranging from 1.0 to 1.3, signifying moderate drainage density. The values of SW15 and SW20 are 1.309 and 1.283, respectively. The third category is for sub-watersheds with high values exceeding 1.3, which reflects a high drainage density that indicates a large concentration of stream flow and a dense drainage network, such as SW4 with a value of 1.736, SW6 with a value of 1.531, and the number of these sub-watersheds is 7.

Seventh: Drainage intensity (Di):

It's a parameter that contributes to determining the amount of water collected in the watershed by the drainage network. The 45 sub-watersheds can be classified according to the (Di) factor into three categories, reflecting the intensity of flow within each one.

The first category includes 22 sub-watersheds with low values (less than 0.7), indicating moderate or low flow, such as SW10 with a value of 0.292 and SW30 with a value of 0.403. The second category includes those with average values between 0.7 and 1.2, and expresses moderate flow with good drainage activity, such as SW8 with a value of 0.839, and SW14 with a value of 0.949. 18 sub-watersheds fall into this category. The third category is for those with high values above 1.2, indicating high drainage intensity and strong flow activity. There are five sub-watersheds in this category, including SW1 with a value of 1.508 and SW45 with a value of 1.240. This classification reflects the variation in surface runoff dynamics within the studied sub-watersheds.

Eighth: Infiltration number (It)

It's an indicator proposed by Faniran in 1968 [15], which combines drainage intensity and discharge frequency. The results of the analysis showed that the 45 sub-watersheds could be categorised according to their ability to discharge water through the watershed network.

The first category includes sub-watersheds with low values (less than 0.7), representing those with low filtration capacity and less active drainage networks. Examples include SW10 with a value of 0.287 and SW19 with a value of 0.281; there are 14 sub-watersheds in this category. The second category includes watersheds with average values between 0.7 and 1.4. These sub-watersheds have an average filtration capacity and balanced discharge intensity. For instance, SW14 has a value of 1.329 and SW1 has a value of 1.387. There are 26 sub-watersheds in this category. The third category comprises watersheds with values above 1.4, indicating high filtration capacity and active, interconnected drainage networks. Examples in point are SW40 with a value of 1.857 and SW4 with a value of 1.745. There are 5 sub-watersheds in this category. This classification accurately reflects variations in the response of sub-watersheds to rainfall, since both geographical and topographical features influence the rate of infiltration and subsequent discharge.

Ninth: Length of Overland Flow (Lo)

As Horton (1945) [4] asserted, the length of overland flow is known to be inversely proportional to the average slope of the stream. This factor can be classified within the 45 sub-watersheds into three categories.

The initial category encompasses 11 sub-watersheds characterised by low values (less than 0.4), which are typified by relatively short courses, such as SW4 with a value of 0.288, SW3 with a value of 0.365. The second category is comprised of those with average values ranging from 0.4 to 0.5, which are distinguished by the presence of moderate streams, with SW1 exhibiting a value of 0.521 and SW7 displaying a value of 0.477. The total number of sub-watersheds included in this category is 27. The third category is for watersheds with high values (above 0.5), which reflect sub-watersheds with long streams. Examples of this include SW13 (0.570) and SW19 (0.657), of which there are 7.

This classification is indicative of the varying lengths of surface flow courses in watersheds, which in turn affects the water arrival time and runoff within each watershed.

Table 3. Linear characteristics of the Oued El Abid watershed

N	Name SW	Form factor (Rf)	Circularity ratio (Rc)	Elongation ratio (Re)	Compactness Coe Cc
SW1	Taghrot	0.526	0.590	0.819	1.352
SW 2	Ait Sidi Aziz	0.488	0.439	0.788	1.508
SW 3	Ait Tazrwalt	0.483	0.367	0.784	1.649
SW 4	sidi mhand ou gaboud	0.481	0.361	0.783	1.665
SW 5	Aqqa n Bou Lghoura	0.469	0.413	0.773	1.555
SW 6	lfanach	0.459	0.260	0.765	1.961
SW 7	Bou Izam	0.454	0.432	0.761	1.521
SW 8	Aqqa -n- Oumsma	0.451	0.455	0.758	1.482
SW 9	Taqqat n charkt	0.447	0.361	0.754	1.664
SW 10	Asif n Wagrfra	0.447	0.360	0.754	1.666
SW 11	wawngarf	0.440	0.461	0.749	1.472
SW 12	Aattal	0.436	0.382	0.745	1.619
SW 13	Bou Inougodan	0.435	0.537	0.744	1.365
SW 14	Mouwajjiwane	0.334	0.404	0.741	1.573
SW 15	Ait Issa Wichchou	0.426	0.360	0.737	1.666
SW 16	Tqqat n Ougard n Inabdane	0.422	0.541	0.733	1.359
SW 17	Ait Du Adouch	0.421	0.358	0.732	1.670
SW 18	Ait Waboud	0.409	0.453	0.722	1.486
SW 19	Assif n Outrouzou	0.408	0.380	0.721	1.621
SW 20	Aqqa n Gard n Tzourine	0.406	0.552	0.719	1.345
SW 21	Touf Agbiyoul	0.404	0.371	0.718	1.641
SW 22	Ihtchawn	0.395	0.435	0.709	1.516
SW 23	Aqqa n Taghbalout n Oudra	0.392	0.640	0.707	1.250
SW 24	akhlaf n ou Benacar	0.378	0.377	0.694	1.628
SW 25	Aqqa -n- Taghya	0.376	0.312	0.692	1.789
SW 26	Aqqa n Ljirrf	0.368	0.252	0.684	1.990

SW 27	Aqqa n Tangouft	0.367	0.533	0.684	1.370
SW 28	Aqqa n Tamda	0.366	0.419	0.683	1.545
SW 29	Aqqa n Moulay Yaqoub	0.361	0.294	0.678	1.845
SW 30	Aqqan Tarehaddach	0.360	0.373	0.677	1.637
SW 31	Ait Wawir	0.350	0.344	0.668	1.706
SW 32	Aqqa -n- hmad ou calah	0.348	0.324	0.665	1.755
SW 33	Aqqa n wamran	0.343	0.305	0.661	1.811
SW 34	Assif n Imarighne	0.335	0.434	0.653	1.518
SW 35	Aqqa Wiffifane	0.325	0.366	0.643	1.653
SW 36	Asif n tizi Nisly	0.319	0.385	0.638	1.612
SW 37	Aqqa Ahlab	0.318	0.244	0.636	2.023
SW 38	Seguia	0.315	0.514	0.634	1.395
SW 39	Aqqa Ourgou	0.312	0.445	0.630	1.498
SW 40	Aqqa n Tzanit	0.300	0.346	0.618	1.699
SW 41	Asif n Ouaghbala	0.272	0.273	0.589	1.913
SW 42	Assif n Ikassane	0.265	0.268	0.581	1.932
SW 43	Oued Attach	0.263	0.363	0.579	1.658
SW 44	Assif n Wirine	0.257	0.403	0.572	1.575
SW 45	Assif n Oughadou	0.256	0.337	0.572	1.721

Table 4. Linear characteristics of the Oued El Abid watershed (Continued)

N	Name SW	Form factor (Rf)	Circularity ratio (Rc)	Elongation ratio (Re)	Compactness Coe Cc
SW1	Taghrot	0.526	0.590	0.819	1.352
SW 2	ait sidi Aziz	0.488	0.439	0.788	1.508
SW 3	Ait Tazrwalt	0.483	0.367	0.784	1.649
SW 4	sidi mhand ou gaboud	0.481	0.361	0.783	1.665
SW 5	Aqqa n Bou Lghoura	0.469	0.413	0.773	1.555
SW 6	lfanach	0.459	0.260	0.765	1.961
SW 7	Bou Izam	0.454	0.432	0.761	1.521
SW 8	Aqqa -n- Oumsma	0.451	0.455	0.758	1.482
SW 9	Taqqat n charkt	0.447	0.361	0.754	1.664
SW 10	Asif n Wagrfra	0.447	0.360	0.754	1.666

SW 11	wawngarf	0.440	0.461	0.749	1.472
SW 12	Aattal	0.436	0.382	0.745	1.619
SW 13	Bou Inougodan	0.435	0.537	0.744	1.365
SW 14	Mouwajjiwane	0.334	0.404	0.741	1.573
SW 15	Ait Issa Wichchou	0.426	0.360	0.737	1.666
SW 16	Tqqat n Ougard n Inabdane	0.422	0.541	0.733	1.359
SW 17	Ait Du Adouch	0.421	0.358	0.732	1.670
SW 18	Ait Waboud	0.409	0.453	0.722	1.486
SW 19	Assif n Outrouzou	0.408	0.380	0.721	1.621
SW 20	Aqqa n Gard n Tzourine	0.406	0.552	0.719	1.345
SW 21	Touf Agbiyoul	0.404	0.371	0.718	1.641
SW 22	Ihtchawn	0.395	0.435	0.709	1.516
SW 23	Aqqa n Taghbalout n Oudra	0.392	0.640	0.707	1.250
SW 24	akhlaf n ou Benacar	0.378	0.377	0.694	1.628
SW 25	Aqqa -n- Taghya	0.376	0.312	0.692	1.789
SW 26	Aqqa n Ljirrf	0.368	0.252	0.684	1.990
SW 27	Aqqa n Tangouft	0.367	0.533	0.684	1.370
SW 28	Aqqa n Tamda	0.366	0.419	0.683	1.545
SW 29	Aqqa n Moulay Yaqoub	0.361	0.294	0.678	1.845
SW 30	Aqqan Tarehaddach	0.360	0.373	0.677	1.637
SW 31	Ait Wawir	0.350	0.344	0.668	1.706
SW 32	Aqqa -n- hmad ou calah	0.348	0.324	0.665	1.755
SW 33	Aqqa n wamran	0.343	0.305	0.661	1.811
SW 34	Assif n Imarighne	0.335	0.434	0.653	1.518
SW 35	Aqqa Wiffifane	0.325	0.366	0.643	1.653
SW 36	Asif n tizi Nisly	0.319	0.385	0.638	1.612
SW 37	Aqqa Ahlab	0.318	0.244	0.636	2.023
SW 38	Seguia	0.315	0.514	0.634	1.395
SW 39	Aqqa Ourgou	0.312	0.445	0.630	1.498
SW 40	Aqqa n Tzanit	0.300	0.346	0.618	1.699
SW 41	Asif n Ouaghbala	0.272	0.273	0.589	1.913

SW 42	Assif n Ikassane	0.265	0.268	0.581	1.932
SW 43	Oued Attach	0.263	0.363	0.579	1.658
SW 44	Assif n Wirine	0.257	0.403	0.572	1.575
SW 45	Assif n Oughadou	0.256	0.337	0.572	1.721

4.4 Terrain characteristics

The study of the terrain characteristics within the Oued El Abid watershed focused on 4 indicators: Relief ratio (Rh), Ruggedness (Rn), Dissection index (Dis), and Relative Relief (Rre).

First: Relief Ratio (Rh)

The relief factor (Rh) of the 45 sub-watersheds can be classified into three categories, which reflect variations in morphometric characteristics and overall relief steepness.

The first category comprises sub-watersheds with high relief values (over 200 m), indicating steep, rugged, mountainous terrain. Examples include SW3 (350.8 m) and SW4 (306.8 m), and there are 13 watersheds in this category. The second category includes watersheds with medium relief values (between 100 m and 200 m), indicating moderate slope terrain and indentation, such as SW1 (167.7 m) and SW10 (123.6 m); this category comprises 20 sub-watersheds. The third category comprises 12, with low relief values (less than 100 m), reflecting relatively flat or geomorphologically stable terrain. Examples include SW41 (25.2 m) and SW43 (29.9 m).

Significant variability in topographic relief across the study area is highlighted by this classification and is an important indicator of longitudinal slope and active geomorphological processes, as sub-watersheds with high (Rh) values are more prone to erosion and rapid surface runoff, whereas low (Rh) values suggest relative surface stability. This, in turn, influences the sub-watershed hydrological behaviour and response to climatic variability.

Second: Ruggedness number (Rn)

The ruggedness number (Rn) of the studied sub-watersheds can be classified into three categories, which show variation in surface structure and extent of ruggedness within each one.

The first category includes 11 sub-watersheds with low values (less than 0.7), indicating relatively smooth terrain and a low level. Examples include SW1 with a value of 0.319 and SW7 with a value of 0.445. Sub-watersheds with average values between 0.7 and 1.5 fall into the second category and are characterised by moderately rugged terrain. The values for SW19 and SW26 are 0.598 and 1.179, respectively, totaling 16 sub-watersheds. The third category includes those with high values above 1.5, indicating very rugged terrain. Examples include SW35 with a value of 2,044 and SW40 with a value of 2,092. This category comprises 18 sub-watersheds.

This classification clearly reflects the topographic variation between the studied sub-watersheds.

Third: Dissection Index (Dis)

The Dissection Index (Dis) of the studied sub-watersheds can be divided into three groups that reflect the level of terrain fragmentation.

The initial group encompasses sub-watersheds exhibiting low values (less than 0.4), signifying a comparatively coherent surface and a marginal degree of discontinuity, as evidenced in SW7 with a value of 0.248 and SW13 with a value of 0.258. The total number of these sub-watersheds is 13. The second group encompasses sub-watersheds exhibiting average values ranging from 0.4 to 0.6, indicative of moderate dissection and topography. This group includes SW3, with a value of 0.540, and SW22, with a value of 0.541. The number of watersheds within this group is 18. The third category comprises watersheds with values exceeding 0.6, denoting terrain exhibiting high levels of discontinuity and a surface structure that is both disjointed and complex. This category includes 14, such as SW15 (0.633) and SW16 (0.637).

This classification demonstrates the structural differences between the studied sub-watersheds, where sub-watersheds with high dissection are more susceptible to erosion and rapid development of stream channels, while lower values indicate relative topographic stability and a slower speed in the development of the hydrographic network.

Fourth: Relative Relief (Rre)

The (Rre) index for the 45 sub-watersheds can be classified into three categories:

The first category includes sub-watersheds with high values (more than 60), indicating branched and complex watershed networks. Examples include SW3 with a value of 86.342 and SW16 with a value of 88.913. There are 13 in this category. The second category includes watersheds with average values between 30 and 60, which show moderately branched watershed networks. For example, SW8 has a value of 59.509, and SW18 has a value of 55.189. These numbers refer to 21 sub-watersheds. The third category includes those with low values of less than 30, indicating simple or few-branched watershed networks. Examples include SW41 with a value of 7.124 and SW43 with a value of 9.905. This category includes 11 sub-watersheds.

Table 5. Terrain variables of the Oued El Abid watershed

N	Name SW	Max Elevation	Min Elevation	Relief ratio (Rh)	Ruggedness number (Rn)	Dissection index (Dis)	Relative relief (Rre)
SW1	Taghrot	1118	785	167.698	0.319	0.298	50.116
SW 2	Ait sidi Aziz	1452	940	188.015	0.521	0.353	50.355
SW 3	Ait Tazrwalt	1848	851	350.786	1.365	0.540	86.342
SW 4	Sidi mhand ou gaboud	1826	944	306.756	1.531	0.483	74.907
SW 5	Aqqa n Bou Lghoura	1459	899	174.369	0.513	0.384	46.199
SW 6	lfanach	1977	942	296.224	1.585	0.524	62.851
SW 7	Bou Izam	1716	1291	116.068	0.445	0.248	31.935
SW 8	Aqqa -n-Oumsma	1630	838	209.917	0.735	0.486	59.509
SW 9	Taqqat n charkt	1910	1340	145.124	0.749	0.298	36.798
SW 10	Asif n Wagrfra	1765	1279	123.578	0.481	0.275	31.301
SW 11	wawngarf	1661	1065	142.456	0.646	0.359	41.149
SW 12	Aattal	2068	769	298.328	1.581	0.628	78.753

SW 13	Bou Inougodan	1670	1239	97.868	0.378	0.258	30.679
SW 14	Mouwajjiwane	1707	1263	97.726	0.525	0.260	26.688
SW 15	Ait Issa Wichchou	2121	779	279.719	1.756	0.633	72.557
SW 16	Tqqat n Ougard n Inabdane	2179	791	278.278	1.777	0.637	88.913
SW 17	Ait Du Adouch	1764	1282	95.571	0.592	0.273	24.885
SW 18	Ait Waboud	2038	980	185.824	1.228	0.519	55.189
SW 19	Assif n Outrouzou	2020	1235	136.248	0.598	0.389	37.129
SW 20	Aqqa n Gard n Tzourine	2126	868	214.954	1.613	0.592	70.720
SW 21	Touf Agbiyoul	2162	783	231.299	1.370	0.638	62.524
SW 22	Ihtchawn	2027	930	166.563	1.260	0.541	49.325
SW 23	Aqqa n Taghbalout n Oudra	2176	807	201.466	1.340	0.629	72.655
SW 24	akhlaf n ou Benacar	1836	1185	82.494	0.709	0.355	23.251
SW 25	Aqqa -n-Taghya	1707	782	114.750	1.049	0.542	29.511
SW 26	Aqqa n Ljirrf	2140	1118	115.191	1.179	0.478	26.932
SW 27	Aqqa n Tangouft	1997	958	116.351	1.172	0.520	39.551
SW 28	Aqqa n Tamda	1930	900	114.083	1.059	0.534	34.421
SW 29	Aqqa n Moulay Yaqoub	2497	859	170.676	1.795	0.656	43.446
SW 30	Aqqan Tarehaddach	2149	1128	105.197	1.121	0.475	30.219
SW 31	Ait Wawir	2257	957	119.645	1.579	0.576	33.439
SW 32	Aqqa -n-hmad ou calah	2412	844	139.861	1.757	0.650	38.125
SW 33	Aqqa n wamran	1901	1041	72.183	0.863	0.452	19.211
SW 34	Assif n Imarighne	2329	1275	80.139	1.119	0.453	25.757
SW 35	Aqqa Wiffifane	2643	876	118.811	2.044	0.669	35.574
SW 36	Asif n tizi Nisly	2032	1297	46.067	0.977	0.362	14.262

SW 37	Aqqa Ahlab	2632	880	107.607	1.886	0.666	26.609
SW 38	Seguia	2411	779	97.152	1.981	0.677	34.981
SW 39	Aqqa Ourgou	2161	919	70.523	1.363	0.575	23.779
SW 40	Aqqa n Tzanit	2704	1040	80.134	2.092	0.615	24.298
SW 41	Asif n Ouaghbala	2114	1331	25.213	0.829	0.370	7.124
SW 42	Assif n Ikassane	3048	1364	48.117	1.745	0.552	13.660
SW 43	Oued Attach	2243	1172	29.867	1.166	0.477	9.905
SW 44	Assif n Wirine	3201	1381	45.665	2.018	0.569	16.148
SW 45	Assif n Oughadou	3097	1381	42.952	1.738	0.554	13.903

5 Discussion

Geographic Information Systems (GIS) enabled us to extract the morphometric characteristics of the 45 sub-watersheds within the Oued El Abid watershed. We calculated approximately 18 morphometric indices covering form, linear, and terrain-related parameters using Microsoft Excel spreadsheets. These indices were then used as input for the Fuzzy Analytic Hierarchy Process (FAHP) to determine priorities.

The results showed that 15 sub-watersheds (33%), including SW6, SW3, and SW10, were classified as high or very high priority. 11 sub-watersheds (24.5%) were categorised as medium priority, including SW35, SW20, and SW2. The remaining 19 sub-watersheds (42%) were categorised as low or very low priority, with SW1, SW2, and SW7 being the most notable examples. A detailed representation of this prioritisation can be seen in the map and table below.

However, it should be noted that the (FAHP) methodology adopted in the study has several limitations. Despite its ability to address the issue of unclear evaluation criteria, including the use of a large number of morphometric indicators that can lead to confusion and overlap between variablesFAHP) also fails to consider some important environmental) , -ors that could influence the prioritisation of suband social factwatersheds, thereby limiting the study's comprehensiveness.

When comparing the results of this study with similar studies in Morocco, we find similarity in the distribution of priorities, as studies such as El Abassi et al. (2024) [11] showed that sub-watersheds with complex morphometric characteristics require greater attention in management and protection. Studies in Mediterranean countries such as Greece and Italy also emphasise the importance of using morphometric analysis to determine environmental priorities for sub-watersheds. The results of Kouli et al. (2006) [10] study are consistent with the findings of this study in focusing on high-priority watersheds that require special management. Similar methodologies have been used in other regions of the world, such as India and Ethiopia, and these are consistent with the findings by Ahmed et al. (2024) [8]. Research has shown the importance of integrating morphometric analysis with decision-making tools such as (FAHP) to improve water resource management strategies (Figure 8; Table 6).

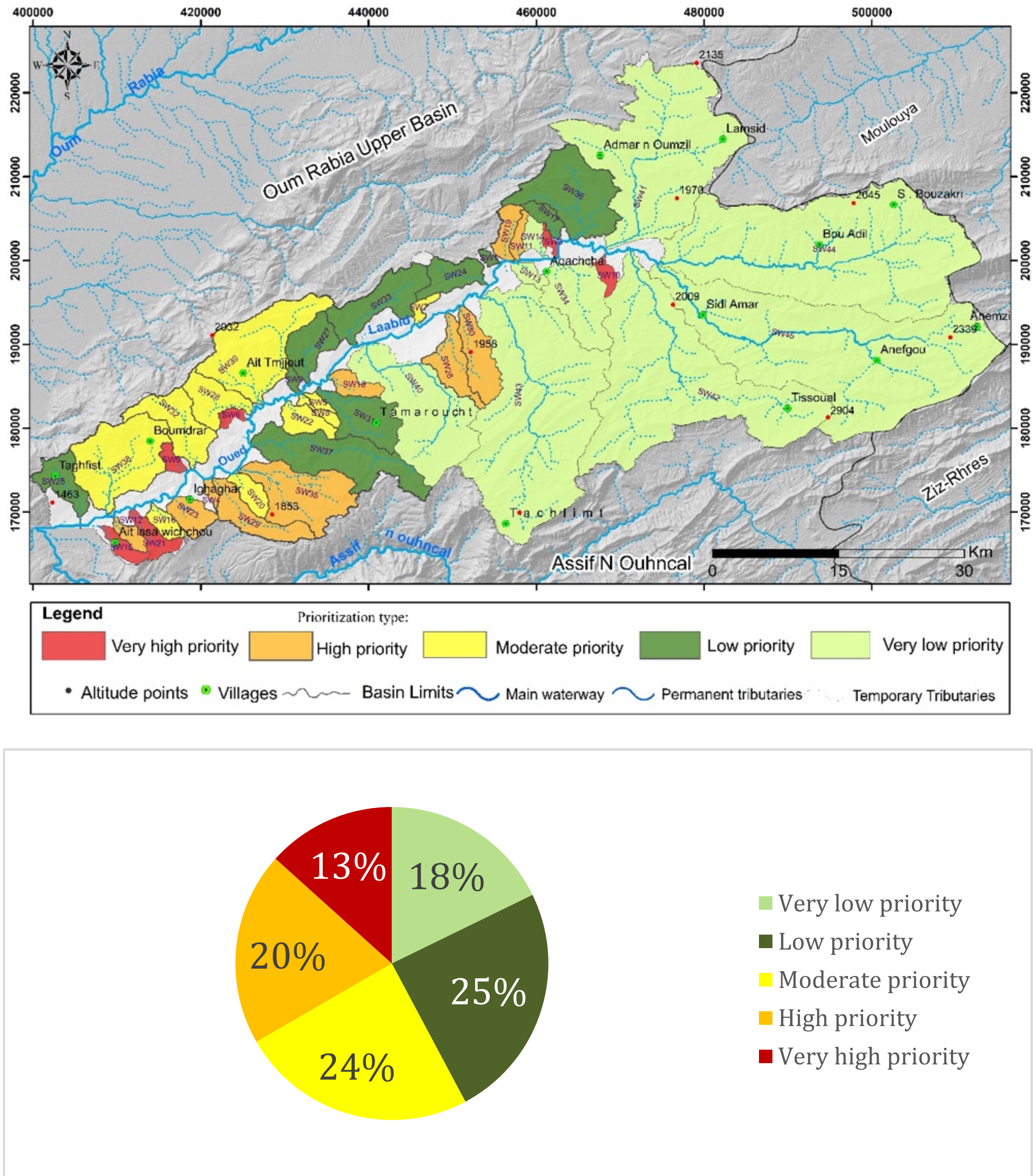


Fig. 8. Prioritisation of Sub-watershed in the Oued El Abid watershed

Table 6. Results of the Fuzzy Analytic Hierarchy Process (FAHP)

Priority	**Values**	**Sub-watersheds**
Very low priority	27.86 - 31.33	13 - 14 - 42 - 43 - 40 - 44 - 41 - 45
Low priority	24.38 - 27.86	2 - 27 - 1 - 17 - 34 - 31 - 24 - 25 - 33 - 36 - 37
Moderate priority	20.90 - 24.38	35 - 20 - 22 - 16 - 5 - 39 - 38 - 32 - 8 - 28 -7
High priority	17.42 - 20.90	4 - 29 - 11 - 12 - 18 - 30 - 26 - 23 - 19
Very high priority	13.94 - 17.42	3 - 6 - 15 - 10 - 9 - 21

6 Summary

Watershed management is a fundamental approach to achieving the sustainability and preservation of natural resources. Prioritising intervention areas that fall within is particularly important, as it plays a decisive role in focusing efforts and defining appropriate management actions.

Classifying sub-watersheds according to their priority is an effective tool for improving the efficiency of both risk management and natural resource governance. The use of Geographic Information Systems (GIS), as a technical supporting tool, is essential to achieve these objectives in a timely and reliable manner.

The findings of this study reveal that 33% of the sub-watersheds fall into the high and very high priority categories, those of medium priority account for 24.5%, while those classified as low and very low priority represent 24.5% and 18%, respectively, of the total 45 sub-watersheds.

Based on the findings of this study, we can make the following recommendations to decision-makers in the field of natural resource management and conservation in the Oued El Abid basin:

- Short term: Prioritize the six high-priority basins, with the aim of mitigating erosion and reducing the amount of sediment reaching the dam. This can be achieved by installing rock and earth barriers to reduce runoff speed and trap sediment, as well as by regulating human activities in these fragile areas, particularly overgrazing.
- Medium term: Rely on afforestation of slopes and ensure the selection of environmentally friendly and drought-resistant plant species to reduce erosion, increase soil cohesion, and decrease surface runoff. Then expand the scope of intervention to include medium-priority areas, as a proactive and preventive measure.
- Long term: Adopt a participatory approach by involving the local population in developing an integrated management plan for the entire river basin.

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