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Evaluation of natural hazard of Inaouene Watershed River in Northeast of Morocco: Application of Morphometric and Geographic Information System approaches

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ABSTRACT: In Morocco, the impact of global climates changes, mainly the climatic hazards, was observed during the last decade on the environmental, agricultural and economical area in Morocco. However, scares are studies carried out to quantify and describe the negative effect of climatic hazards on the stability and the conservation of soil, water and bio-resources, including the principal watersheds highly exposed to erosion phenomenon. The present research aim's the prioritization of the erosion risk in the basin of Inaouene, situated in the northeast of Morocco. The application of Remote Sensed Data allowed the determination and delineation of thirteen sub-watersheds. The morphometric analysis using different parameters (linear, sharps parameters and relief aspects) and ranking of each estimated parameter for each sub-basin allowed the classification of these sub-watersheds in three prioritization categories regarding the priority for conservation and management of resource. High priority was assigned to the SBV01, SBV04, SBV05, SBV06, SBV11 and SBV12, which are subject to a maximum soil erosion, medium priority for the SBV02, SBV03, SBV07, SBV08, SBV09 and SBV10, and low priority for SBV13. The group with high priority is concerned by high risk of erosion and soil degradation, stressing immediate action to prevent possible natural hazards. Special attention for the sub-watersheds SBV05 and SBV06 characterized by very low compound value (CP) are very susceptible to erosion risk. These sub-basins are of highest priority and needs urgent interventions to protect the soil. These sub-basins were integrated as data base together with morphometric parameters, into geographical information systems in order to establish different maps showing sub-watersheds with high risk of erosion.

KEYWORDS: Inaouene River; climate change; DEM; watershed; morphometric parameters; prioritization; erosion; GIS; Priority.

1 INTRODUCTION

Morocco, country situated in north of Africa, is concerned by the effect and impact of climate changing. In this new context, the frequency of the natural hazards (flooding, soil erosion, land sliding and drought) will be high and could causes a huge damages affecting the population, environment and natural resources. The evaluation of the effect of natural risks occurrence (flood, soil erosion…) on the watershed systems requires a good understanding of the hydrological, geological, geomorphological, ecological and climate factors (land cover, slope, land use and hydrographic network) to determine those affecting the geneses of these natural risks. These indices are required to determine the prioritization of watersheds and to establish viable programs to reduce the damages caused by theses natural hazards.

The management of a watershed and the study of hierarchy of sub watersheds, requires the use of novel tools and technologies (geographic information systems (GIS) and digital terrain models (DTM) type SRTM), to evaluate the slopes, drainage systems, topography, geomorphology and lithology. GIS techniques are currently used for assessing several terrain and morphometric parameters of the drainage basins or watersheds, as they provide a flexible environment and a powerful tool for the manipulation and analysis of spatial information [1]. The management of the drainage basins requires the prioritisation of the sub watershed in order to identify the most susceptible sites to the natural disasters. [1] reported that in the watershed of Romushi - Sasar Catchment, Kashmir Valley in India, the sub-watersheds have been classified into three categories high, medium and low in terms of priority for conservation and management of resources, based on morphometric analysis. The use of the Linear parameters, Relief aspects and Ariel parameters, and land use practices parameters allowed the prioritisation of sub watershed of the Dungra watershed in India into three classes (high, medium and low) depending on the natural hazards damages [2]. The results of these analyses on the prioritisation of the sub-watershed may be taken into account in the conservation measures by engineers and decision makers planning for developments and management of natural resource.

The aim the present work was the application of the morphometric analyses to the prioritisation of the sub-watershed of Inaouene River (Northeast of Morocco) to identify the most susceptible sites to the natural disasters.

2 MATERIALS AND METHODS

2.1 STUDY AREA

The watershed of Oued Inaouène (*Fig.01*) located between coordinates of 33° 30'& 35 ° N latitudes and 3° 30' & 5° W longitude. It is situated in the east of the Sebou basin between the last medium-Atlasic foothills and pre-Rif mountains, covering an area of 5153 km2 with a perimeter of 320 km. This location bounded by the basin of the middle Moulouya river at the east, by Ouergha basin at the northwest and by Sebou river at southwest [3].

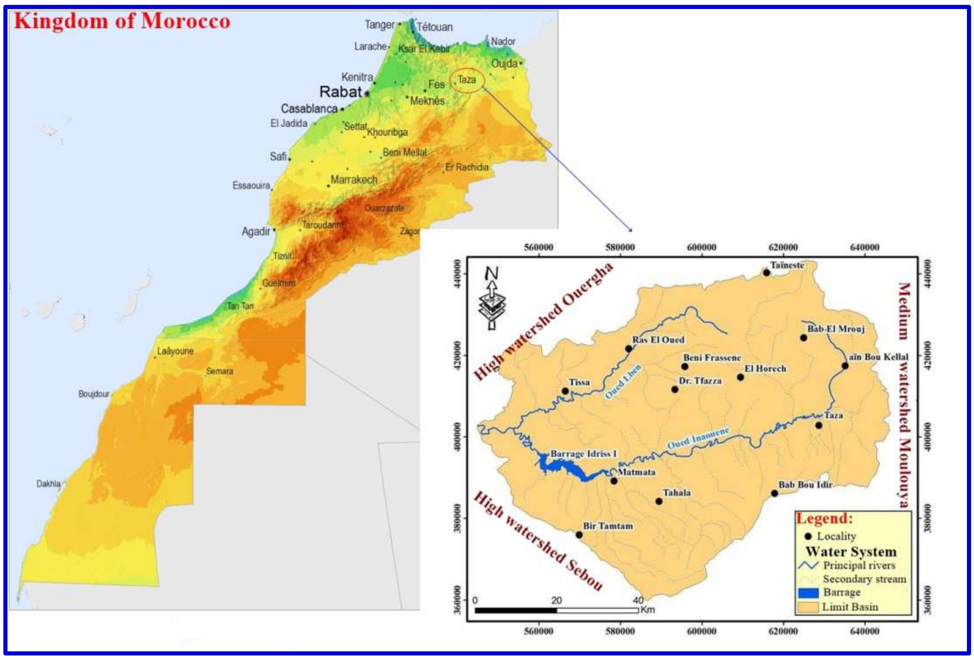

Fig. 1. Geographical situation of the Inaouene watershed in the northeast of Morocco

2.2 GEOMORPHOLOGY AND GEOLOGY OF THE TARGET AREA

The watershed concerned by the present study is characterized by a vertical drop of 200 to 2500 m. It is bordered by two mountains borders (Rif and middle atlas mountains) with the dominance of marl and clay hills soil typology. The Middle Atlas side is characterized by staggered tablelands, dominated by folded chains [4]. The watershed of Inaouene River is characterized by impermeable bedrock marl, almost armed by limestone and sandstone beds, covering approximatively 60% of the total area of the basin (*Fig .02*). These tender lithological formations are subjected to severe erosion, contrary to the carbonate formations of Tahla and Tazekka tablelands [5].

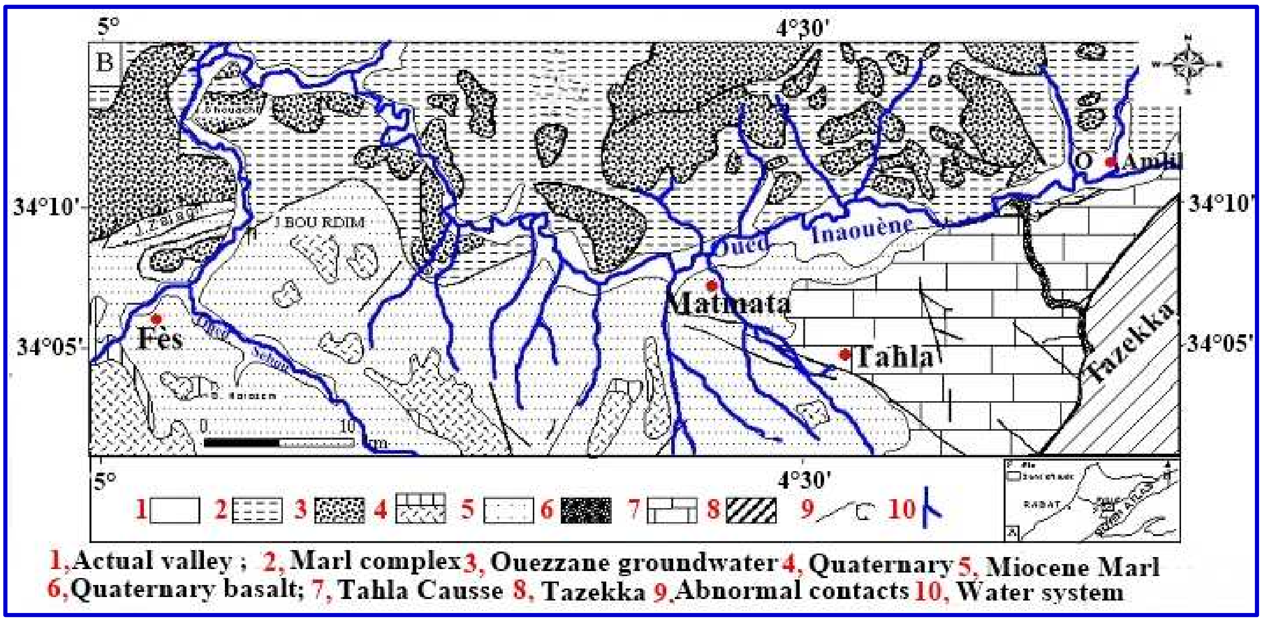

Fig. 2. Simplified geological map of the study area (source: [6])

2.3 CLIMATE OF THE STUDIED AREA

The Inaouene watershed location is considered as semi-arid Mediterranean bioclimatic area characterized by a rainy winter and hot and dry summer [7]. Climate data from four meteorological stations (Fez, Azzaba, Marzouka and Taza) situated along the corridor show that the wet season is situated between November and May, with annual rainfall average of 470 mm. Annual temperature recorded by the four stations show that the hottest months are July and August (with maximum of 35 °c), while December, January and February (with a minimum of 5°c) are the coldest ones [8].

2.4 WATER SYSTEM

The watershed of Inaouène is characterized by a dense branched river system (*Fig.03*), showing a continued evolution controlled by several and complicated factors (lithology, tectonic structures, climate, vegetation, human pressing, topographical and hydrological parameters) of drained soils [9]. The tributaries were organized in a homogeneous dendritic network.

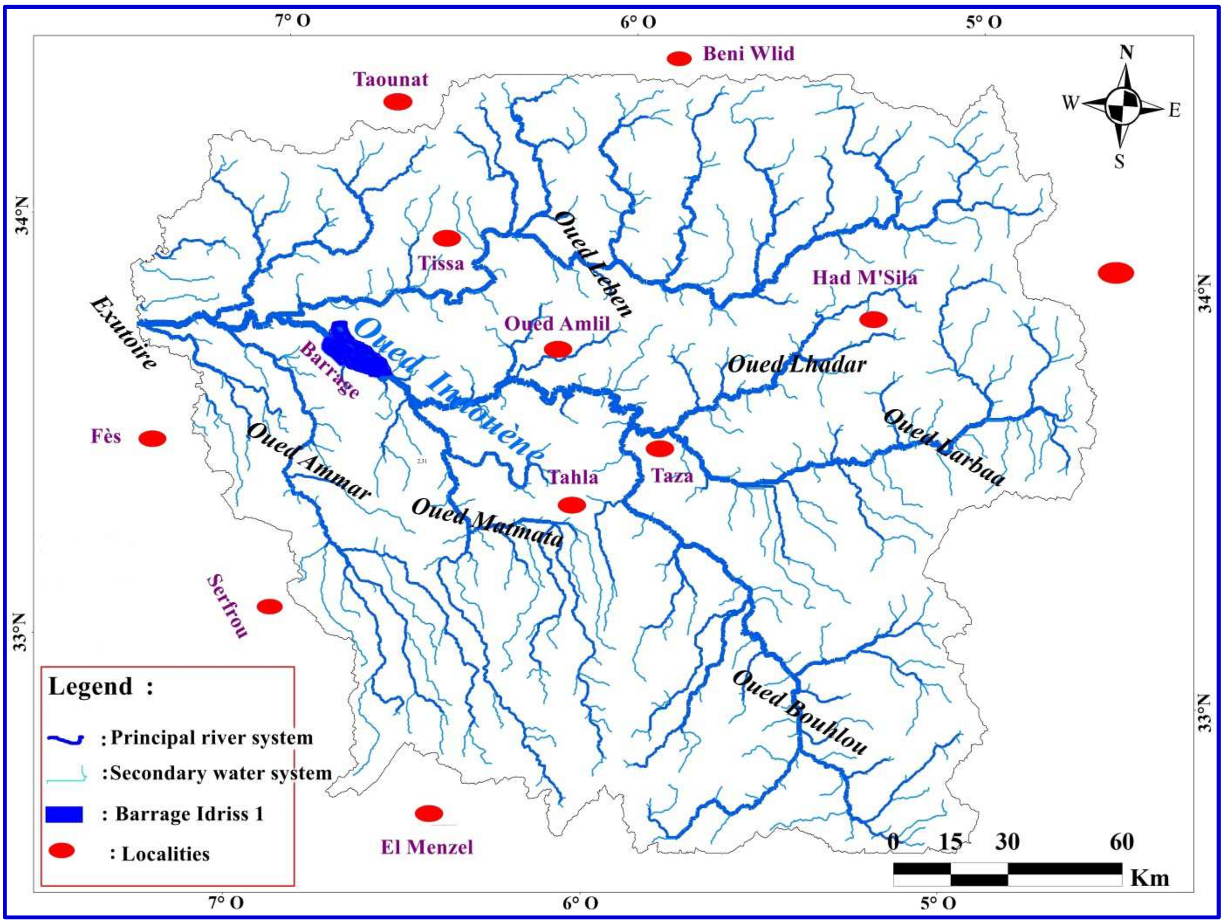

Fig. 3. River system of Inaouène watershed

The direction of the Inaouene river flows was east-west. From the right bank, the most important tributaries powered on are the rivers of Larbaa, Lahdar and Amlil. These tributaries collect runoff prerifains hills. In the left bank, this river is fueled in part by the primary massive of Tazekka tableland and limestones of the Middle Atlas Mountain. The main tributaries of the left bank are the rivers of Bou Hellou, Zireg, Matmata and Ahmar [10].

2.5 METHODOLOGY

The methodology followed in the present research is that adopted by [1].The scale of the topographic map used in the present work is of 1/50000. This map is used to validate the hydrographic network extracted from a digital elevation model (DEM), applying the SRTM data application with a resolution of 90 m (Shuttle Radar topography Mission: refers to the topographical raster and vector files provided by two US agencies: NASA and NGA). The number and the length of streams of each order and the scope, the length and the width of the basin were derived from DEM using Open Source software Quantum GIS (QGIS). These parameters are used to calculate the drainage density, the frequency of drainage, the shape, the form factor, the circulatory ratio and the ratio of elongation (*Fig.04*).

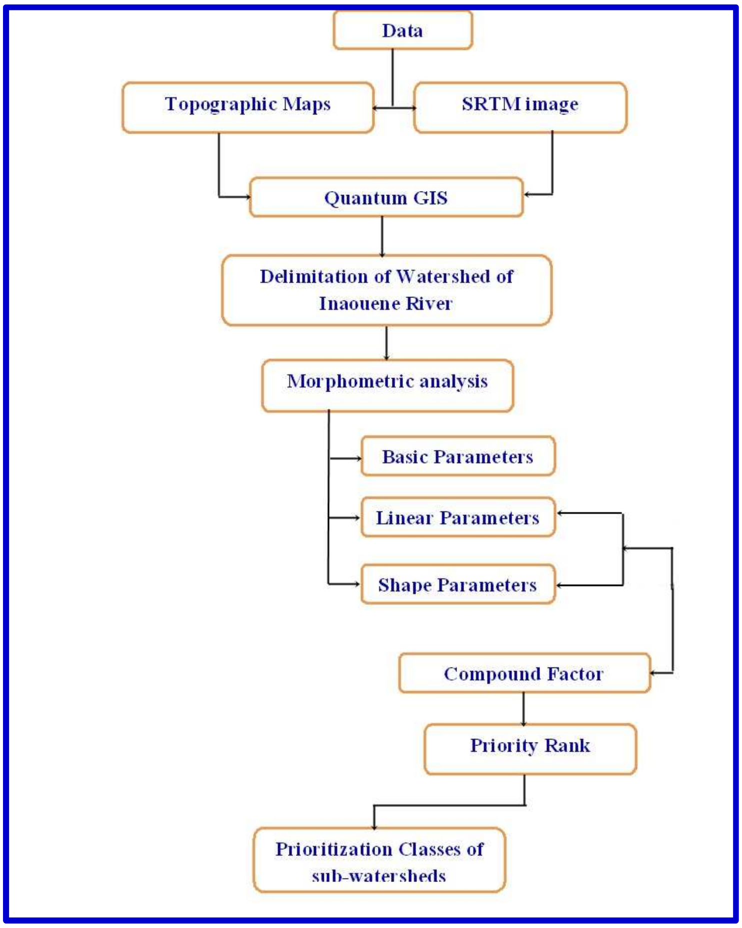

Fig. 4. Flowchart of the methodology of work

To determine the order of prioritization of sub-watersheds of the area, the morphometric parameters were divided into three classes (*Tab.01*): linear parameters, the parameters of shape and processing parameters of the appearance of the terrain sub-watershed.

Table 1. Formulae adopted for computation of morphometric parameters.

N°	Morphometric Parameters	Formula	Reference
Linear parameters	Stream length (Lu)	Length of the stream Strahler	[11]
	Mean stream length (Lsm)	Lsm = L u / N u	[12]
	Stream length ratio (RL)	R L = L u / (L u + 1)	[11]
	Bifurcation ratio (Rb)	(Rb) = Nu / Nu + 1	[13]
	Mean bifurcation ratio (Rbm)	Rbm = Average of bifurcation ratios of all orders	[12]
	Drainage density (Dd)	Dd = L u / A	[11]
	Drainage texture (T)	T = Dd × Fs	[14]
	Stream frequency (Fs)	Fs = Nu / A	[11]
	Length of overland flow (Lo)	Lo = ½ Dd	[11]
Shape parameters	Elongation ratio (Re)	Re = D / L	[13]
	Circularity ratio (Rc)	Rc = 4 πA / P 2	[12]
	Form factor (Ff)	Ff = A / L 2	[11]
	Compactness constant (Cc)	$Cc = 0{,}2821P/A^{0,5}$	[11]
Relief Aspects	Basin relief (Rb)	Rb = H - h	[15]
	Relief Ratio (Rr)	Rr = R / L	[16]
	Relative Relief (Rre)	Rre = Hx 100/P	[16]
	Ruggedness number (Rn)	Rn = Rre x Dd	[16]

3 RESULTS AND DISCUSSION

Prioritization of the studied watershed was carried out using the software is based on the method [17]. The rivers whose upstream end is a source of order (1), the confluence of two courses of order water (n) gives an order (n + 1) and the confluence of a course water nth order with an order (n + 1) gives an order streams (n + 1). The order of the section thus arriving at the outlet is the maximum order of the basin (*Fig.05*).

LINEAR PARAMETER

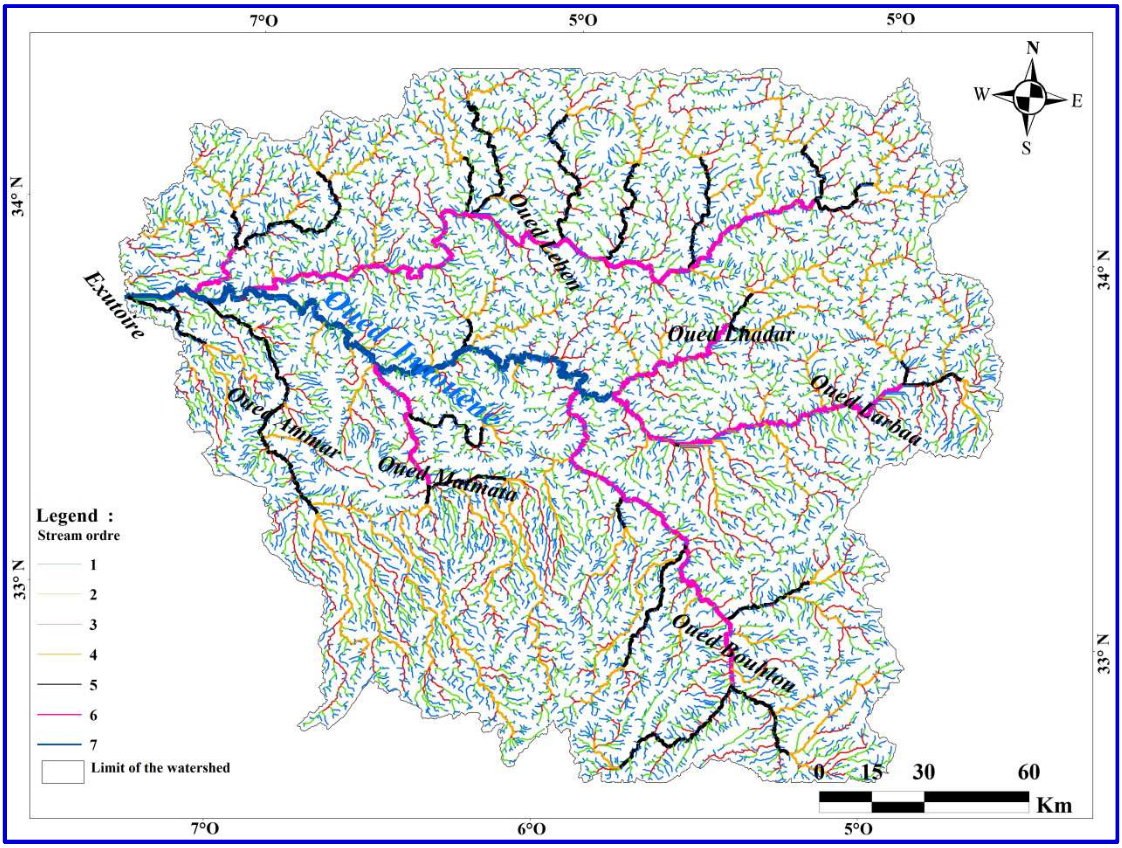

Fig. 5. Map of hierarchical water system of Inaouène watershed.

To establish the prioritisation of the basin of Inaouene river, the watershed was subdivided into three thirteen subunits, the morphometric parameters of each subunits were analyzed (linear parameters, forms and settings relief appearance settings) (*Fig.06*). The result of the linear parameters analysis showed that the number of streams varied between 11576 for the sub-watershed 02 (SBV02) and 165 for the sub-watershed 13 (SBV13). The variation in order and size of the sub-watersheds is largely due to physiographic and structural conditions of the region, similar to the results obtained by [1]. Is to note that x sub-watershed showed a high number of streams, indicating high indices of erosion in that sites. The stream length of different sub-watershed varied between 5994 km for SBV02 and 115 SBV13. The pattern of the evolution of the length of streams is negatively correlated to that of the number of stream (*Fig.07*). Highest number of streams, lowest is the length of stream. The present results coinciding with those reported by [11] and [1]. However, the streams length of the SBV3, SBV4 and SBV10 was positively correlated with the number of stream. In these cases, the lengths of streams were higher. This phenomenon could be explained by the presence of moderately and highly steep slopes in these sub-watersheds [18], resulting in the acceleration of the water flow. Moreover, in these sub-watersheds the lithology of the soil is marl, resulting in higher erosion process and the development of the badlands.

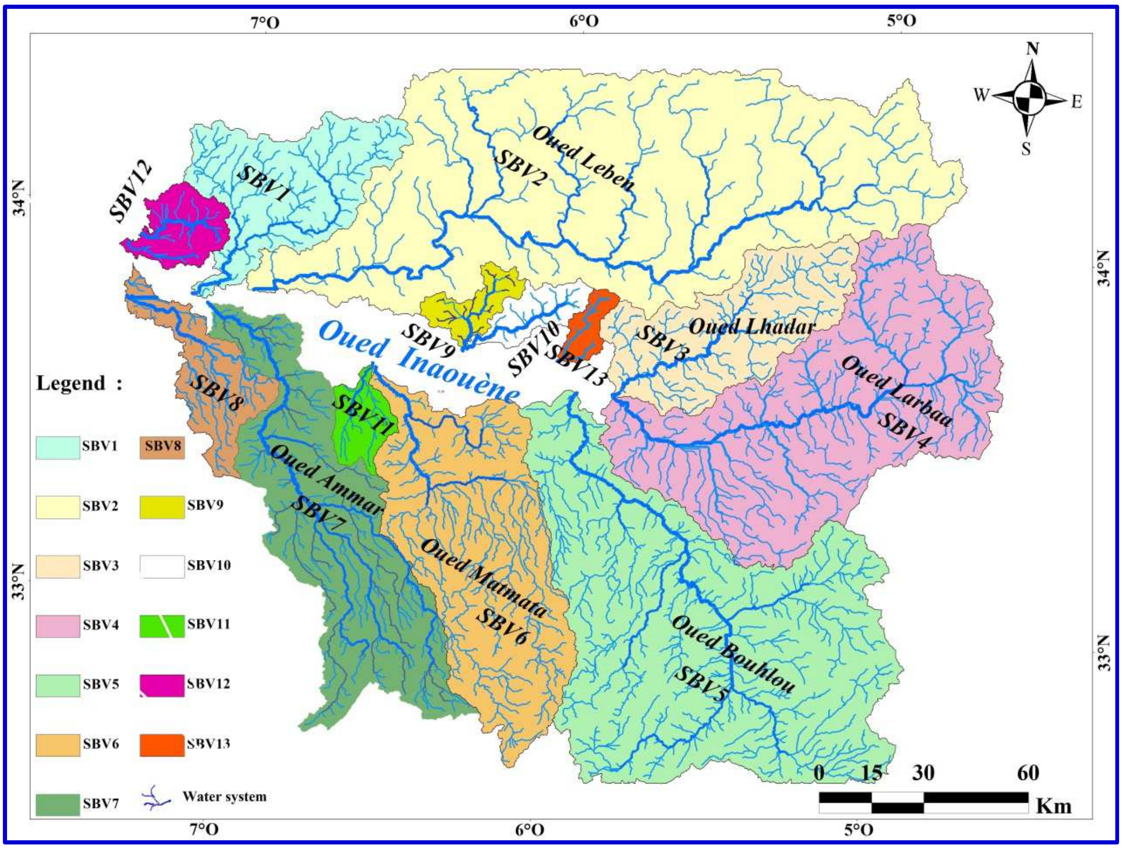

Fig. 6. Map sub-basin and the river system of Inaouène watershed

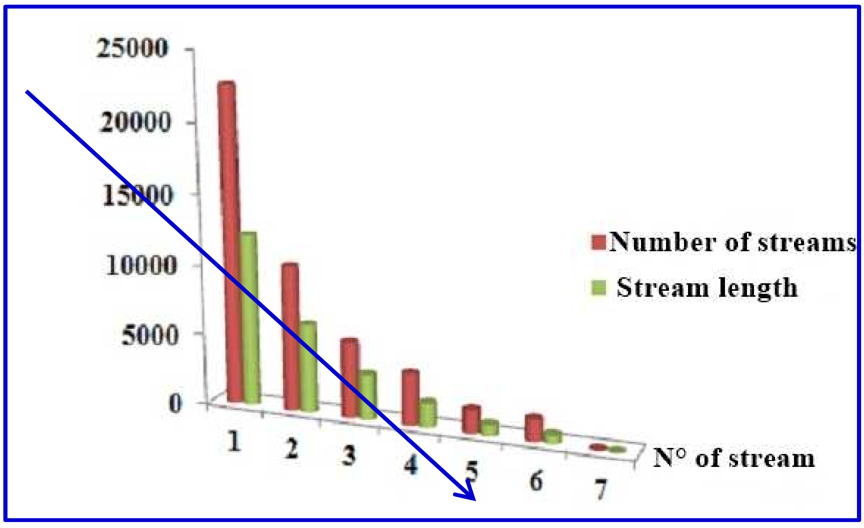

Fig. 7. Number and stream length of each order of Inaouene watershed

Concerning the frequency of the stream, this parameter is defined as the total number of stream segments of all orders per unit area [19]. The results showed that in the first 11 sub-basins of the watershed of Inaouene River, the frequency of the stream was 1.28, reaching a maximum of 2.11 in the SBV 12 and minimum value of 0.9 in SBV13. As general rules, high frequency of stream is related to an impermeable material. Higher frequency of streams produces more runoff in comparison to others [1]. In the present study the SBV12 produce more runoff and presenting limestone lithology. The low frequency variation of the flow is explained by the dominance of marl in the studied area.

River systems differ in their efficiency as agencies for collecting and conducting water. In some systems the surface waters are quickly assembled, and the discharge therefrom reflects somewhat sensitively the variations of the available supply. In others 'the surface drainage is longer delayed and the discharge is released slowly [20]. The drainage density (Dd), expressed in km / km^2, was introduced by [19] as the total length of the river system per unit area of a watershed. It is controlled by several factors including the geological nature of the terrain, the ability of soil infiltration and basement, climatic conditions and vegetation cover of the basin [21]. The drainage density of the established sub-basins of the Inaouène River varies from 0.62 to 5.17 km/km^2. Low values of this density indicate that the floor and the basement are very permeable, while the high values show that the land is waterproof. In the present study, the watershed of Inaouène is largely characterized by impermeable bedrock marl. The canopy in the studied area is almost bare, with the exception of the presence of scattered trees, which promotes land erosion. Moreover, the contrast between seasons and the influence of downpour accentuate the erosion phenomenon of the marl.

The texture of the drainage is defined as the total number of stream segments of all orders by perimeter of the area [11]. This parameter depends on several natural factors (climate, rainfall, vegetation, lithology of the rocks and soil type, infiltration capacity and relief). As general rules, the drainage texture is characterized by five categories: very coarse (<2), coarse (2-4), moderate (4-6), fine (6-8) very fine (> 8) [1]. The results show that this parameter of the catchment sub-basins Inaouene River ranged from 2.19 to 17.25. According to [1], four texture types were found in the present study. The texture was very fine for drainage for SBV02 (17.25) SBV04 (14.77) SBV05 (15.33) SBV06 (14.73) and SBV07 (8.95), fine for SBV01 (7.78), and SBV03 SBV12 (7.28), moderate for SBV08 (4.04) and SBV11 (4.84) and coarse for SBV09 (3.24) SBV10 (3.80) and SBV13 (2.19).

Concerning the bifurcation ratio (Rb), parameter expresses the degree of branching of the drainage network [22]. It is defined as the ratio between the numbers of order flow segments given the number of segments of the next higher order [13], and is used as an indicator of the stage of evolution of watersheds [12]. The results show that the bifurcation ratio values of the sub-watersheds of the River Inaouène ranged from 1.66 to 7.21. The high value of Rb indicates a strong structural control on the drainage system, while the low value indicates that the sub-basin is less affected by structural disturbances. The average value of Rb of the watershed varied between 3 and 5 point out to the influence of geological structures on the drainage network is negligible [23]. Basing on these criterions, bifurcation of Inaouene basin could be classified into three classes : Low for SBV02(1,66), SBV04(2,49), SBV07 (1,74), SBV08 (1,85), SBV09 (2,76), SBV11 (1,9) and SBV12 (2,31) (Rb<3) , medium for SBV10 (3,10) (3<Rb<5), and high for SBV01 (43, 24), SBV03 (24, 00), SBV05 (23, 74),SBV06 (7, 60) and SBV13 (20, 1) (Rb> 5).

The overland flow length (Lo) is inversely proportional to the average channel slope [24]. The length of overland runoff of the sub-catchments of Inaouene River was ranged between 0.31 and 2.58. Lowest values of this parameter, fastest is runoff process. This case was detected in the SBV02 and SBV13. However, slow trickle process was observed the SBV11, with high stream length (2.58).

The analysis of the linear parameters applied to the prioritisation of the Inaouene watershed showed direct relationship of the variable considered in the present study and soil erosion phenomenon. This relationship could be due to the presence of active and dynamic factors of erosion in the river of Inaouene. The results showed that the sub-basins SBV11, SBV12 and SBV06 are characterized by high values, indicating a high probability of soil erosion.

3.1 SHAPE PARAMETERS

The shape parameters include form factor (Ff), elongation ratio, compactness ratio and circulatory ratio. The form factor is defined as the ratio of the total area length of the watershed [19]. In the literature, it has been reported that a value less than 0.78 of this parameter is suitable for perfectly circular basin [1]. These authors sentenced that high value of form factor stating the circular shape of the basin and smaller the value of form factor more elongated will be the basin. The results herein reported show that the values of the form factor (Ff) of thirteen sub-watersheds were ranged from 0.17 to 0.28. The sub-watersheds from the SBV02 to SBV08 were more extended, while the sub-watershed SBV01, SBV09, SBV10, SBV11, SBV12 and SBV13 are less elongated. The lengthened watershed with low value of form factor found for Inaouene river point out that the basin will present a flatter peak flow for longer duration. Flood flows of such elongated basins were reported to be easier to manage than from the circular basin ([1]; [25]; [26] and [27])

The elongation ratio, factor used to describe the relief of the watershed is, the elongation ratio is defined as the ratio between the diameter of the circle of the same area as the drainage basin and the maximum length of the basin [13]. As general rules, the values of the elongation ratio (Re) of the different sub-watershed were ranged from 0.6 to 1 above wide climatic and geological factors. Values close to 1 are typical of regions of very low relief, while values varied between 0.6 and 0.8 are generally associated with high relief and steep terrain [12]. The values of the elongation ratio of the sub-basins of

Inaouene river found to be ranged from 0.52 to 0.68 (tab.05). The sub-watersheds SBV8 to SBV13 with value of elongation ratio ranged between 0.6 and 0.8 show high relief and steep terrain, the contrary of the rest sub-watersheds identified in the present study. These values can be grouped into three categories, namely circular (>0.9), oval (09-0.8) and elongated (<0.7) [28].

The ratio of the surface of a basin in the area of a circle having the same circumference as the perimeter of the basin, defined as circulatory ratio (Rc) (Miller 1953), is controlled by several factors such as the length, the frequency streams, the tectonics, the lithology, the climate, the slope and the vegetation cover of the basin [22]. The values of the circularity ratio of sub-watersheds of the Inaouene River varied between 0.18 and 0.42. In the literature it has reported that this parameter is positively correlated to the age or to the basin life cycle stages ([29]; [28] and [22]). The highest values of circulatory ratio were found in the SBV11 and SBV13, indicating that these sub-watersheds have reached the terminal stage of maturity.

Finally, to evaluate the risk of erosion, the compactness coefficient (Cc) defined as the perimeter of the basin divided by the circumference of a circle with the same area of the basin [30], the compactness coefficient is independent of the size of watershed and dependent only on the slope [32] was calculated. A lower value signifies less vulnerability for risk factors, while higher values indicate great vulnerability of the site. In our study, the values of compactness coefficient ranged from 1.55 for SBV11 to 2.36 for SBV07. Thus, the sub-watersheds SBV07 and SBV08 are more exposed to risk of erosion. The risk of erosion of these sites stresses the implementation of required measures of protection and conservation of soil to attenuate the effect of erosion on the quality and stability of the soil. Basing on the results of the analysis of shape parameters, the almost sub-basin established in the present study seems to prone to erosion, mainly those located in the right side of the river of Inaouene.

3.2 RELIEF PARAMETERS

Relief aspect of the watershed plays an important role in drainage development, sub-surface and surface water flow, permeability, landform development and associated features of the terrain. Relief is the maximum vertical distance between the highest and the lowest points of a basin [33]. The relief aspect of watershed was evaluated by the determination of the basin relief (H), relative relief (Rr), relief ratio (Rh) and Ruggedness number (Rn) [28] and ground slope.

The basin Relief, is defined as the difference in altitude between the lowest point (outlet) and the highest point (divide) of a watershed [34], plays an important role in the development of landforms, of surface of drainage and the flow of groundwater [22]. The relief of sub-basins of Inaouène River varied considerably depending on the altitude of the location, the highest value was observed for SBV05 (2926 m) and the lowest for SBV12 (208 m). The SBV02 to SBV07 characterized by an important relief, indicating that these sub-basins will be exposed to a significant drainage and low value of infiltration. However, the sub-basins SBV08 to SBV13 and SBV01 showed low basin relief values.

The relief ratio measures the overall slope of a drainage basin. Additionally it has been used as an indicator of the erosion intensity processes happening in a watershed [13]. The values of this variable varied from 0.009 to 0.025. The highest value was obtained for the SBV11, while the lowest values were observed for SBV01 and SBV02 (*Fig.8*). High value of relief ration indicates that the sub-basins have steep slope.

The index relative relief (Rr) considered an important morphometric variables to estimate the general morphological characteristics of the land [1]. The sub-watersheds with higher relative projection have a higher potential runoff than other [1]. The values of the relative relief determined for the thirteen sub-watershed of Inaouène river varied from 0.001 for SBV12 and 0.007 for SBV11 and SBV13. The present results confirm that the SBV11 and SBV13 have a high potential for flood, taking into the account that these sub-basins are characterized high circulatory ratio. In the literature it has been reported that a sub-watershed with low values of circulatory ratio are prone to low flood hazard [35].

The ruggedness number (Rn) variable is the product of the drainage density (Dd) and basin relief (H) ([17] & [36]), used in the present study to evaluate the drainage density of the drainage respecting to the relief inclination. In this study the values of ruggedness number varies between 0,173 and 4,803. In the literature it has been reported that the minimal threshold is more than 3 ([37]; [1] & [6]). In the present study, taking account the characteristics of the watershed of Inaouene (number of streams, shape form and relief), we have considered that the minimal high value of the ruggedness to consider for the established sub-basins is 2. Thus, the highest value of this variable was observed in the SBV11 (4.803) and (SBV6) (2.077). These sub-watersheds are characterized by high relief and drainage density values, with moderate to high slope. The sub-watersheds having low relief but high drainage density are ruggedly textured as areas of higher relief having less dissection [1]. In relief aspect calculation, some of the linear (length, perimeter, etc.) and shape (drainage density) parameters are applied. Thus, the morphometric description could be considered adequate method to differentiate and describe the hydrotopographical behaviour of the Inaouene watershed through the analysis of linear, areal and relief aspects of the sub-watersheds.

3.3 Ranking and Prioritization of Sub-watersheds Based on Morphometric Analysis

The morphometric parameters are considered to evaluate and determine the risk of erosion and natural hazards and were used to rank the sub watersheds ([39]; [40]; [41] and [42]). The linear parameters have direct and proportional relationship erodibility. Higher value of these parameters, higher is the erodibility (Tab.02).

Table 2. Classification of linear parameters of sub-watersheds of the Inaouene River

SBV	The Linear Parameters									
	(Dd)	Clas	(Fu)	Clas	(Rb)	Clas	(Td)	Clas	(Lo)	Clas
SBV01	0,71	6	1,32	4	43,24	1	7,78	7	0,35	6
SBV02	0,63	11	1,23	7	1,66	13	17,25	1	0,31	9
SBV03	0,66	10	1,20	8	24	2	8,93	6	0,33	8
SBV04	0,68	8	1,26	6	2,49	8	14,77	3	0,34	7
SBV05	0,71	6	1,18	9	23,74	3	15,33	2	0,35	6
SBV06	0,79	4	1,52	2	7,60	5	14,73	4	0,39	4
SBV07	0,77	5	1,28	5	1,74	12	8,95	5	0,38	5
SBV08	0,87	2	1,14	10	1,85	11	4,04	10	0,43	2
SBV09	0,69	7	1,26	6	2,76	7	3,24	12	0,34	7
SBV10	0,67	9	1,32	4	3,10	6	3,80	11	0,33	8
SBV11	5,17	1	1,42	3	1,9	10	4,84	9	2,58	1
SBV12	0,83	3	2,11	1	2,31	9	7,28	8	0,41	3
SBV13	0,62	12	0,90	11	20,1	4	2,19	13	0,31	9

Shape parameters have an inverse relationship with erodibility. Lower are these parameters, higher is the erodibility. Thus, the values of each linear parameter are ranked in ascending order, being the highest value with rank 1 and the lowest value with rank n depending on the classification ([43]; [44]). According to this rule, we have classified the different shape parameters as presented in the table.08. Appling the same criterion, the ordering the sub-basins was determined by assigning the highest priority ranking based on the highest value in the case of linear parameters and the lowest value in the event parameters form (Tab.03).

Table 3. Ranking of the shape parameters of the sub-watersheds of the Inaouene River

Subwatershed	Shape Parameters									
	(Ff)	Clas	(Rc)	Clas	(Ra)	Clas	(Bs)	Clas	(Cc)	Clas
SBV01	0,21	4	0,24	2	0,59	6	4,76	7	2,02	10
SBV02	0,17	1	0,26	3	0,52	1	5,98	13	1,95	9
SBV03	0,21	4	0,34	9	0,58	5	4,85	8	1,71	3
SBV04	0,18	2	0,32	7	0,54	3	5,54	11	1,77	4
SBV05	0,17	1	0,29	4	0,53	2	5,76	12	1,84	7
SBV06	0,19	3	0,32	8	0,56	4	5,26	10	1,77	4
SBV07	0,19	3	0,18	1	0,56	4	5,21	9	2,36	12
SBV08	0,19	3	0,18	1	0,61	7	4,32	6	2,34	11
SBV09	0,26	6	0,26	3	0,66	10	3,76	2	1,94	8
SBV10	0,26	6	0,30	5	0,65	9	3,81	3	1,82	6
SBV11	0,26	6	0,42	11	0,65	9	3,81	4	1,55	1
SBV12	0,25	5	0,31	6	0,64	8	3,98	5	1,79	5
SBV13	0,28	7	0,40	10	0,68	11	3,50	1	1,57	2

To establish the final classification of the thirteen sub-basins regarding the risk degree of each sub-watershed, the factor composed was calculated from these parameters. This factor will help us to make a priority ranking of each sub-basin. The highest rank was assigned to the sub-basin with the lowest factor compound and so on.

Based on the average value of these parameters, the sub-basins with the low value are considered the first priority, and the sub-watershed having the highest value factor compound is the lowest priority. The factor composed value determined in the present case varied between 4.8 and 8. According to these results, sub-watersheds were classified into three categories prioritization (high, medium and low) (*Fig. 8*). In agreement with to this prioritisation, the sub-watersheds SBV01, SBV04, SBV05, SBV06, SBV11 and SBV12 presents high risk of erosion. The sub-basins SBV02, SBV03, SBV07, SBV08, SBV09 and SBV10 show medium risk and finally the SBV13 present low risk. The watershed with high risk of erosion stresses the intervention to attenuate the damages that could be caused by this phenomenon on the stability of basin and the natural resources.

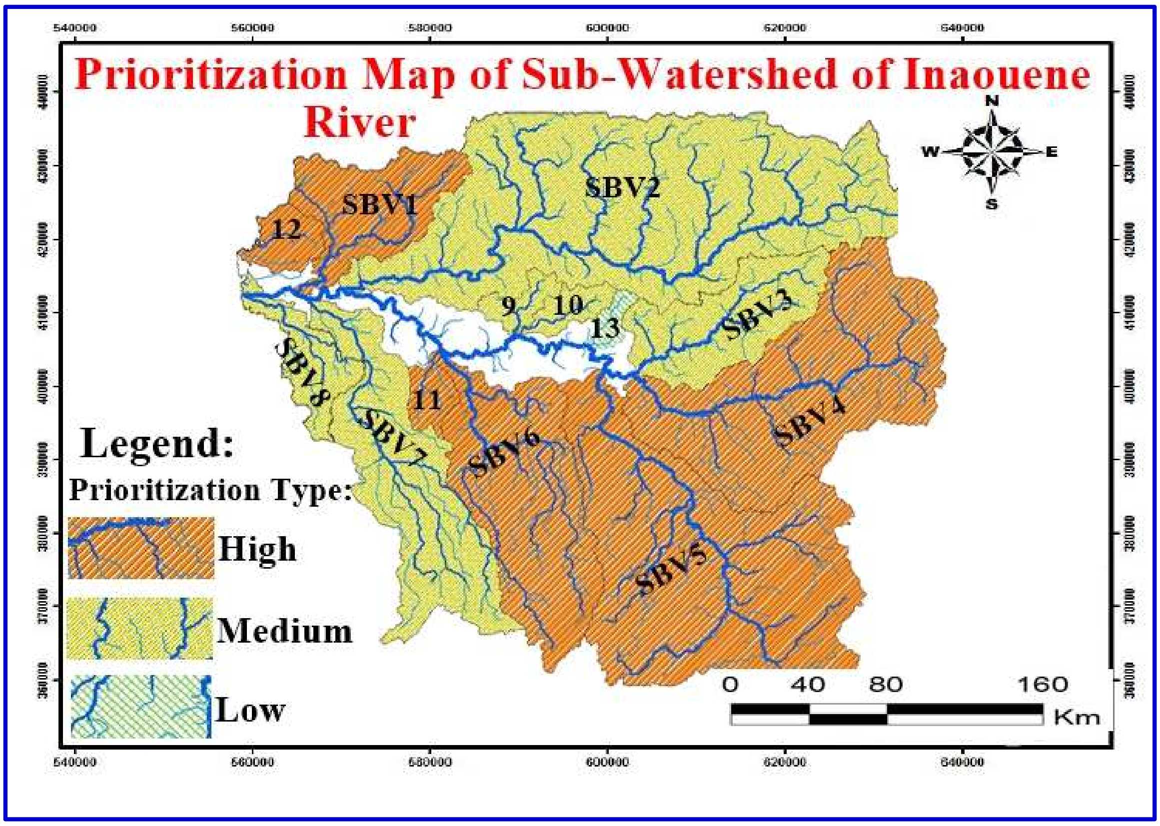

Fig. 8. Prioritization map of sub-watersheds of the Inaouene River

4 CONCLUSION

Watershed prioritization is one of the most relevant approaches in planning natural hazard management and implementation of sustainable development programs. The results of the analysis of the morphometric parameters clarified and described hydrological behavior response of the Inaouene watershed river. They allowed a hierarchy of sub-watersheds in terms of prioritization. The analysis of the number of streams using Digital Elevation Model (DEM) allowed the partition of the Inaouene sub-watershed into thirteen sub-basins. These sub-basins are characterized by different lithology, geological structure, slopes, local climatic conditions and scares vegetation's. The watersheds SBV01, SBV04, SBV05, SBV06, SBV11 and SBV12 were classified as a high priority, and consequently are succumbed to high risk of soil erosion. The erosion phenomenon in these localities could induce the release of several natural hazards and damages. In the context of climates changes, characterized by high frequency of rainstorms, the possibility of resilient floods could take place in these breakables and susceptible sub-basins, resulting in the degradation and erosion of the soil and landslides. This situation could be accentuated by the lack of vegetation. The use of Geographical Information Systems for natural hazard mapping, in our case for soil erosion, are resulted very useful and of high interest to calculate the morphometric parameters and to establish different maps. These maps are suitable when the programs and territorial plan managements against soil erosion of the Inaouene watershed will be implemented. These results stress the immediate and special attention of decision makers of different administrations to take measures to protect these watersheds to reduce natural hazards, in order to conserve and manage the natural resources.

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