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Research Article

FACING FLOODS IN TÉBESSA CITY, EASTERN ALGERIA, A MORPHOMETRIC AND CARTOGRAPHIC APPROACH TO PRIORITIZE INTERVENTION IN THE CITY'S SUB-WATERSHEDS USING GIS AND REMOTE SENSING

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ABSTRACT

The objective of this work is to determine the importance of the five partial sub-watersheds that penetrate the city of Tébessa and their water networks in the “Oued El Kabir” watershed , belonging to the semi-arid climate Characterized by torrential rains constituting a natural danger, in terms of the real dimensions of the floods, especially since the hydromorphological characteristics of the valleys are not clear on the ground, because of the urban expansion which carried them away. The study was based on the morphometric and cartographic approach which allows the comparison of sub-watersheds between them, through 12 indicators, to determine the most influential sub- watersheds using GIS and remote sensing The results showed that the “ennagues” sub-watershed is the most dangerous for the city, it is a priority for its protection, and the need to manage the most vulnerable parts.

Keywords: sub watershed; Tébessa city; flood; morphometric; natural danger.

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1. INTRODUCTION

The classification of the sub-watersheds according to their morphometric characteristics [1].

and their degree of severity, and which are the areas to be protected against flooding in the city with priority, is the specific problem under this study , the partial basins and their Valleys of the “Oued El Kabir” basin, which penetrate the city of Tébessa, belongs to the “Semi-arid à hiver frais” [2], [3]. climate, Depending Emberger coefficient $Q_E = 2000P/(M^2-m^2)$, where P=270,03mm and M= 31,04 and m = 1,31 we find Q_E= 43,04 . We used the (DEM) [4]. Downloadable from the site (https://earthexplorer.usgs.gov) with a resolution of 29 m, for the production of all digital spatial informations [5]. (zonal and linear), in addition to the precise mapping of the water network, in the five sub-watersheds that penetrate the urban perimeter of the city. The latter takes a general orientation westward and perpendicular to the valleys of these sub-watersheds and tributaries [6]. Which accentuated the problem.

2. FIELD OF STUDY

The field of study (see Fig. 1) includes the watershed of the city and, the five sub-watersheds

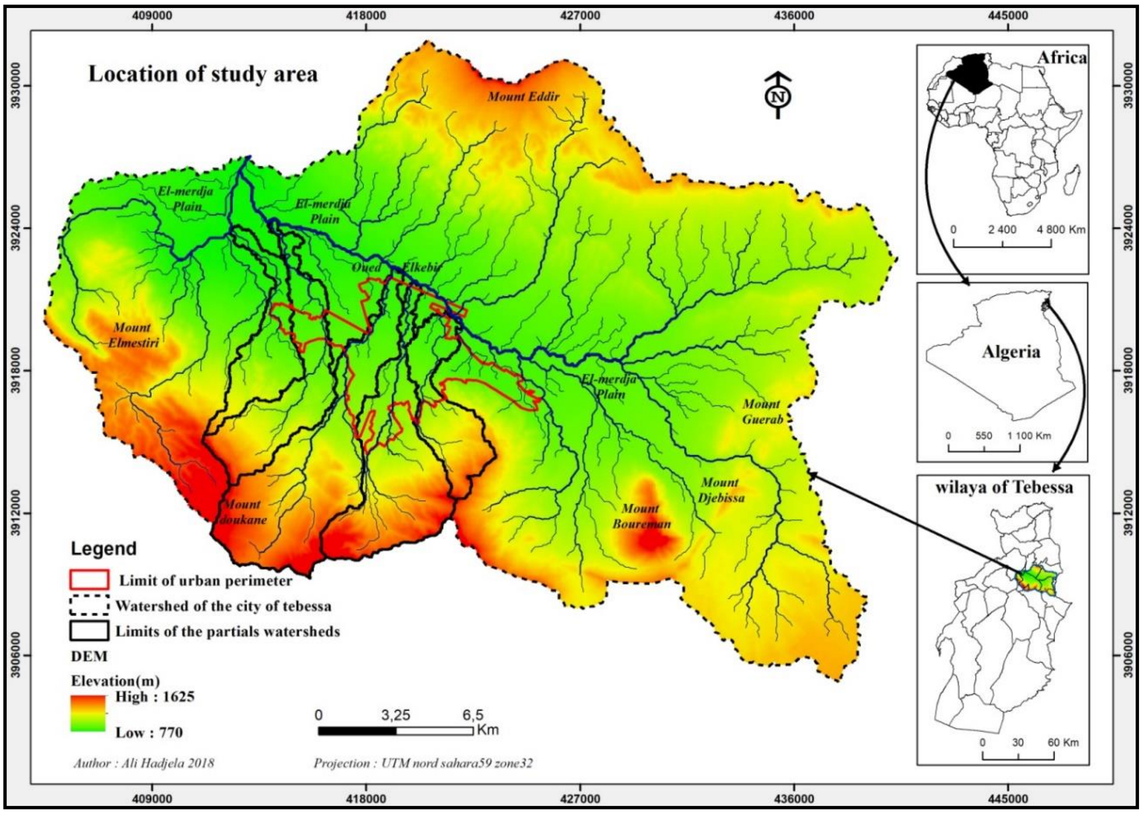

Fig.1. Location of study area (Oued Zaarour, Oued Al-Nagues, Oued Rafana, Oued Al-Sagui, and the sub-watershed of the Ghezala in the west of the city's urban perimeter)

The watershed of Tebessa and the five partial sub-watersheds are part of the “Mellegue” Watershed. The latter belongs to the twelfth

one, between 17 Algerian watersheds. Its area is equal to 576 km2 and the Length of basin circumference is estimated at 132 km. The limits of the watershed are set according to the DEM of 29 meters resolution, and from the exutoire at the point of geographical coordinates (8.041 ° E, 35.48 ° N), This basin extends from the north of the town of “El-Huijebat” across the mountains (Jebel Gharab, Jebel Jbissa, Boureman) between The last two mountains lies the city of “Bakaria”, up to the mountain of “Mestiri”, and the plateau of “Tazbant” to the west, and the mount “guenifda”, and djebel “eddir” to the north, and “Talla” and “Joua” mountains and “Dukan” to the south. The elevations in the watershed range between 770 meters above sea level at Al Oued Al Kabeer Bank in the North and 1625 in the Upper Dokan Mountains to the south, with a height difference of 855 meters. The urban perimeter of the city of Tebessa extends within this basin on an area of 2998 hectares. The basin of Tebessa city is located in the northern part of the wilaya; the latter located in the far east of Algeria.

2.1. The Sub-watersheds crossing the city of Tebessa: The hydrological basin or drainage basin is the area where water flows from each point to a common point called bank. It consists of three basic parts: Reception basin, drainage channel and bank. If the soil is impermeable, the topographic basin corresponds to the watershed, whereas when the soil is permeable, the two basins may not be identical except in the case of a strong underground drainage, as in the karst formations [7].

The urban perimeter of Tebessa is penetrated by many valleys and, consequently, its partial basins intersect with it, we study the most important and influential (Fig. 2).

2.1.1. The sub-watershed of Oued Zaarour: with 13.12 km2 located in the south-east of the city extends from the dividing line of water of Mount joua 1400m, Mount Osmur 1463 m, mountain talla 1591 m, and then narrow in his central part in the eastern part of the neighborhood Zaytoon and neighborhood The old Zaouia, where the illegal individual constructions spread, and then expand again in the northern part to include some neighborhoods of the city in whole or in part, such as Al-Bassateen, Al-Zuhour, Al-Kenissiya and Zaydi Lamin. The Oued_elkebir ends in northeast of the city

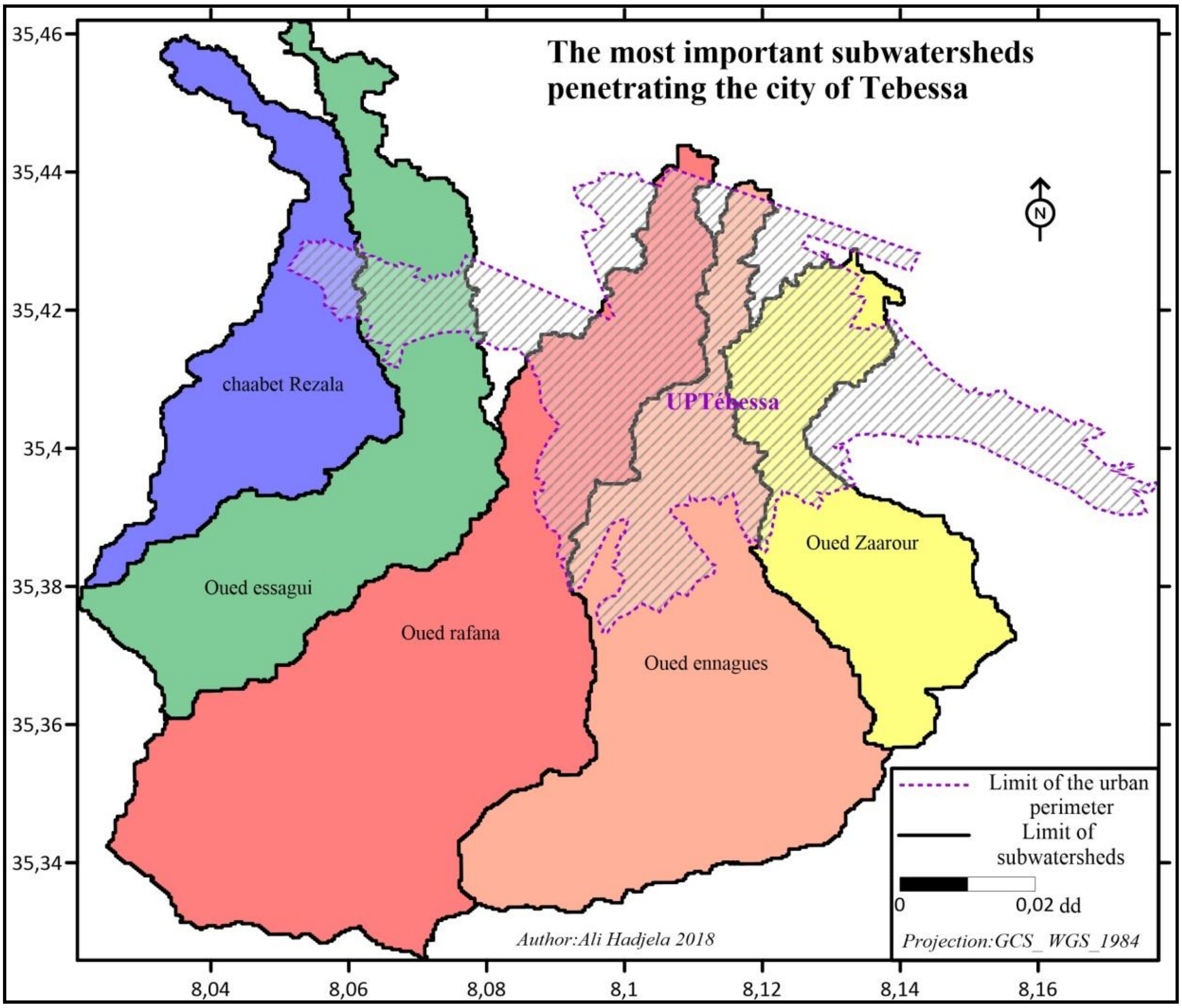

Fig. 2. The most important sub-watersheds penetrating the city of Tébessa

2.1.2. The sub-watershed and the Ennagues valley: The area of 26.55 km2 its origin is from the heights of Jebel al-Doukan 1718 m, It is characterized by the wide area in the southern part, and then it grows wider and narrower towards the north, One of the main parts penetrated by the basin and its main waterway, and its tributaries. It is the largest part of the Zaytoun, Al-Mizab, Al-Jorf neighborhoods in the south of the city, until Hawari Boumediene Street, where it runs into an underground channel. And as we move north, the sub-watershed grows narrower and wider.

2.1.3. The sub-watershed Oued Rafana: In the west of the former and the largest in terms of area (35,27 km 2) stems starting from the mountain Doukan 1718 m, similar to the former characterized by its breadth south and narrow north. This basin includes the area of the city's expansion (The new pole of Doukan), at the wilaya road 08 (connecting the city with the two towns elma_labiod and elogla_elmalha on the south) , the Residential allocation of Rafana and the central part of the industrial zone. To the end of the downstream area of eloued elkebir north, the rise at the estuary 797 meters.

2.1.4. Secondary sub-watershed Essagui: Located in the south west of the city with a total area of 19.21 km2, which extends in strip form despite its relatively large southern part, heading north to end with the plain of Merdja, The waterway passes close to the neighborhood (600 dwellings) near The Faculty of the exact sciences, and the sciences of the nature and the life, at the intersection of the basin with the urban perimeter it also includes the neighborhood of 600 inhabitants, Jebel Anoual and part of the district first of November.

2.1.5. The Chaabet Rezala Sub-Watershed: Located to the south-west of the city's urban perimeter, it extends northward between Machtat Bir Salem and Al Merahdiya to cross the 1Nov. district and the university. It is the only basin that continues its course in the valley of Bouakous before joining Eloued elkebir at the north of Marja, with an area of about 12.25 km2, which is the smallest basins area, begin tributaries of the Mountain Doukan in the south, has a narrow source and then soon to expand before taking a form of long and narrow.

3. DATA AND METHODS: In this study, we used satellite imagery that allowed us to extract the morphometric properties of the sub-basins, including the 30-meter digital elevation models (DEM) of the US Space Agency, and we also used the European multi-spectral Sentinel satellite images with a resolution of 10 meters to study the index of normal différentielle vegetation (NDVI), and the geological map 1/50000, by means of Geographical information system programs (GIS).

4. ANALYSIS AND CLASSIFICATION OF SUB-WATERSHEDS

4.1. According to the geometric and topographic characteristics

4.1.1. Characteristics of the form: It has an effect on the concentration and volume of the water and the speed of its flow, in addition to other factors.

4.1.1.1. Area and perimeter of the sub-watershed: with the Gravelius (1914) index of compactness ($Kg = 0, 28 * P / (A^{0, 5})$) [8].the following table shows that this index values all than 2, and this means that these sub -watersheds are long and this is what we observe on the ground. It is not coherent in terms of the fact that the activity of eroding by water process varies from place to place within the basin. And therefore the time of collecting rainwater in the valleys is relatively slow. However, this varies from one sub-watershed to another; Oued Al-Nagues is on top of it, as shown in Table 01.

Table 01. Index of Gravilius (KG)

Partial watershed	Basin area (km^2) (A)	Length of perimeter of basin(P)	Kg
Al - Nagues	43,210	26,55	2,348
Zaarour	30,566	13,12	2,362
Rafana	50,460	35,27	2,379
Chaabet Rezala	34,568	12,25	2,766
Essagui	44,312	19,21	2,831

Source: Researcher's account

4.1.1.2. Dimensions of profile sections: On the basis of the topographic sections obtained using the digital elevation model, we obtained the results (Table 02), which reflects the relationship between the elevation difference (upstream and downstream: H) and the length of the stream or watercourse [9]. (L) . It turned out that Oued Zaarour represents the most dangerous and the most important (53.01 m / km), which is relatively proportional to its steep slope compared to the rest of the rivers, Oued rafana is due to the size of its catchment and its length in last place (38.65 m / Km).

Table 02. Dimensions of profile sections of sub-watershed valleys

Partial watershed	valleys	upstream (m)	Downstream (m)	H	L (km)	H/L
Zaarour	Zaarour	1333	805	528	9,96	**53,01**
Al - Nagues	Al - Nagues	1495	803	692	14,9	**46,44**
Rezala	Chaabet Rezala	1260	775	485	11,7	**41,45**
Essagui	Al - Sagui	1400	778	622	15,3	**40,65**
Rafana	Rafana	1513	798	715	18,5	**38,65**

Source: Researcher's account

4.1.2. Water Network: Among the hydrological criteria that can be used to compare watersheds are:

4.1.2.1. Drainage density (DD): Used by (Horton, 1945) is defined by the sum of the lengths of the grid divided by the watershed area [10]. And taken from 3-4 values in areas where the runoff is limited.

4.1.2.2. Hydrographic density (HD): Is equal to the number of watercourses (N) in the partial sub-watershed divided by its area (A), the results are summarized in Table (03); It shows a marked convergence of density at both at sub-watersheds level. The sub-watersheds of, Rezala and Rafana and essagui are present in the introduction according to the density of drainage, rafana and zaarour according to the hydrological density. This information was obtained by drawing on the water network map.

Table 03. Distribution of drainage density and hydrographic density across partial hydrological Basins

Partial watershed	(N)	L:(km)	Basin area A: (km2)	DD:(km/km2)	HD=(N/A)
Al - Sagui	210	76,88	19,21	**4,00**	**10,93**
Rezala	123	47,452	12,25	**3,87**	**10,04**
Rafana	395	131,76	35,27	**3,74**	**11,20**
Zaarour	146	48,46	13,12	**3,69**	**11,13**
Ennagues	272	97,54	26,55	**3,67**	**10,24**

Source: The researcher's calculation based on the (DGEM) 29 m by Arcgis10.3

4.1.2.3. Confluence ratio (Rc): The ratio of the number of x-level waterways to the number of waterways with the rank x + 1, river level on the map according to the most widely used Strahler (1957) The relation of coefficient is as follows: Rc = Nx / N (x + 1). The higher the confluence coefficient, the greater the flow [11].

4.1.2.4. Length factor: (RL): The length of the waterways of a given grade (Lx) to the length of the other with grade (Lx + 1), where RL = Lx / L (x + 1). The coefficient of height reflects the density of the water network. See (Fig. 3), Table 04 also arranges partial basins according to the confluence and length factor.

Table 04. Distribution of confluence and length coefficients through sub-watersheds

sub-watersheds	NX , X=1	N(x+1)	Lx , X=1	L(x+1)	RC	RL
Rezala	63	26	23536,85	12214,45	**2,42**	**1,93**
Ennagues	137	59	46651,32	18625,64	**2,32**	**2,51**
Zaarour	74	32	22958,2	11862,04	**2,31**	**1,94**
Rafana	201	90	69008,69	31202,73	**2,23**	**2,21**
Al - Sagui	105	50	37067,49	18381,57	**2,10**	**2,02**

Source: The researcher's calculation based on the (DGEM) 29 m and by Arcgis10.3

4.1.2.5. Coefficient of torrentiality: We obtain it **[12].** By multiplying the drainage density of waterways with the rank 1 in the total density Ct = Dt * Dn1.

It is noticed from table (05) that the sub-watersheds extending west of the city are the largest in terms of the torrentiality and therefore the large number of tributaries of rank 01 in their sources, and therefore the sub-watersheds located southeast of the city are saturated faster than others, look at map (Fig. 3).

Table 05. Distribution of the torrentiality coefficient in sub-basins

sub-watersheds	Basin area A: (km2)	L1 (Km)	Dt	Dn1= L1/ A	Ct
Al - Sagui	19,21	37,06749	4,00	1,93	**7,72**
Rezala	12,25	23,53685	3,87	1,92	**7,44**
Rafana	35,27	69,00869	3,74	1,96	**7,32**
Zaarour	13,12	22,9582	3,69	1,75	**6,46**
Ennagues	26,55	46,65132	3,67	1,76	**6,45**

Source: The researcher's calculation based on the (DGEM) 29 m

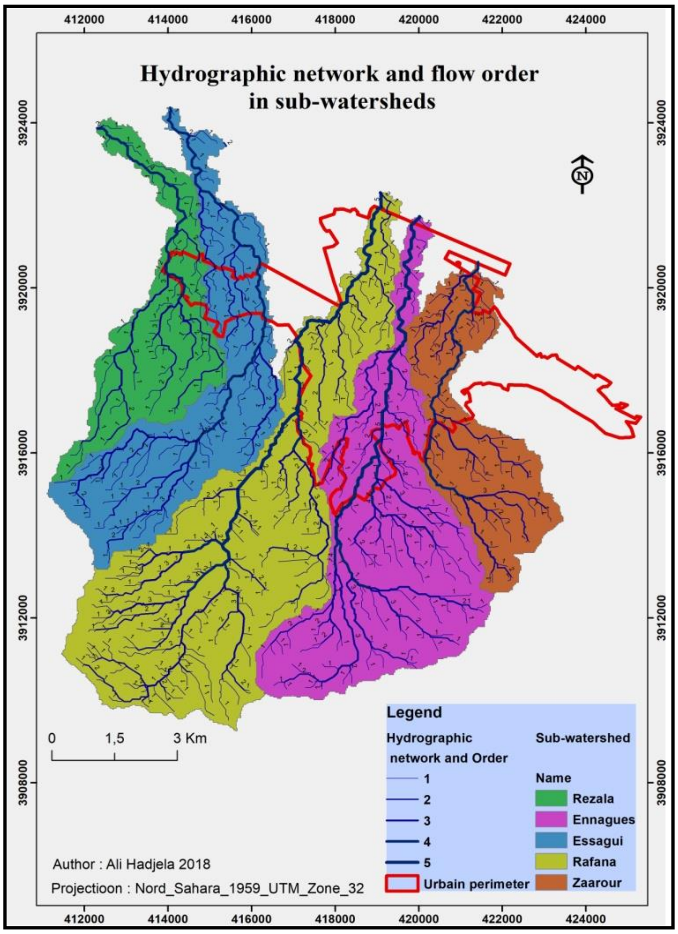

Fig. 3. Hydrographic network and flow order

4.1.2.6. distribution of concentration time: To determine the length of time required for the collection of water in the valleys of the basins passing through the city of Tebessa, we rely on the application of the law of Giandotti (1934) (after Fang et al. 2005), which takes the following relationship: $Tc = ((4 * A^{0.5}) + (1.5 * L)) / 0.8 (Hmoy-h)^{0.5}$ Where A: area in km2, L: The length of the waterway. Hmoy: average altitude in m, h: low altitude in m. Tc: concentration time in hour [13]. The concentration time of the sub-watersheds is generally short, particularly for

Table 06. Concentration time

bassin	A	L	Hmoy	h min	Tc
zaarour	13,12	9,96	1024,6	806	2,49
ennagues	26,55	14,9	1122	798	2,98
rezala	12,25	11,7	904,02	774	3,46
rafana	35,27	18,5	1136,61	796	3,49
essagui	19,21	15,3	982,88	776	3,52

Source: The researcher's calculation

zaarour, ennagues basins and less than 3 hours, which increases the likelihood of serious flooding in these sub-watersheds, as happened 12/ 09/2018 [14].

4.1.3. Slopes: Increase direction in the south as shown by the map (Fig. 4), Sub-basins can be compared in Average slopes. Because increasing slopes reflect significant hilly terrain, but large, regular slopes increase runoff velocities, which is expressed by the small values of the standard deviations of the slope, and therefore the percentages of the coefficient of variation, where : coefficient of variation = (standard deviation/ average)*100.

$Sd = (\Sigma ni (xi-a)^2/N)^{0.5}$ Where Sd: standard deviation, ni: frequency, a: average, N= Σni. Table (07) shows the order of these basins as mentioned. As it turns out that the coefficient of variation in the Rafana basin is the smallest (75,13) and the largest value recorded in the

Table 07. Slopes distribution through the partial basins across the city

bassin	Average %	Standard deviation	Coefficient of variation (%)
rafana	15,2	11,42	**75,13**
ennagues	16,99	13,66	**80,40**
zaarour	13,88	11,79	**84,94**
rezala	10,26	9,81	**95,61**
essagui	11,86	12,27	**103,46**

Source: The researcher's calculation based on the digital elevations model (DGEM) 29m.

Essagui basin (103,46), The two irrigation basins, in the west side of the city (essagui, rezala) are more complex in terms of slopes, and hence the higher coefficient of variation.

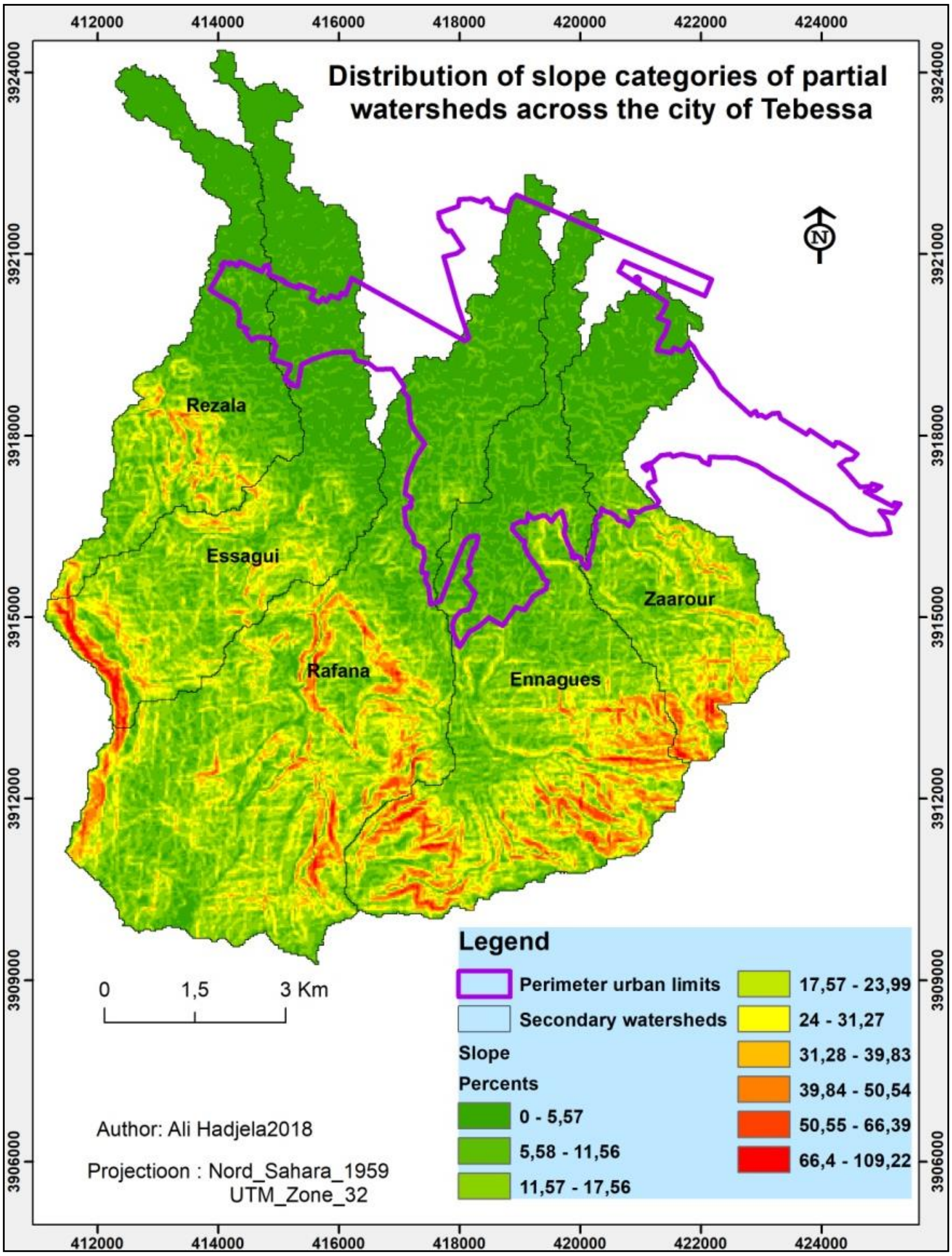

Fig. 4. Distribution of slope categories of Partial watersheds across the city of Tébessa

4.1.4. Vegetation: Forests and vegetation generally help to block some rain, with leaves and have a significant impact on the reduction of runoff. Regulating the flow of rivers and suppressing low- and medium-capacity floods. While less impact in the case of maximum flows caused by catastrophic floods, on the contrary, low-retention bare soil promotes very rapid flow of water. Vegetation is one of the most important factors that control the runoff of water in basins and thus help reduce Flood risk [15]. [16].

The landsat08 satellite provides us with multi-spectral images (msp) with a resolution of 30 to 15 meters, and is available to remote sensing and GIS specialists free of charge (2013-2016), but we have adopted a distinction between vegetations in the Partial Hydrological Basins across the City on the Normalized difference vegetation index NDVI. By the European satellite images (sentinel-2) [17]. Which is a series of Earth Observation satellites from the European Space Agency, developed under the Copernicus program, of which the first two copies were in orbit in 2015 and 2017, see: https://en.wikipedia.org/wiki/Sentinel-2. Using the fourth and eighth bands [18], with a resolution of 10m they are preferred in such studies. NDVI= (NIR-R)/(NIR+R) [19]. (Harry West, et al 2018) From Table 08 and Map (Fig. 5), it is clear that the NDVI index is lower in the western basins (Essagui and Rezala) As well as in the city, and that it lacks more vegetation. Based on this

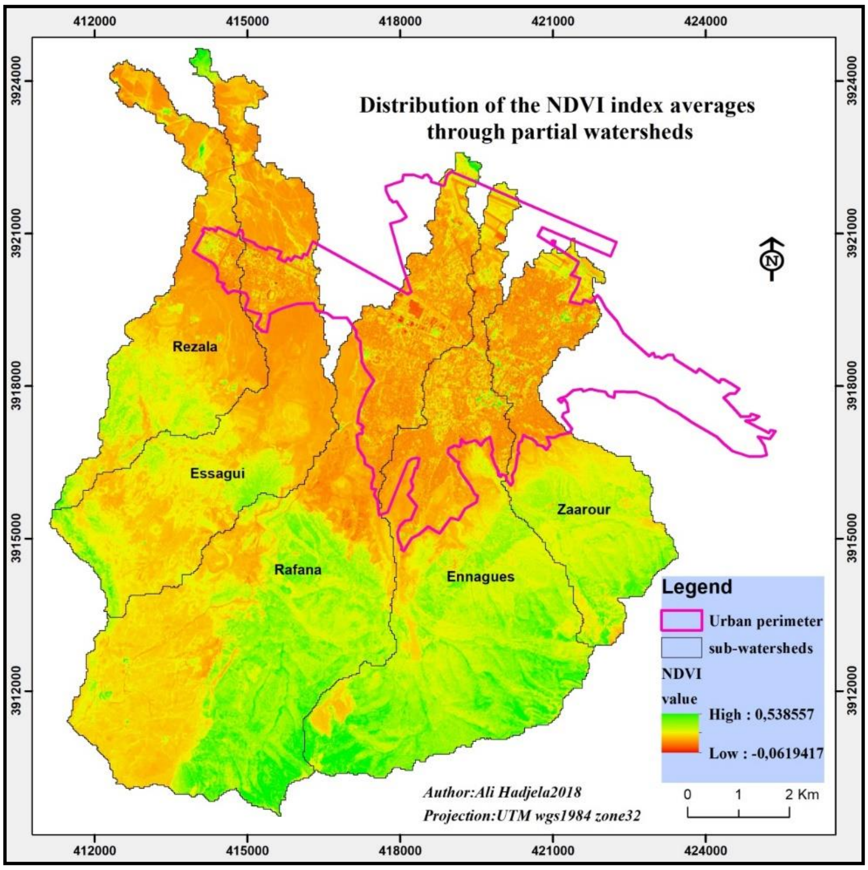

Fig.5. Distribution of the NDVI index averages through partial watersheds

factor, it lacks water retention capacity and is more dangerous during flood precipitation.

the city, and that it lacks more vegetation. Based on this factor, it lacks water retention capacity and is more dangerous during flood precipitation.

Table 08. NDVI Distribution, through partial basins on 28/07/2018

Partial basins	Ennagues	Rafana	Zaarour	Essagui	Rezala
NDVI averages	0,18	0,16	0,15	0,11	0,11

Source: The researcher's calculation based on the image of the European satellite Sentinel_2 (msp).

4.1.5. Geological formations and permeability: On the basis of the geological formations of the study area (geological map 1/50000 of Tebessa), we can know the characteristics of the rocks, in particular their permeability. The following map shows the geological formations of the partial watersheds extending from the south of the city to the north. At the edge of Oued-elkebir near Tebessa Airport. The map (Fig. 6) reveals that:

- The Quaternary incoherent gypsum and clay sediments, which at the same time represent the northern parts of the studied basins.
- Consisting of black or gray or stratified leaves, Secondary formations (calcareous rocks or marl) located south-west.
- Upper Cretaceous or sediments of limestone alternating with rocks composed of marl or limestone in the south-east.
- Depending on their resistance and cohesion, it is possible to distinguish solid rocks, resistance and rocks of medium hardness, resistance and other weak resistance, which is reflected on the permeability of these rocks, the ratios of solid and medium resistance rocks shown in the following table

Table 09. The ratio of solid and medium hard rock to partial basins

partial basins	Zaarour	Ennagues	Rafana	Essagui	Rezala
Percentage of solid and moderate rocks (%)	65,32	71,38	77,67	55,39	28,73

Source: Based on geological map 1/50000 of Tebessa

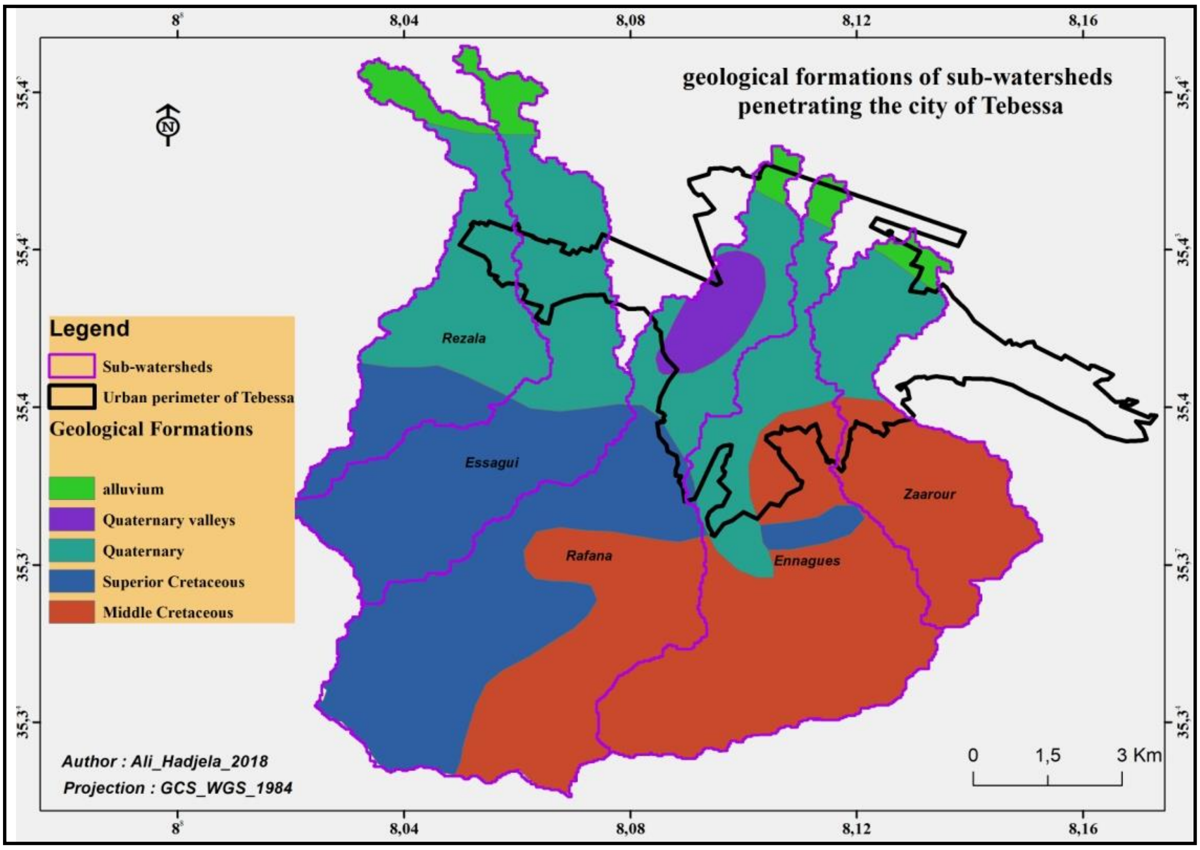

Fig. 6. Geological formations of sub-watersheds penetrating the city of Tébessa

4.1.6. The area of the partial basins belonging to the urban perimeter: Represents the urban perimeter of the city and especially the built part, the biggest bet that requires protection. If the rain flood is a threat to the city (Alea), by increasing the area between the urban perimeter and the partial basins of buildings and infrastructure, the risk increases (Alea + Enjeu = Risque Majeur).

Through table10 and after calculation, we find the size of the danger posed by the three basins, Rafana with (23,90 %) of urban area, Ennagues (22,19%), Zaarour (15,54%), are the basins that cover larger areas of the city. this is also evident in map (Fig. 7), which represents the common areas of the sub-watersheds with the urban perimeter and their percentage as compared to the total area of the city estimated at 2998 hectares.

Table 10. Distribution of the Common parts of the partial basins with the urban perimeter of the city

partial basins	Rafana	Ennagues	Zaarour	Essagui	Rezala
Common areas(ha)	716,56	665,35	465,75	177,19	83,09

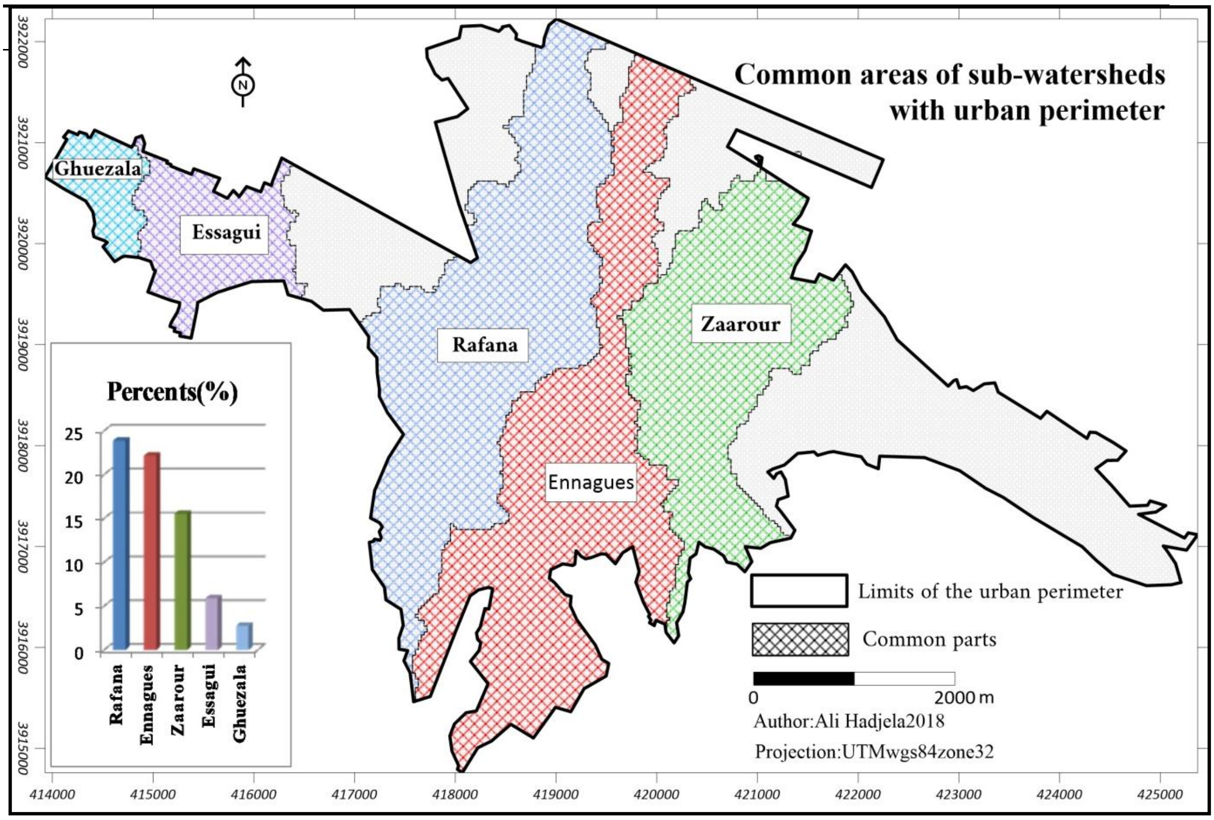

Fig.7. Common areas of sub-watersheds with urban perimeter

5. RESULTS AND DISCUSSION

5.1. Concerning the classification of partial basins

The classification process depends on the factors or Indicators discussed in this work, which are 12 indicators (Table 11). Some of which are related to morphological characteristics, such as geometric shape, gravelius index, valley length profiles, others are related to the morphometric characteristics of the hydrographic network such as drainage density, hydrographic density, and confluence Coefficients, length and torrentiality, concentration time, slope variation coefficient, as well as the NDVI index mean for the density of vegetation in the sub-basins, as well as the degree of hardness and resistance of the rocks through the geological formations in addition to the index of common spaces between the urban perimeter and the basins surrounding the city of Tebessa. These indicators are organized according to the level of risk they pose, are they factors that increase or reduce the risk of flooding in the city, which requires the creation of a table or matrix with the names of partial basins in the rows, the Indicators were evaluated in Columns. We adopted the classification of partial hydrological basins based on the values:

Total of Σ indicators (2, 3, 4, 5, 6, 11, 12) and then reduce Σ indicators (1, 7, 8, 9, 10).

Table 11. Indicators adopted in the classification of partial Hydrological Basins

N°	Indicator
01	Gravilius index $Kg = 0,28 * P / (A^{0,5})$
02	Dimensions of longitudinal sections (H/L)
03	Drainage density DD = L/A
04	Hydrographic Density HD = (N/A)
05	Length factor: RL = Lx/Lx+1
06	Confluence ratio: (Rc) = Nx/Nx+1
07	Coefficient of torrentiality: Ct =Dt*Dn1
08	Concentration time: $Tc = ((4*A^{0,5}) + (1,5*L)) / 0,8(hmoy\text{-}h)^{0,5}$
09	Slopes: coefficient of variation = (standard deviation/ average)*100
10	NDVI Index for 28/07/2018: NDVI=(NIR-R)/(NIR+R)
11	Percentage of solid and moderate rocks (%)
12	Common parts

5.2.Concerning the Prioritization of intervention in partial basins : As mentioned above, based on Table 12 and map(fig .08), we find that the partial basin of Oued Ennagues is the most dangerous ,and tops the arrangement of partial sub-watersheds, in terms of priority And the degree of gravity ,and calls for taking the necessary measures to reduce the repercussions of the occurrence of floods on the urban perimeter of the city, In a second order, and no less dangerous, we find the secondary partial basin of Oued Zaarour. After him and to a lesser extent, the basin of the Rafana, and after it the basin of Essagui and then the basin of the Rezala. In fact, these five sub-watersheds are all very dangerous for the city of Tebessa, which was shown by the repeated disasters caused by the floods of water due to overflowing rivers, And the material and human losses that resulted, as was the case on September 12, 2018.

As can be seen from the table 12 and map (fig .08), the first three basins should receive more attention than others, and their interventions should be a top priority for local authorities in charge of city affairs, in order to prevent the expected flooding risks of these sub-watersheds.

Table 12. Conversion of indicator values (12 indicators) to percentages and partial basins classification

Indicators / Basins	1	2	3	4	5	6	7	8	9	10	11	12	Σ	Rank
Ennagues	83,04	87,61	91,75	91,43	100	95,87	83,55	84,66	77,71	100	91,90	92,85	**222,44**	**01**
Zaarour	83,39	100	92,25	99,38	77,2	95,45	83,68	70,74	82,10	83,33	84,10	65,02	**210,16**	**02**
Rafana	84,10	72,91	93,50	100	88,4	92,15	94,82	99,15	72,62	88,89	100	100	**207,39**	**03**
Essagui	100	76,68	100	97,59	80,4	86,78	100	100	100	61,11	71,31	24,73	**76,38**	**04**
Rezala	97,88	78,19	96,75	89,64	77,2	100	96,37	98,30	92,41	61,11	36,99	11,59	**44,29**	**05**

Source: Based on Table 12

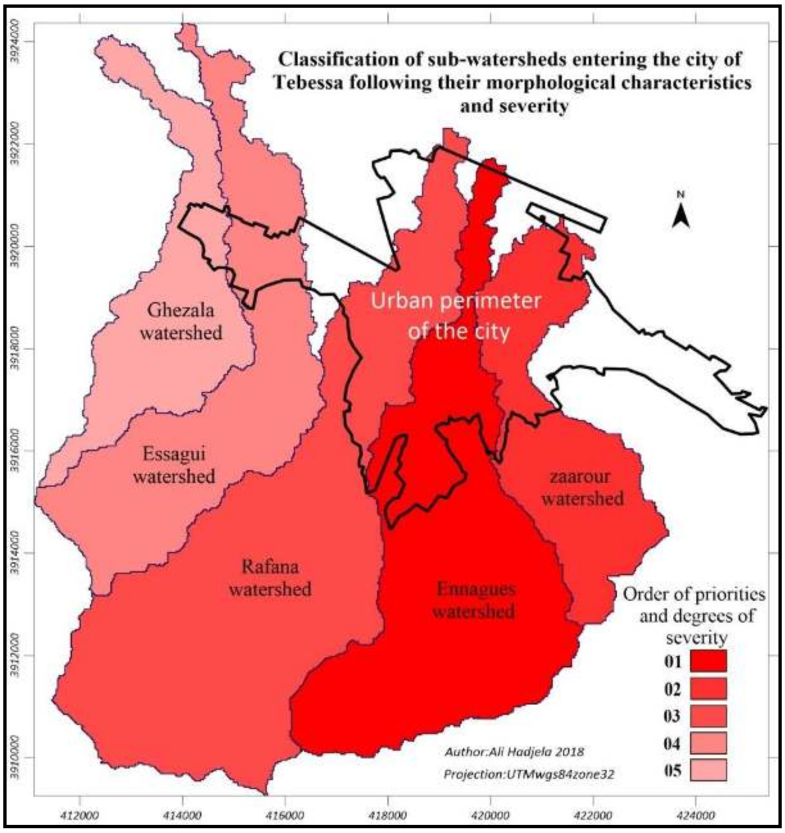

Fig. 8 Classification of sub-watersheds entering the city of Tébessa following their morphological characteristics and severity

and as is evident from the result of the classification using a matrix of 12 indicators, the most dangerous of these partial sub-watersheds for the city is the the sub-watershed of Oued Nagues, which must be given priority within the interests of local authorities and their strategy to face the danger of floods.

5.3. The most vulnerable (exposed to flooding) parts of the city of Tébessa:

In this work, according to the map of the urban perimeter and its intersection with the partial hydrographic basins and their rivers or waterways, the most vulnerable areas of the city spread between the sources and estuaries of the five valleys as follows:

a) **Oued Zaarour:** In the east and southeast of the city, an area stretches from the Zaytoun and Mardja districts to Tagda.

b) **Oued Nagues :** From Al-Mizab and Al-djourf neighbourhoods in the south, through Houari Boumediene Street to the north of the Airport district, this became more evident through the floods of 12/09/2018.

c) **Oued Rafana area:** From the neighbourhood of 200 dwellings. Near the civil protection in the Fatima Zahra district. It should be noted that the Rafana, Nagues and Zaarour basins are considered the most dangerous for the city according to the indicators adopted in the study.

d) **Oued Essagui:** Frome district of 600 dwellings to Elouiam district.

e) **The Rezala waterway** in the West of the urban perimeter the "first of November" district, and the university area.

6. CONCLUSION AND RECOMMENDATIONS:

Through this work, we have been able to arrive at the classification and arrangement of the partial hydrological basins transiting the city of Tébessa according to twelve indicators, including those related to geometric form, the drainage network, and vegetation cover, etc.

However, this study is only a beginning, and remains open for further studies on other factors, especially those related to flow and maximum amounts of rainfall, As well as the solid load of these sub-watersheds and their changes over time and space.

It was found that the "**Wad Al-Nagues**" sub-watershed is the most dangerous and next, we find the "Zaarour" and "Rafana" basins almost as similar. The intervention should be according to the priorities and the danger represented by partial hydrological basins for the city, As well as according to the five most vulnerable areas mentioned above. some of the guidelines we put in place are :

a) **Conducting a rehabilitation process for water courses and reforestation**: Reforestation of southern parts of upstream basins to stabilize the soil and minimize soil erosion and reduce the load of the solid water current (Hadjela. A, Larouk. M., Op-cit p16-18).

b) **Correction of watercourses**: Including the modification of their tracks, and construction of water barriers to reduce their solid load.

c) **Rainwater Drainage System Rehabilitation**: This is achievable by establishing an effective network of appropriate dimensions, taking into account maximum valley flow caused by large flash floods, and precipitation data, to avoid severe losses as a result of flooding.

d) **Ensure respect for planning instruments and appropriate guidelines for construction and town planning.**

e) The local authorities shall take the necessary measures to **ensure the permanent maintenance of the rainwater drainage system**, including the activation of the recovery of plastic and non-plastic waste to avoid clogging of water sinks and reaching zero waste level in order to achieve a sound and balanced urban ecosystem in terms of inputs and outputs.

f) The need to carry out studies related to the city flood risk prevention plan (PPRI) mainly based on field work, climate data, **GIS and remote sensing.**

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