Sediment transport study in Zeddine wadi and Harreza wadi

Etude du transport solide dans Oued Zeddine et Oued Harreza

Farida Bouras[1]*, Yassine Djebbar[2] & Lakhdar Djemili[1]

* Departement of hydraulic, Badji Mokhtar University, Po Box 12, 23000, Annaba, Algeria.
** Departement of Civil Engineering, University of Med Cherif Messaadia, 41000, Souk Ahras, Algeria.

Article Info

Article history:

Received 18/09/2018
Revised 07/01/2019
Accepted 20/01/2019

Keywords

Statistical modeling, Geographic Information System, Zeddine and Harreza watersheds, Specific degradation

ABSTRACT

This work is essentially based on a comparative study of the solid suspension transport modeling of two neighboring Zeddine and Harreza sub-watersheds, both of which belong to the Haut Cheliff watershed. The first part consists of a statistical modeling which aims to study the responses of both watersheds to liquid and solid flows in order to develop a specific model for each watershed, to assess the volume of sediment transported and to determine the specific degradation. Water and sediment flow rates are generally related by a power model. The Zeddine basin carries an average specific solid load of around 3.12 ton / ha / year, while that of the Harreza basin is around 1.64 ton / ha / year. In the second part, the Geographic Information System (GIS) developed in ArcGIS 10.3 was used to determine maps of areas vulnerable to erosion according to the universal USLE soil loss equation. The Zeddine basin has an average specific degradation of 5.28 ton / ha / year, while the Harreza basin has an average specific degradation of 2.94 ton / ha / year.

RÉSUMÉ

Le présent travail est essentiellement basé sur une étude comparative de la modélisation du transport solide en suspension de deux sous bassins versants voisins Zeddine et Harreza qui appartiennent tous deux au bassin hydrographique du Haut Cheliff. La première partie consiste en une modélisation statistique qui a pour but d'étudier les réponses des deux bassins versant aux débits liquides et solides pour développer un modèle spécifique à chaque bassin versant, évaluer le volume des sédiments transportés et déterminer la dégradation spécifique. Les débits solide et liquide évoluent en général suivant un modèle en puissance. Le bassin de Zeddine transporte une charge solide spécifique moyenne de l'ordre de 3.12 tonne/ha/an, alors que celle du bassin de Harreza est de l'ordre de 1.64 tonne/ha/an. Dans la deuxième partie on a utilisé le Système d'information Géographique (SIG) développée dans ArcGIS 10.3 qui a pour objectif de déterminer les cartes des zones vulnérables à l'érosion selon l'équation universelle de pertes de sol USLE. Le bassin de Zeddine présente une dégradation spécifique moyenne de 5.28 tonne/ ha/an, de sa part le bassin de Harreza présente une dégradation spécifique moyenne de 2.94 tonne/ ha/an.

Mots clés

Modélisation statistique, Système d'Information Géographique, Bassins versants Zeddine-Harreza, Dégradation spécifique

*** Corresponding Author**
Farida Bouras
Department of hydraulic, University of Badji Mokhtar, Po Box 12, Annaba, 23000, Algeria.
Email: lf.farida@gmail.com

1. INTRODUCTION

Water erosion is a qualitative and quantitative degradation phenomenon, affecting large areas of soils, particularly in Mediterranean zones [1]. In addition to the high sensitivity of rocks to erosion, heavy rainfall and hydrological variations, the presence of a rugged terrain and poor vegetation are all favorable conditions for materials training and transportation [2].

Erosion agents (wind, rain) pull off fine particles or aggregates from the soil surface. Once detached, these elements are transported by wind or runoff to the streams, resulting in increasing water turbidity and therefore the sediment discharges. This then will affect the downstream infrastructures such as water reservoirs, irrigation canals, water treatment stations and hydroelectric plants.

Many studies have been conducted to quantify the suspended sediment transport during single flood events, to identify the impact of human works on the sediment balance, estimate the filling of dams by fine materials [3-6] and monitor the seasonal and spatial variations in the concentration of suspended solids in various morpho-climatic contexts [7-12]. In Algeria, several modeling works of erosion and sediment transport phenomena, have developed relationships linking solid transport to liquid flows [13-21]. Other studies conducted on erosion showed that soils are particularly susceptible to runoff and erosion [22-26]. Sediment transport is therefore, by its importance, a major problem in Algeria, as the rate of specific erosion reaches values exceeding 2000 t/ km^2/ year [27].

The aim of the work is to try to describe and explain the dynamics of suspended solids, to quantify water erosion and to evaluate its spatial and temporal distribution, applying the Universal Soil Loss Equation (USLE). We have proceeded to a comparative study of the solid transport in suspension of two neighboring sub-watersheds; Zeddine and Harreza to compare their hydrological behavior and their erosion reports.

2. DATA AND METHODS

2.1. Study area

2.1.1. Basin of Oued Zeddine

The sub watershed of Oued zeddine is located on the left bank of Oued Rouina tributary of Oued Chelif; it covers an area of 421 km^2 (Tab.1) [28].

Table 1: Morphometric characteristics of the two studied watersheds

Name sub watershed	Harraza	Zeddine
Code sub watershed	0117	0119
Area (km^2)	142	421
Perimeter (Km)	142,68	173,69
Equivalent length (Km)	58,66	74,84
Equivalent width (Km)	12,68	12,01
Medium elevation (m)	575	640
Minimum elevation (m)	300	200
Maximum elevation(m)	1600	1700
Gravelus index (kc)	1,76	1,62
Overall slope index (Ig) (m/km)	23,87	21,38
Vertical drop specific (Ds) (m)	651,09	640,87
Percentage of vegetation cover (PVC)	20	25

The Oued Chelif remains the longest river in Algeria; its length is 725 km (Figs.1 and 2). This river is located in the north-west of Algeria; it starts in the Tell Atlas and flows into the Mediterranean Sea. It delivers, in times of flood, 1500 m3 per second [29]. It is situated between 1 ° and 1 ° 51 of 'east longitude and between 35 ° and 36 ° 15' of north latitude [30]. Altitude differences are very large, the main wadi goes indeed from 1786 m to 328 m in less than 30 km.

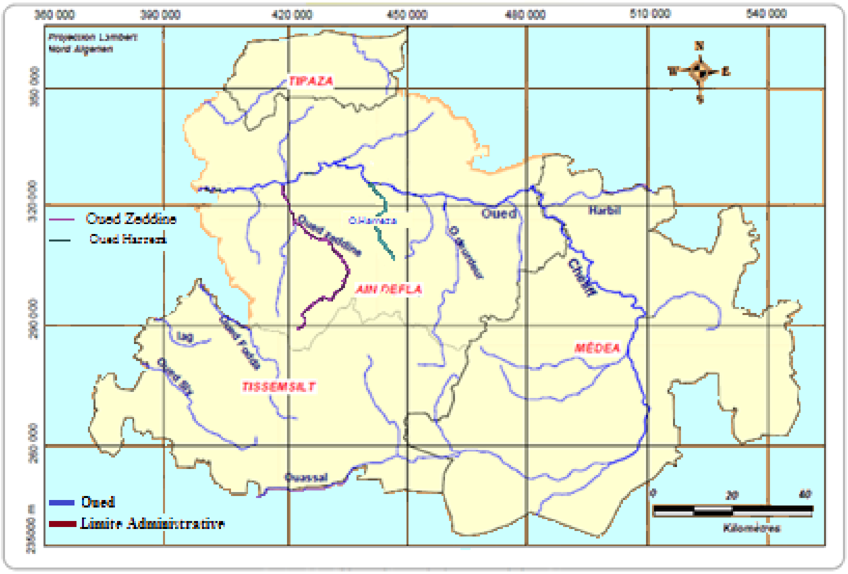


Figure 1: Wadis situation in the study area

The Zeddine watershed is subjected to tectonic ply of the massive Tellien dominated by Jebel Ouarsenis, a limestone peak of 1983 meters but little extended, belted with thermal sources and come. Other formations, all highly impermeable, include flysch of the Albo-Cenomanian, which cover 68% of its surface [28]. It is mostly flysches, which outcrop the tectonized and steep basin. The rest of the pool is cut into the sandstone of Jebel Meddad, marl and marl limestones of the Cretaceous. The selected study sites are those equipped with gauging stations allowing to obtain the relatively long series of hourly flows.

2.1.2. Basin of Oued Harreza

The sub watershed of Oued Harreza is part of Wadi Cheliff Basin (Figs. 1 and 2). It covers 142 km^2 (Tab.1). It is located between 2 ° and 2 ° 40 of 'East longitude and between 36 ° and 36 ° 40' of North latitude. The Oued Harreza travels a distance of 40.5 km in a Northwest direction. South of the basin, the relief reaches an altitude of 765 meters, while the lowest point is at the outlet with an altitude of 313 meters. Watershed Harreza is located in the geological area between the slate mountains Boumaad and the first foothills of the Ouarsenis. It is one of the landforms, with altitudes greater than 1500 meters which are formed of limestone, metamorphic and igneous rocks shale deeply cut by steep ravines [23].

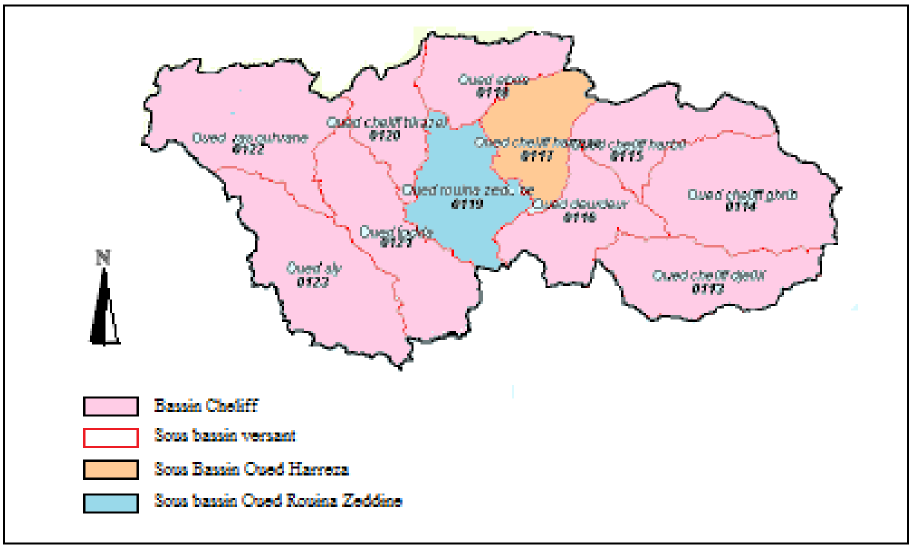


Figure 2: Sub-Basins situation in the studied area

2.2. Statistical modeling

The study focuses on the instantaneous values of water flow rates, given in m^3/s and concentrations of suspended sediment given in g/l over a period stretching from 1990 to 2013. The Bir Ouled Tahar station coordinates are as follow: X = 443.95 m; Y = 318.05 m and Z = 320 m; it covers an area of 421.5 km^2 of the zeddine basin. The El Ababsa station, with coordinates: X = 431.10 m; Y = 313.25 m and Z = 280 m, covers an area of 142 Km^2 of the Harreza basin. These measurements were performed by the services of the National Agency of Water Resources ANRH, during the period from September 1990 to February 2013. The rates are calculated in two ways; either from the water level read on a staff gauge or from the analysis of water level data recorded by a pneumatic gauging station [31].

- The sediment flow is calculated using the formula:

$$Qs = QC \qquad (1)$$

Where;

Qs: suspended sediment flow rate (kg/s), C: suspended sediment concentration (g/l) and Q: water flow rate (m^3/s).

- The flow of suspended solids As exported to the outlet is calculated using the formula :

$$As = \sum_{j=1}^{n} \frac{[(Q_{j+1}\, C_{j+1}) + (Q_j C_j)]}{2} (t_{j+1} - t_j) \qquad (2)$$

Where

Cj and Cj +1 are the concentrations corresponding to the liquid flow Q j and Q j + 1 took in the moments tj and tj + 1 between two samples.

- Water erosion (Es) expressed in tons / km2 / year is calculated by dividing the annual solid contribution As [t / year] by the basin surface A [km²] using the following formula:

$$Es = \frac{As}{A} \qquad (3)$$

2.3. Cartographic modeling

The Universal Soil Loss Equation (USLE) (Wischmeier and Smith, 1978) has been the most widely used model in predicting soil erosion loss [32]. USLE is an empirical equation that estimates the average annual soil loss caused by sheet and rill erosion. The USLE uses the simple equation:

$$A = R \ x \ K \ x \ LS \ x \ C \ x \ P \qquad (4)$$

Where *A* is the mean annual soil erosion rate (t /ha/ year), *R* is the rainfall erosivity factor (MJ mm ha^{-1} h^{-1} y^{-1}), K is the soil erodibility factor (t h MJ-1 mm-1), *LS* is the topographic factor, *C* is the crop management factor and *P* is the erosion control practice factor.

2.3.1. Rainfall erosivity Factor (R)

The rainfall erosivity factor (R) was calculated using the Modified Fournier Index [33].

$$R = \sum_{i=1}^{12} \frac{Pi^2}{P} \qquad (5)$$

Where R is the rainfall erosivity factor, Pi is the total amount of precipitation in ith month of the year and P is the total amount of precipitation during the year.

The spatial distribution and temporal variations of the R-factor are very important for quantifying soil erosion [34].

2.3.2. Soil erosivity Factor (K)

The K factor was calculated from the textural class of the soil. It depends on the physical and chemical properties of the soil (granulometry, aggregation, structural stability, porosity, organic matter content, etc.). The erodibility map was created from the pedology data of the Harmonized World Soil Database organization. The estimating equation for K_{USLE} values given by William's is [35, 36]:

$$K_{USLE} = f_{csand} \cdot f_{cl-si} \cdot f_{orgc} \cdot f_{hisand} \quad (6)$$

Where:

f_{csand} is a factor, that lowers the K indicator in soils with high coarse-sand content and higher for soils with little sand; f_{cl-si} gives low soil erodibility factors for soils with high clay-to-silt ratios; f_{orgc} reduces K values in soils with high organic carbon content, while f_{hisand} lowers K values for soils with extremely high sand content:

$$f_{csand} = \left(0.2 + 0.3.exp\left[-0.256.m_s.\left(1 - \frac{m_{silt}}{100}\right)\right]\right)$$

$$f_{cl-si} = \left(\frac{m_{silt}}{m_c + m_{silt}}\right)^{0.3}$$

$$f_{orgc} = \left(1 - \frac{0.25.orgC}{orgC + exp[3.72 - 2.95.orgC]}\right)$$

$$f_{hisand} = \left(1 - \frac{0.7.\left(1 - \frac{m_s}{100}\right)}{\left(1 - \frac{m_s}{100}\right) + exp\left[-5.51 + 22.9.\left(1 - \frac{m_s}{100}\right)\right]}\right)$$

Where:
ms: the sand fraction content (0.05-2.00 mm diameter) [%];
msilt: the silt fraction content (0.002-0.05 mm diameter) [%];
mc: the clay fraction content (<0.002 mm diameter) [%];
orgC : the organic carbon (SOC) content [%].

2.3.3. Topographic factor (LS)

This factor characterizes the effect of slope topography on soil erosion as a function of length (L) and inclination of slopes (S). The values of this factor were obtained from GIS treatments of digital terrain model (MNT) by applying a formula [37]:

$$LS = Power([Flow\ accumulation] * resolution / 22.1, 0.4) * Power(sin([slope] * 0.01745)/0.09, 1.4) * 1.4 \quad (7)$$

2.3.4. Crop management factor (C)

In the universal soil loss equation, the vegetation action translated by the factor C is the most determining parameter [38]. The different classes of vegetation and / or soil occupation were mapped from the supervised classification of a Landsat satellite images. The C factor ranges from 0 (full cover) to 1 (bare land).

2.3.5. Support practice factor (P)

The P factor describes the conservative human actions of soils that are practiced to counter water erosion. It generally varies from 0 to 1 [39], depending on the practice and the slope. In the absence of any support intervention the factor P takes the value 1.

2.3.6.Spatial distribution of erosion risk

The multiplicative superposition of the five thematic layers representing the factors of erosion in Raster format made it possible to develop, at the basin scale, the map of potential erosion. The average value of erosion is expressed in ton / ha / year.

3. RESULTS AND DISCUSSION

3.1. Hydrological results

3.1.1. Analysis of sediment discharge

For a long time, sediment discharge Qs has been related to water flow rate Q to determine a relationship that allowed the estimation of the former from the latter. Water and sediment flow rates are generally related by a power model [28,40]:

$$Q_s = a\, Q^b \quad (8)$$

For the estimation of solid transport by carriage, we only have data on the concentration of suspended sediments, so the assessment of total solid flows can only be approximate, given the absence of data on carriage, which is generally estimated between 20 and 30% of suspended transport [23, 41].

If we compare the equation (8) to the equation (1), using the coefficient b = 1, we will have:

$Q_s = a\,Q$ (9)

The solid flow bed load is calculated with this formula [23, 41], with:

$a = (20 \text{ à } 30)\ \%.C$

So: $Q_{sch} = (20 \text{ à } 30)\%.CQ$ (10)

Where:

Qsch: solid rate by bed load (kg /s)

C: concentration (g /l)

Q: liquid flow rate (m^3 /s).

In order to provide a current average estimate of the solid flow, we analyzed the relationships between solid and liquid flow rates for all measurements (N) from 1990 to 2013 (3083 pairs of values for the Zeddine and 1957 for Harreza) (Tab.2).

Table 2: Coefficients of the regression Qs-Q for the interannual scale

	Zeddine				Harreza			
	N	R²	a	b	N	R²	a	b
All data	3083	0,8173	15.878	1.3991	1957	0,8094	15.645	1.2493

The variation coefficient of determination R² shows the degree of correlation of the solid discharge to liquid flow rates through the power model (Fig. 3). The magnitude of the variation of the parameter '*a*' is greater than that of the parameter '*b*'. It is noted that the *a* coefficients are almost of the same magnitude, indicating that the two basins belong to the same hydrogeological Class (Unconfined aquifer receiving no significant alimentation by infiltration by series of conditions of unfavorable surfaces) [42], while the different exponents *b* indicate that they belong to a different percentage of the vegetation cover [2].

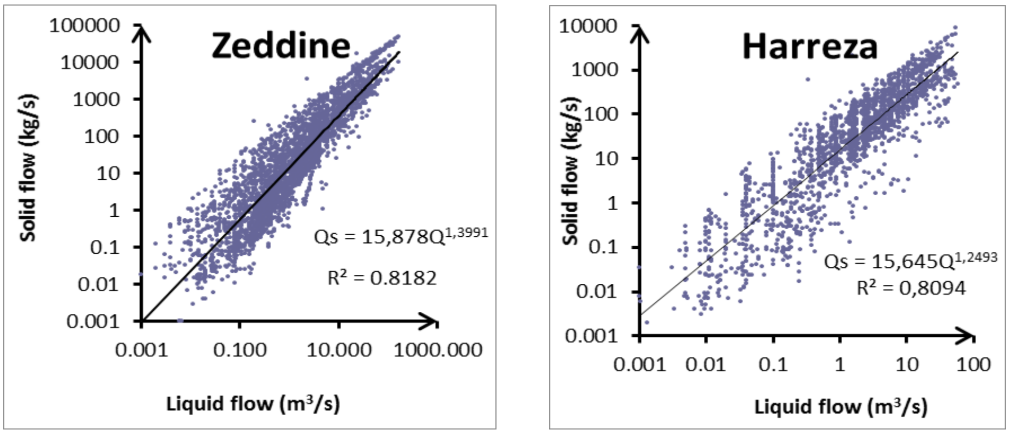


Figure 3: Relation between liquid and solid instantaneous rates

The variation of parameters *a* and *b* established for each year is given in Table 3. The parameter value differed from one year to another, but follows the same direction of variation for both basins. This may be due to the same direction of rainfall variability each year (Fig. 4). Strong values of the coefficient *a,* correspond to easily mobilized sediments during rain events. The parameter *b* can be interpreted as the erosive power of the river [8].

Table 3 : Coefficients of the regression Qs-Q for the annual scale

	Zeddine			Harreza		
	N	R²	Modèle	N	R²	Modèle
1990/1991	840	0.821	$Q_s = 16.328\ Q^{1.382}$	196	0,858	$Q_s = 16.545\ Q^{1.449}$
1991/1992	177	0.743	$Q_s = 9.874\ Q^{1.407}$	151	0,823	$Q_s = 13.883\ Q^{1.186}$
1992/1993	109	0.764	$Q_s = 40.339\ Q^{1.312}$	58	0,950	$Q_s = 31.958\ Q^{1.194}$

1993/1994	112	0.811	$Q_s = 21.575\ Q^{1.696}$	62	0,825	$Q_s = 21.370\ Q^{1.078}$
1994/1995	238	0.701	$Q_s = 18.121\ Q^{1.277}$	180	0,848	$Q_s = 19.499\ Q^{1.126}$
1995/1996	257	0,815	$Q_s = 11.063\ Q^{1.320}$	245	0,810	$Q_s = 8.575\ Q^{1.306}$
1996/1997	104	0,912	$Q_s = 18.299\ Q^{1.488}$	99	0,846	$Q_s = 24.235\ Q^{1.293}$
1997/1998	227	0,807	$Q_s = 10.939\ Q^{1.519}$	95	0,770	$Q_s = 16.747\ Q^{1.199}$
1998/1999	197	0,791	$Q_s = 8.680\ Q^{1.449}$	55	0,881	$Q_s = 11.145\ Q^{1.460}$
1999/2000	70	0,87	$Q_s = 14.993\ Q^{1.603}$	34	0,758	$Q_s = 2.817\ Q^{1.350}$
2000/2001	251	0,828	$Q_s = 20.439\ Q^{1.421}$	162	0,784	$Q_s = 15.092\ Q^{1.361}$
2001/2002	45	0,846	$Q_s = 28.591\ Q^{1.403}$	42	0,844	$Q_s = 24.612\ Q^{1.179}$
2002/2003	248	0,872	$Q_s = 11.230\ Q^{1.452}$	180	0,788	$Q_s = 10.611\ Q^{1.326}$
2003/2004	186	0,819	$Q_s = 11.590\ Q^{1.375}$	58	0,819	$Q_s = 9.758\ Q^{1.512}$
2004/2005	79	0,616	$Q_s = 10.092\ Q^{1.150}$	99	0,818	$Q_s = 22.008\ Q^{1.267}$
2005/2006				27	0.789	$Q_s = 15.624\ Q^{0.962}$
2006/2007	109	0,848	$Q_s = 11.843\ Q^{1.688}$	59	0,901	$Q_s = 22.577\ Q^{1.233}$
2007/2008	91	0,857	$Q_s = 27.085\ Q^{1.295}$			
2008/2009	129	0,655	$Q_s = 18.768\ Q^{0.971}$	88	0,708	$Q_s = 25.467\ Q^{0.871}$
2009/2010	82	0,865	$Q_s = 31.387\ Q^{1.138}$	39	0,837	$Q_s = 52.672\ Q^{0.819}$
2010/2011	64	0,779	$Q_s = 25.311\ Q^{1.234}$	15	0,705	$Q_s = 57.743\ Q^{0.859}$
2011/2012	48	0,801	$Q_s = 21.060\ Q^{0.976}$	20	0,967	$Q_s = 17.545\ Q^{0.937}$
2012/2013	12	0,915	$Q_s = 33.040\ Q^{1.147}$	11	0,9□8	$Q_s = 25.731\ Q^{1.118}$

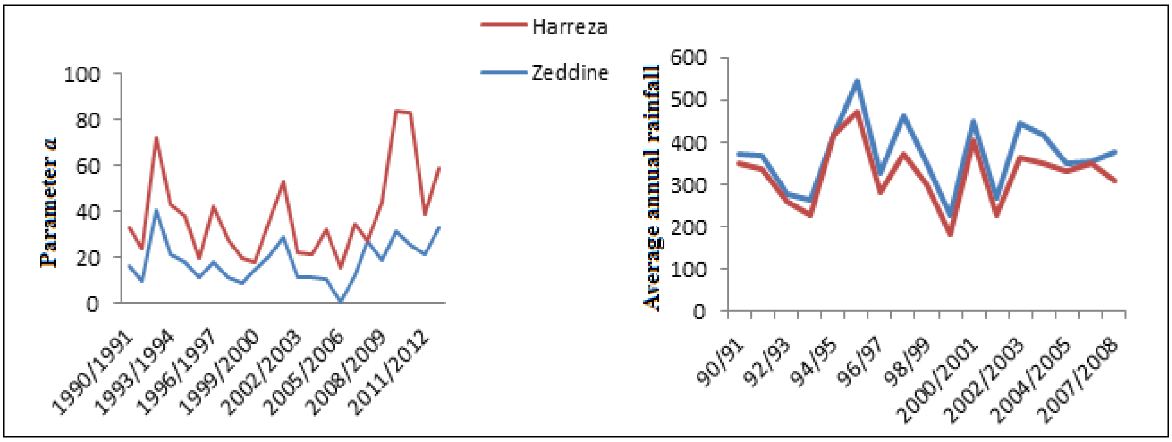


Figure 4: Parameter *a* and average annual rainfall in the two basins

3.1.2. Flow of suspended solids

The Zeddine basin has no flood plain. This is essential in the flow velocity and the origin of floods. It can be considered capable of an extremely short concentration time and of a fast propagation speed of floods, which encourages runoff and violent erosion [43]. The Zeddine basin covers a surface which is three times greater than that of Harreza. These points show that the sediment transport is more important in the basin Zeddine than Harreza confirming that these factors are among the most explaining parameters of the sediment transport phenomenon [44].

Most of the sediment transport occurs fairly regularly in the fall (Fig.5) it alone covers 46% of solid contribution to Zeddine and 43% for Harreza. Seasons contributing to the rest of the transportation are spring, winter and more randomly summer (August storm). At the monthly level, an important part of the solid contribution is observed during the months of early autumn and late spring. The solid contribution of the four months of September, October, April and May, represent about 52% of the annual solid contribution to the Zeddine basin and 51% for the Harreza basin (Fig.6).

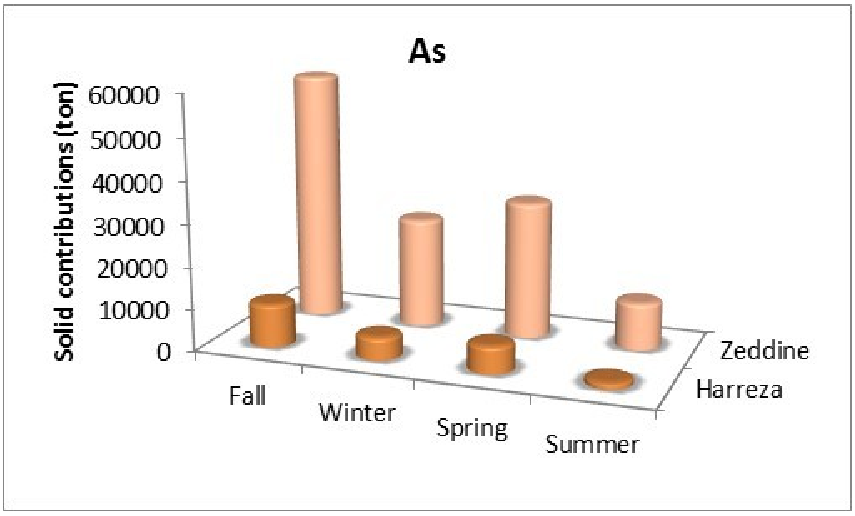


Figure 5: Change in seasonal solid contribution

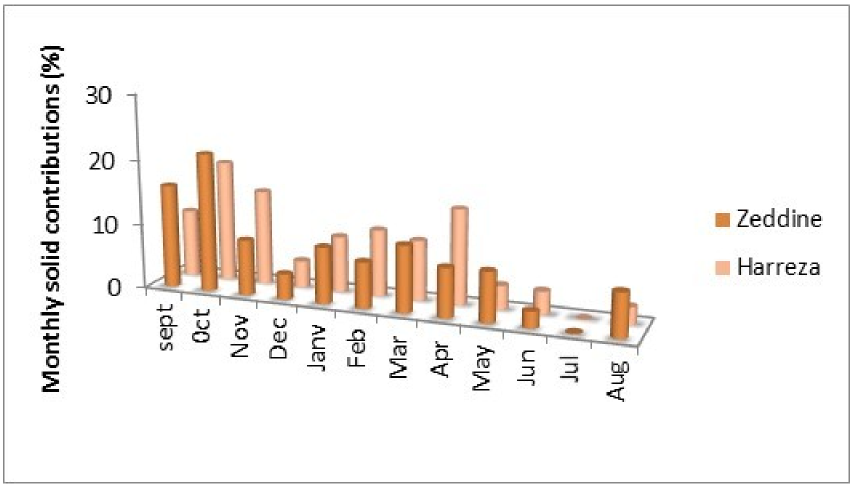


Figure 6: Monthly Distribution solid contribution

3.1.3. Specific water erosion

The Zeddine basin carries an annual average of 0.131 million tons of sediment, a water erosion on the order of 3.12 ton / ha / year, while the Harreza basin carries an annual average of 0.023 million tons of sediment, or a water erosion of about 1.64 ton / ha / year. The lithological, topographic characteristics and the structure of both basins are very close. This solid intake difference is due to the fact that the surface of Zeddine basin is greater than that of Harreza which confirms what was found previously by the authors themselves [44].

During the study period, there was a decrease of erosion rates for the two basins since the year 2000-2001 during which, a significant specific degradation was engendered: more than 15.30 ton / ha / year for the Zeddine and 6.82 ton / ha / year for the Harreza. Before this year; from 1990 to 1999 an average of respectively 3.37 and 1.83 ton / ha / year was engendered and which is lower than that from 2001 until 2013 and is worth 1.76 and 1.01 ton / ha / year (Fig.7).

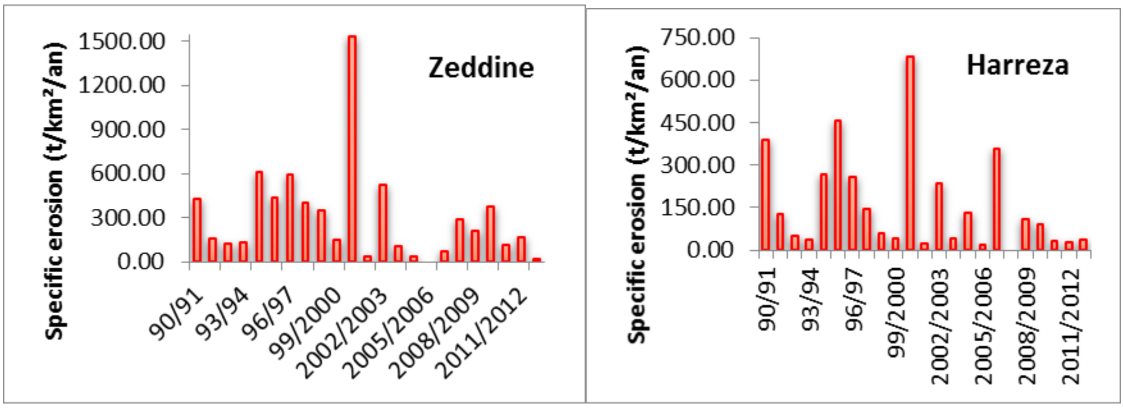


Figure 7: Annual change in specific erosion

Annually, the morphological behavior of Algerian catchments is irregular; there is no proportionality between rain and specific erosion [6, 24]. This has been confirmed by an analysis for the year 2000/2001.

Before and after the year 2000-2001, there is a sudden change of specific erosion passing from 1.48 to 15.29 then to 0.35 ton / ha / year for Zeddine and from 0.42 to 6.82 and then to 0.25 ton / ha / year for Harreza. This change almost coincided with that of the rainfall, which varies from 229.15 to 448.37 and then to 269.01mm for Zeddine and from 182.52 to 403.25 then to 226.31 mm for Harreza (Fig.8). In general, there is a balance between formation and soil erosion, rain promotes vegetation creating a protective layer that reduces the impact of raindrops on the soil and runoff effects [17]. But once this balance is broken, erosions are accentuated, water from the rain, which was largely absorbed by vegetation, flows to the lower coasts, carrying and breaking up the soil. So once the layer of loose material washed away by runoff water, the ground remains clean and protected against subsequent action of water.

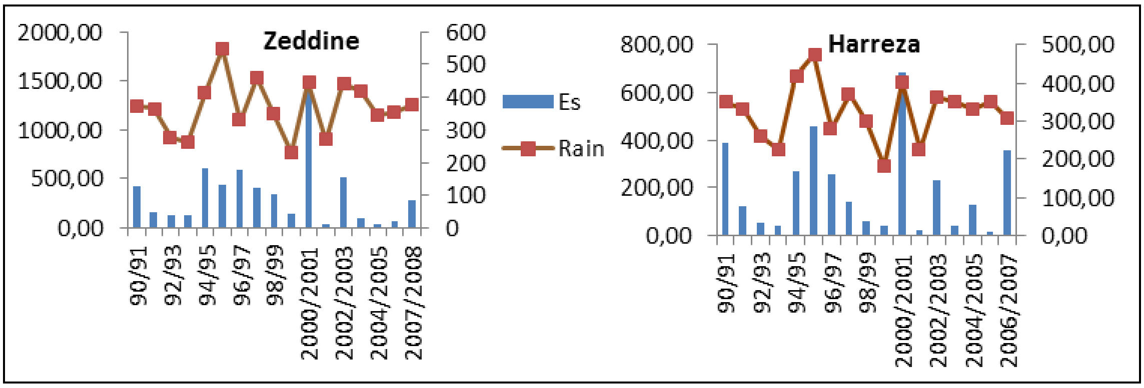
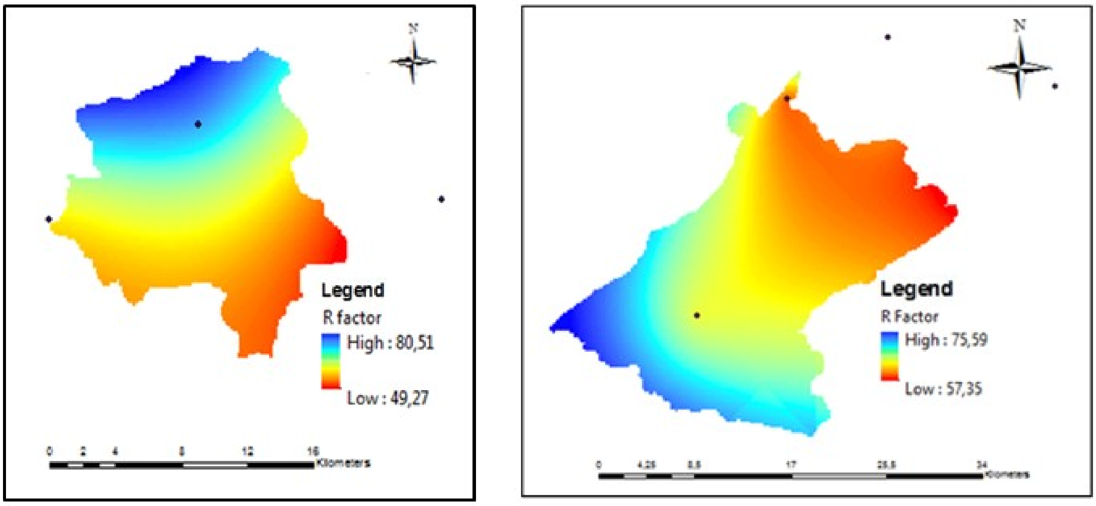


Figure 8: Annual change in specific erosion and rain

3.2. Cartographic result

3.2.1. Rainfall erosivity Factor (R)

In the Zeddine Basin, the R-factor values range from 57 to 76 MJ mm / ha / h (Fig.9.a). For the Harreza basin, the R-factor varies from 49 to 81 MJ mm / ha / h (Fig.9.b).

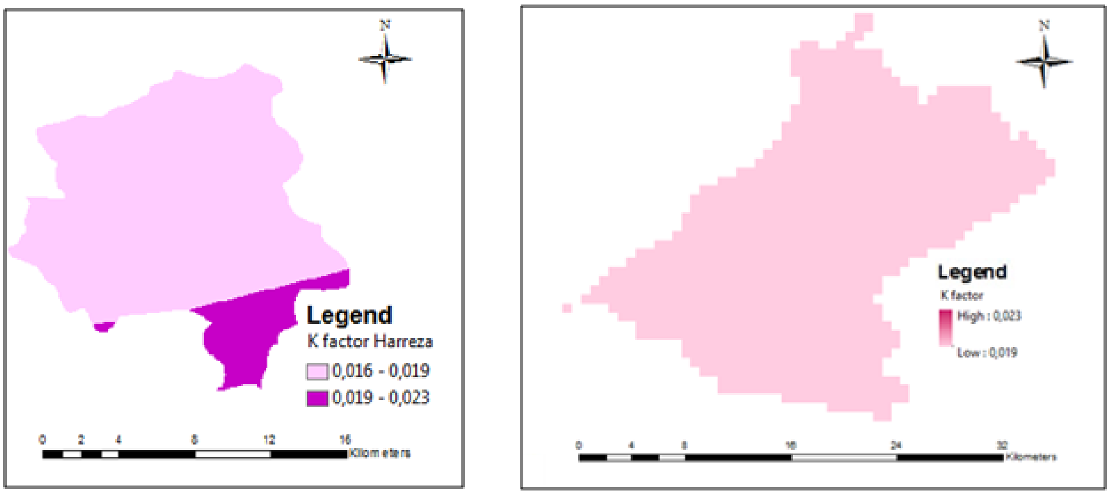


a: Harreza basin b: Zeddine basin

Figure 9: Rainfall erosivity factor map of study area

3.2.2. Soil erosivity Factor (K)

Most of the Harreza Basin is characterized by a K factor ranging from 0.016 to 0.019 th MJ-1 mm-1 (Fig.10.a) except for the southern part of the basin with a higher K factor of 0.023 which confirms the presence of a calcareous substratum. The Zeddine basin has K values that range from 0.019 to 0.023 th MJ-1 mm-1 (Fig.10.b), due to the presence of flysch in the Eastern part, marls and marly limestones of the Cretaceous in The Central part of the basin.

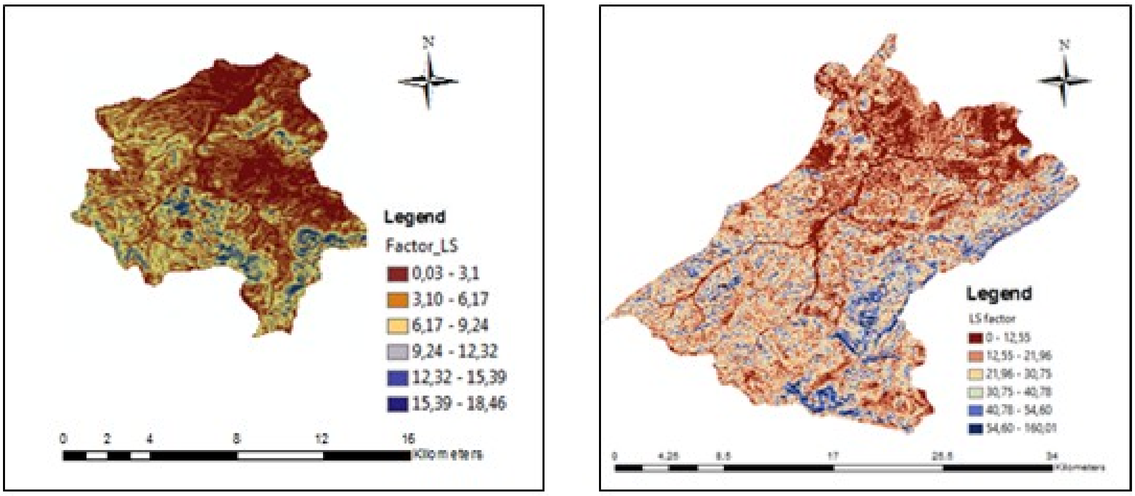


a: Harreza basin b: Zeddine basin

Figure 10: Soil erosivity factor map of the study area

3.2.3. Topographic factor (LS)

In general, the LS factor is low to moderate in the Harreza Basin (Fig.11.a). Many sectors have values of less than 6, including the North-Eastern region of the basin. The areas with the highest LS factor are in the South-East and South-West of the basin. Most of the Zeddine basin is characterized by an LS factor of less than 30 (Fig.11.b). Almost all of the land in the North and Center of the basin belongs to this class. Higher values ranging from 30 to 160 are located in the Eastern and South-Western branch of the basin, which generally coincide with areas of high altitudes and high slopes.

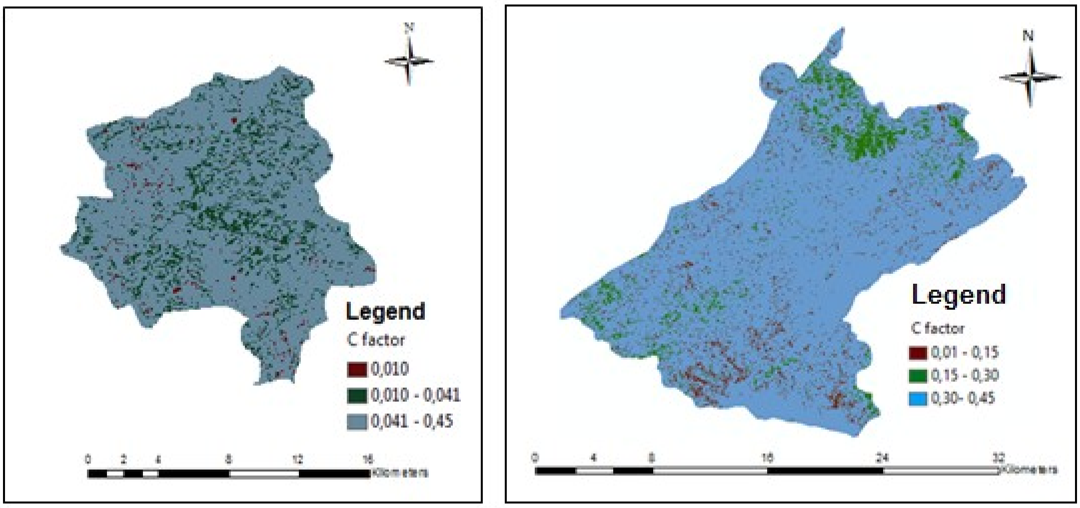


a: Harreza basin b: Zeddine basin

Figure 11: Topographic factor map of study area

3.2.4. Crop management factor (C)

A strong dominance of values ranging from 0.30 to 0.45 is observed for the two Harreza and Zeddine basins for the factor C (Fig.12), these zones are generally associated with the maquis / garrigue and matorral formations. However, a concentration of values ranging from 0.01 to 0.04 is observed in the center of the Harreza basin, following forest formations. Another class consists of a factor C between 0.15 and 0.30, which lies in the North and South-West of the Zeddine basin, which is manifested by the practice of agricultural activity.

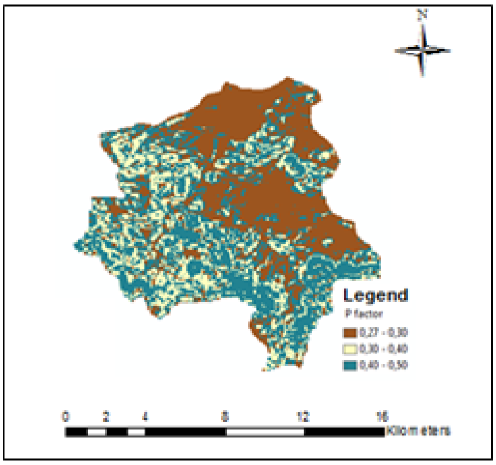


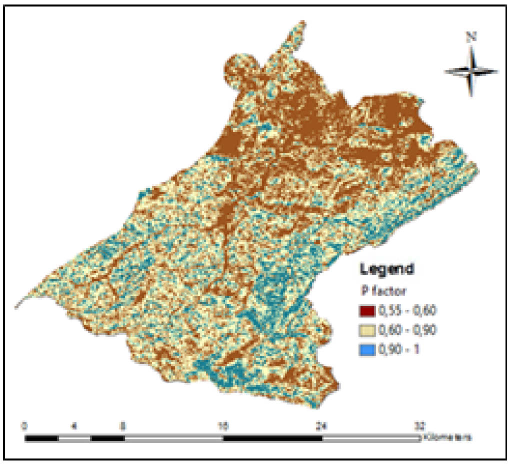
a: Harreza basin b: Zeddine basin

Figure 12: Crop management factor map of study area

3.2.5. Support practice factor (P)

The P factor generally varies in the Harreza basin between 0.27 and 0.3 for the low slope zones and between 0.3 and 0.5 for the steep slopes (Fig.13.a). The cultural techniques practiced are crops in contour, or in alternate bands. In the Zeddine basin, the values of the factor P are high, ranging from 0.55 to 0.6, the support practices used are crops that are following contour lines. Higher values between 0.8 and 1 are located in the Eastern basin where conservation practices are modest because of the presence of acute slopes(Fig.13.b).



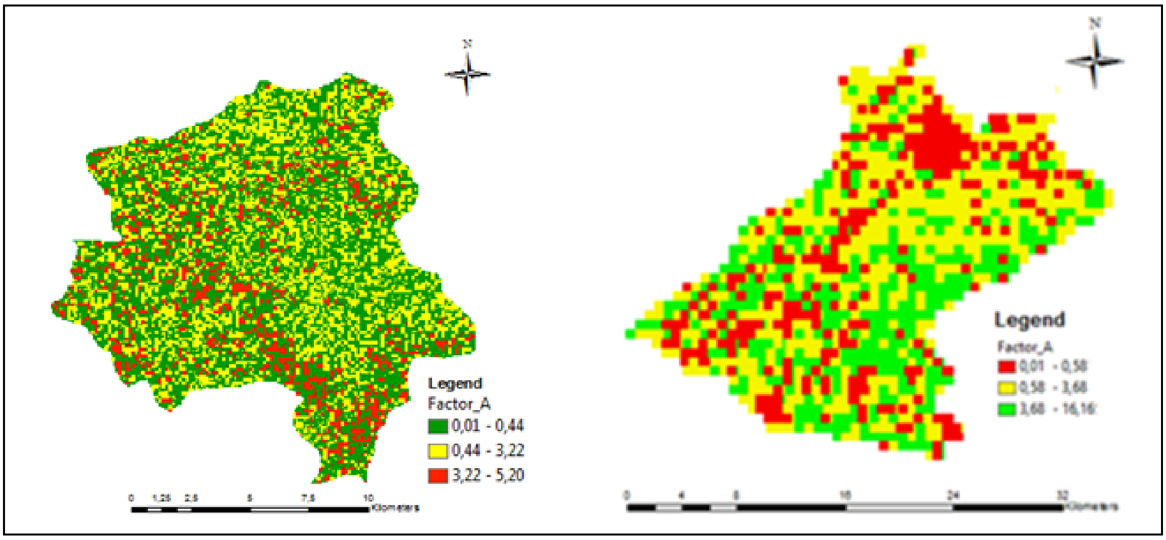


a: Harreza basin b: Zeddine basin

Figure 13: Support practice factor map of study area

3.2.6. Erosion risk map

According to the USLE model, more than 78% of the surface of the Harreza basin is affected by low and average erosion rates generally lower than 3.2 tons / ha / year which are dispersed throughout the basin (Fig. 14.a). A higher erosion approximately 5.2 tons / ha / year represents almost 22% of the basin area and is concentrated in the North-West and South-East basin. This peculiarity is explained by the formation of maquis / garrigue and the forest-massifs. on the other hand, more than 92% of the area in the Zeddine basin has low and medium erosion zones of less than 3.6 tons / ha / year according to USLE (Fig.14.b). On the Eastern part of the basin (Tiberkoukine) and on the South-Western bordure, we identify areas that are very sensitive to erosions in the order of 16 tons / ha / year, which are generally characterized by agricultural crops on steep slopes.



a: Harreza basin b: Zeddine basin

Figure 14: Erosion risk map of study area

4. CONCLUSION

The analysis of liquid and solid flows for all the measurements carried out from 1990 to 2013 for the two Harreza and Zeddine watersheds shows that they are generally related by a power model [20], with a coefficient of determination exceeding 80%. High values of the coefficient *a*, correspond to sediments easily mobilizable during rainy events. The parameter *b* can be interpreted as the erosive power of the basin.

Graphical analysis reveals that the autumn is distinguished by strong river discharges leading to important transport of solids; it alone covers 46% of total solid contribution for the Zeddine basin and 43% for the Harreza basin. On a monthly basis, a significant portion of the solid intake is observed during the early fall and late spring months. These results corroborate with those of the study of Terfous et al [24] which states that the torrential rains occurring in October and November degenerate a large amount of solids. The average annual soil loss estimated for the entire watershed is 3.12 ton / ha /year for Zeddine and 1.64 ton / ha / year for Harreza.

The annual morphological behavior of the two watersheds is irregular; the results obtained during the year 2000/2001 show a sudden variation of the specific erosion coinciding with that of the rain. The latter favors vegetation which reduces the effects of runoff, once this equilibrium is broken erosions are accentuated, the layer of loose materials is washed away by the runoff and the land remains cleaned and protected against the subsequent action of the water [13, 15].

For erosion risk map, the study revealed that low and medium soil loss, cover 92% and 78% of Zeddine and Harreza basins respectively. A high erosion is more important in Zeddine basin (16 t / ha / year) than in Harreza basin (5.2 t / ha / year). The Zeddine basin is considered to be capable of extremely short concentration time, a very rapid rate of flood propagation, the differences in altitude are very large in a very small basin, the main wadi passes indeed from 1786m to 328 m [28]. The lithological, topographical and structural characteristics complement each other to promote violent erosion. On the other hand, the Harreza basin has alluvial plains and terraces that will laminate and brake the flow.

The average annual soil loss map will definitely be helpful in identification of priority areas for implementation of soil conservation measures and effective checking of soil loss.

ACKNOWLEDGEMENT

Thanks to the ANRH, the ANBT for providing data. Thanks to the USGS, the USDA for making data accessible to the public. Thanks to Pr.Abida Habib for the passionate lecture. Thanks to Dr. Chiraz Laifa for the help to translate this paper.

REFERENCES

[1]. B. Barthès et E. Roose, 2001. "La stabilité de l'agrégation, un indicateur de la sensibilité des sols au ruissellement et à l'érosion: validation à plusieurs échelles. Cahiers Agricultures, Vol. (10), p. 93-185.

[2]. A. Gartet, 2005. Dégradation spécifique et transports solides dans le bassin de l'Oued Lebène (Prérif central, Maroc septentrional). Papeles de Geografía, Vol. 41–42, p. 85–100.

[3]. G.H. Old et al., 2005. Discharge and suspended sediment dynamics during two jökulhlaups in the Skaftá river, Iceland. Earth Surface Processes and Landforms, 30(11), 1441-1460.

[4]. J. Boardman and J. Poesen, 2006. Soil erosion in Europe. John Wiley & Sons, Ltd., 878 p.

[5]. J. Xu and Y. Yan, 2010. Effect of reservoir construction on suspended sediment load in a large river system: thresholds and complex response. Earth Surface Processes and Landforms, 35(14), 1666-1673.

[6]. E. Hallot et al., 2012. L'envasement du lac de Butgenbach (Ardenne, Belgique). Bulletin de la Société géographique de Liège, 59, 39-57.

[7]. H.M. Sichingabula, 1998. Factors controlling variations in suspended sediment concentration for single-valued sediment rating curves, Fraser River, British Columbia, Canada. Hydrological Processes, 12(12), 1869-1894.

[8]. N.E.M. Asselman, 2000. Fitting and interpretation of sediment rating curves. Journal of Hydrology, Vol.234 (3-4), p.228-248.

[9]. A.J. Horowitz, 2002. The use of rating (transport) curves to predict suspended sediment. In Turbidity and Other Sediment Surrogates Workshop, 30 April- 2 May, Reno, Nevada.

[10]. A.J. Horowitz, 2003. An evaluation of sediment rating curves for estimating suspended sediment concentrations for subsequent flux calculations. Hydrological Processes, 17, 3387-3409.

[11]. P. Gao and M. Josefson, 2012. Temporal variations of suspended sediment transport in Oneida Creek watershed, central New York. Journal of Hydrology, Vol.426-427, p.17-27.

[12]. A. Gericke and M. Venohr, 2012. Improving the estimation of erosion-related suspended solid yields in mountainous, non-alpine river catchments. Environmental Modelling & Software archive, Vol 37, p. 30-40.

[13]. A. Benkhaled et B. Remini, 2003. Analyse de la relation de puissance: débit solide -débit liquide à l'échelle du bassin .versant de l'Oued Wahrane (Algérie). Revue des sciences de l'eau, Vol.16 (3) p.333-356.

[14]. A. Bouanani, 2004. Hydrologie, transport solide et modelisation, etude de quelques sous bassins de la Tafna (NW – Algérie). Thèse de doctorat. Universite Abou Bekr Belkaid. Tlemcen. 250 p.

[15]. H. Bouchelkia et B. Remini, 2003. Quantification du transport solide dans le bassin versant algérien du Chellif. Ingénieries - E A T, IRSTEA, p. 45 - 56.

[16]. A. Demmak, 1982. Contribution à l'étude de l'érosion et des transports solides en Algérie septentrionale. Thèse de docteur-ingénieur, Paris. 323 p.

[17]. A. Nekkache Ghenim et A. Megnounif, 2013. Estimation de la précision de la relation en puissance reliant la concentration au débit liquide. Revue « Nature & Technologie ». C- Sciences de l'Environnement, n° 09, p. 54-60.

[18]. J.L. Probst et A. Bazerabachi, 1986. Transport solide en solution et en suspension par la Garonne supérieure. Sciences Géologiques. Bulletin, Strasbourg, 39(1), p.79-98.

[19]. A. Saidi, 1991. Érosion spécifique et prévision de l'envasement. Colloque sur l'érosion des sols et l'envasement des barrages. Alger, 1–3 décembre1991. Alger: Agence nationale des ressources hydrauliques, 26-204.

[20]. B. Touaibia, 2000. Erosion-Transport solide-Envasement des barrages: Cas du bassin versant de l'oued Mina. Thèse de doctorat. INA. Algérie.

[21]. D.E. Walling and H. Webb, 1981. The reliability of suspended sediment load data: Erosion and sediment transport measurement. Proceedings of the Florence Symposium, Florence: IAHS publ. 133, p. 177-194.

[22]. M. Achite and S. Ouillon, 2007. Suspended sediment transport in semi-arid wtareshed :WadiAbd, Algeria (1973-1995). Journal of Hydrology, Vol. 343 (3-4), p. 187-202.

[23]. K. Meguenni et B. Remini, 2008. Evaluation du débit solide dans le bassin versant de Harreza. Larhyss Journal, Vol.7, p.7-19.

[24]. A. Terfous et al., 2001. Etude du transport solide en suspension dans l'Oued Mouilah (Nord-Ouest Algérien). Revue des Sciences de l'eau, Vol. 14 (2), p.173 – 185.

[25]. J. Tixeront, 1960. Débit solide des cours d'eau en Algérie et enTunisie. Assemblée générale de Helsinki. Wallingford, UK: IAHS Press, IAHS Publ. 53, 26–42.
http://iahs.info/redbooks/a053/053004.pdf.

[26]. M. Meddi, 1999. Etude du transport solide dans le bassin versant de l'oued Ebda (Algérie). Zeitschrift für Géomorphologie, Vol.43, p.167–183.

[27]. A. El Mahi et al., 2012. Analyse du transport solide en suspension dans le bassin versant de l'Oued El Hammam (Algérie du Nord), Hydrological Sciences Journal, Vol. 57(8), p. 1642-1661.

[28]. J. Capolini et al., 1969. Etude des Caractères physiographiques et prévision des apports annuels, des crues et des transports solides dans les bassins du Riou - Sly - Fodda -Deurdeur - Zeddine - Ebda. Etude SES, n° 13-12/DH2, S.E.G.G.T.

[29]. Archive El Mouradia, partie Principaux lacs et cours d'eau.
http://www.elmouradia.dz/francais/algerie/geographie/geographie.htm

[30]. S. Berbache et B. Remini, 2013. Phénomènes exceptionnels d'érosion et de transport solide, cas des bassins versants de Zeddine et Tikazale. Proceedings, 5ème colloque international sur les Ressources en eau et le Développement Durable, Alger, 647-652.

[31]. M. Mehaiguene et al.., 2015. Hydrologic balance and surface water resources of the Cheliff-Zahres basin, International Journal of Environmental, Chemical, Ecological, Geological and Geophysical Engineering, Vol 9(12), p. 1435-1438.

[32]. K.G. Renard et al., 1997. Predicting Soil Erosion by Water: A Guide to Conservation Planning with the Revised

Universal Soil Loss Equation (RUSLE), Agricultural Handbook No. 703, US Department of Agriculture, Washington DC.

[33]. J.M.J. Arnoldus, 1977. Methodology used to determine the maximum potential average annual soil loss due to sheet and rill erosion in Morocco Food. Agric. Org., FAO Soils Bulletins, Vol.34, p. 39-51.

[34]. L. Hamlaoui-Moulai et al., 2013. Detecting hydro-climatic change using spatiotemporal analysis of rainfall time series in Western Algeria. Natural. Hazards, Vol. 65 (3), p.1293–1311.

[35]. S.L. Neitsch et al., 2000. Erosion Soil and Water Assessment Tool Theoretical. Documentation Texas Agricultural Eksperiment Station, p. 625.

[36]. J.R., Williams, 1995. The EPIC model in V.P. Singh (ed.) Computer models of watershed hydrology. Water Resources Publications, Chapter 25, p. 909-1000.

[37]. W.H. Wischmeier and D.D. Smith, 1978. Predicting rainfall erosion losses. A guide to conservation planning, USDA. Agriculture Handbook No. 537, Washington, DC.

[38]. K.G. Renard et al., 1991. RUSLE: revised universal soil loss equation. Journal of Soil and Water Conservation, Vol .46 (1), p. 30-33.

[39]. D.D. Smith and D.M. Whitt, 1948. Estimating soil losses from field areas. Agriculture Engineering Soil, Vol.29, p. 394-398.

[40]. J. Corbonnois, 1998. Les facteurs de la variation spatiotemporelle des transports solides et dissous. Géomorphologie, Vol. 4, p. 313-329.

[41]. B. Larfi et B. Remini, 2006. Le transport solide dans le basin versant de l'Oued Isser. Larhyss Journal, Vol.5, p. 63-73.

[42]. J. Margat, 1975. Projet de nouvelle légende de carte hydrogélogique, 75 SGN 259 AME.

[43]. J.P. Bravard et F. Petit, 1997. Les cours d'eau. Dynamique du système fluvial, A. Colin, 222 p.

[44]. F. Bouras et al., 2010. Estimation de l'envasement des barrages, une approche non paramétrique ; Network Environmental Management Conflicts, Santa Catarina – Brazil, Vol.1(1), p. 113-119.