ISSN 2229-5518

Contribution to the solid transport study of the lower Guir watershed , South-West of Algeria

Abdeldjalil Belkendil[1], Samir Haddad[2], Abdelmajid Hamouine[3], Mohamed Habi[3]

Abstract— Water is the only wealth which cannot be dispensed through the ages, because it is the source of creatures life, each state seeks to find different ways to best use this resource, dams are among the most important ways to achieve this goal. But the danger which threatens the dam is the risk of siltation by the phenomenon of erosion by rainwater and wind. The Igli dam will form a huge source for the region of Saoura in its implementation because it is located in the confluence point between Zousfana's river in the East and Guir's river in the West, but the feasibility study which was established for this dam in 2009, warned of the risk of siltation in the dam's reservoir, our study is to estimate the amount of soil loss in the watershed of lower Guir to determine the degree of participation of this watershed in the siltation of eventual dam's reservoir.

Index Terms— Dam, Erosion, Guir, Igli, Saoura, Sedimentation, USLE, Water retention.

1 Introduction

Dams are important water infrastructures view their role in the socio-economic development. However, these works are amputated annually 45 million m3 of their overall capacity (Remini, 2004; Remini et al., 2009), where siltation is ranked among one of the most important factors in the loss of capacity. The reduction in the storage capacity of hydraulic structures is seen grow constantly over the past time and for the following two key reasons: first, natural is favored by climate aggressivity, the alternation of dry and wet periods, fragile geological formations and the absence of adequate plant cover; the second, due in part to the bad studies and assessments of the problem before the phenomenon is made effects, and also due to a bad exploitation of appurtenant structures such as drainage valves and racking structures.

Under this context, In our work we look for the feasibility study of a potential dam at the outlet of the river of Guir at Igli (state of Bechar South-West of Algeria).

The Universal Soil Loss Equation (USLE) was developed by Wischmeier and Smith based on data from more than 10,000 experimental plots across the United States in 20 years (Wischmeier and Smith, 1965). The USLE have six factors and it's applicable to calculate the sheet and rill erosion only but does not take into account sedimentation rate (SDR) arriving at the outlet. For this reason the sedimentation rate was calculated. The objective of this article is to proceed a solid transportation study and its probable impact on the siltation of dams based on the erosion rate estimation in the lower watershed of Guir using the USLE model to geo-localize the vulnerable zones by erosion and sedimentation rate (SDR) model to estimate the sedimentation quantity, using two relations (SDR - Surface drainage) and (SDR-slope / watershed reliefs).

2 Study Area Presentation

The watershed of Guir is is located in South-West of Algeria between the Algerian-Moroccan border with a total area A = 45057 km2 and a perimeter P = 1805.1 km, the watershed area is shared between two countries almost equally Morocco (23243 km2) and Algeria (21814 km2), the main river of this watershed is the river of Guir which originates in the Moroccan high atlas in Timjnatine mountain and flows at distance of 450 km to the outlet in the Algerian territory in the city of Igli where it receives the river of Zousfana to form the Saoura river. The watershed is characterized by a steep slope in the North (High Atlas) and low slope in the Algerian side. Altitude is varied between Hmax = 2703 m , Hmin = 497.6 m and the average altitude Hmoy = 1200 m. The slope varies from 0° to 61.45° and the average slope is 2.87°, the average temperature is 21.7 ° C and the average annual rainfall is 126 mm/y.

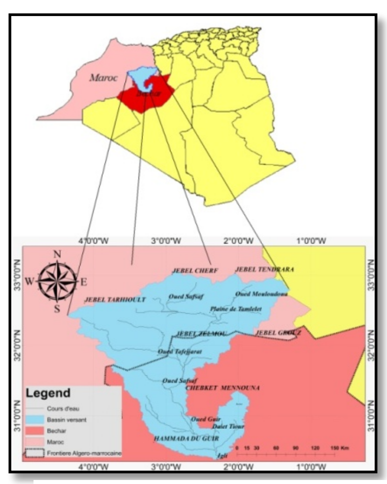


Fig. 1. Watershed delineation.

- *Abdeldjalil Belkendil is currently pursuing Phd degree program in hydraulic management engineering in TlemcenUniversity, algeria, PH-00213663982540. E-mail: authoralgeria7002@gmail.com*
- *Samir Haddad is phd in hydraulic engineering in University of bejaia, Algeria,. E-mail: haddad362002@gmail.com*
- *Mohamed Habi is professor in hydraulic engineering in University of Tlemcen, Algeria,. E-mail: moha.habi@gmx.de*
-

3 PROCESSING METHOD

Before beginning the necessary steps of treatment using the USLE model, we considered a number of difficulties that can face the development of this work, the first obstacle was that the studied watershed is shared between two countries (Algeria-Morocco) the thing which creates the problem of getting data especially in the Moroccan side, because our objective of this work is to calculate the sedimentation rate arriving at the outlet of the studied watershed (Igli). We have benefited from the existence of a dam in the Algerian territory called dam of Djorf -Torba which localizes in the main river of Guir watershed, due to the sediment transport effect, all the resulting solids yield of the Moroccan party will be accumulated in the reservoir of the dam Djorf–Torba. To verify this hypothesis, we used the decantation rate relationship (trap efficiency TE) where the settling rate (TE) is the percentage of incoming sediment which is deposited or trapped in a reservoir.

Heinemann has developed an equation which concern TE which is a ratio between the area and the watershed capacity (C / W) based on data from 15 reservoirs:

$$TE = 100\left(1 - \frac{1}{1 + 0.0021\, D\frac{C}{W}}\right) \quad (1)$$

Where C is the storage capacity of the reservoir expressed in m3 and W is the reservoir area expressed in km2. The values of D are between 0.046 and 1, with an average value of 0.1 and they are dependent on the characteristics of a reservoir.

The Djorf-Torba dam is Located on the river of Guir, about sixty kilometers West of Bechar. It controls a watershed of 22000 km^2. The reservoir capacity is 360Hm^3.

In order to know the impact of Djorf Torba dam, we use the Heineman equation (2) to quantify the sediment settling rate in the Djorf –Torba dam using the characteristics of the reservoir in the normal retention elevation which is 699 m, the characteristics are as follows:

Storage capacity C=360 000 000 m^3
Dam's reservoir area W=83.28 Km^2
Used value de D=0.1

Then TE=99.88 %

We can observe that almost the resulting sediment from the upper part of the watershed (Upper Guir) meet in the Djorf Torba dam and deposited in its reservoir, the thing that allow us to eliminate the upper watershed of Guir from our study especially that the accessibility to this part (Moroccan Party) remains an obstacle to study the entire watershed (Moroccan Party - Algerian party). The final delimitation of Guir's watershed which it will be used for the of sediment transport estimation is illustrated in the figure 2.

TABLE 1
WATERSHED CHARACTERISTICS

Characteristics	Value
Area	11524.04 Km^2
Perimeter	1114.32 Km

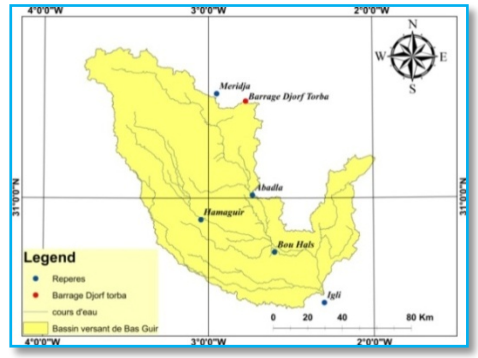


Fig. 2. The lower Guir.

4 MODEL APPLICATION

The Universal Soil Loss Equation (USLE) was developed to estimate the rate of long-term annual average erosion (A) using five factors as follows:

$$A=R.\ K.\ LS.\ C.\ P \quad (2)$$

Where (A) is the annual erosion rate (t/ha/y); R is the erosivity factor of rainfall (Mj.mm/ha/h) ,K is the soil erodibility factor; L is a factor of the slope length, S is the factor of slope stiffness; C is the vegetation cover factor and the P is support practices factor for soil conservation.

4.1 Erosivity Factor (R)

The rainfall erosivity factor (R), is calculated as the product of the kinetic energy of storm events and intensity of maximum 30 minutes storms. To calculate this factor and because of gaps in rainfall data of the studied region, we used the regression of Arnoldus (1977) which it has been developed in Morocco $R = 0.264\ F^{1.50}$ where (F) is the modified Fournier index proposed by Arnoldus (1977) to solve the problem involved in the distribution of monthly precipitation during the year where:

$$F = \sum_{i=1}^{12} \frac{r_i^2}{P} \quad (3)$$

Where r_i is the monthly precipitation and P is the annual precipitation.

4.2 Soil Erodibility Factor (K)

Soil erodibility factor (K) is the susceptibility of soil to erosion, sediment transportability under standard conditions. The standard state is the basic plot, 72.6 feet long with a 9% slope continuously maintained in summer fallow (Weesies, 1998). It depends on the physical and chemical properties of the soil, such as texture, aggregate stability, shear strength, the infiltration capacity, organic matter content, etc. (Nisar et al., 2000).

In our study, we used an experimental relationship resulting by the test on (225) soil type linked by the geometric mean particle diameter of soil, the relationship is expressed as

IJSER

ISSN 2229-5518

follows:

$$K = 7.594\left\{0.0034 + 0.0405\, exp\left[-\frac{1}{2}\left[\frac{\log(Dg) + 1.659}{0.7101}\right]^2\right]\right\} \quad (4)$$

Where

$$Dg(mm) = \exp(0.01 \sum f_i \ln m_i) \quad with \quad r^2 = 0.983 \quad (5)$$

Where

Dg: Geometric mean particle diameter.

Dg is the fraction of primary particle size in %, and *mi* is the arithmetic mean of the particle size limits of this dimension (Shirazi and Boersma 1984).

4.3 Topographic Factor (LS)

The effect of topography on soil erosion is taken into account by the LS factor in USLE, which combines the effects of slope length factor (L) and the slope steepness factor (S). Wishmeier and Smith (1978) defines the slope of length as the distance between the origin point of surface flow at the point where the slope decreases enough that the deposition starts or the point where the flow is concentrated in a defined channel . The stiffness of the slope reflects the influence of the slope on soil erosion (Wischmeier and Smith, 1965).

4.4 Vegetation Cover Factor (C)

The cover management factor is one of the most important parameters of the Universal Soil Loss Equation (USLE) , it measures the combined effect of all related covers between them and the management variables; the C factor will be between 1 and close to 0 when C = 1 which means no effect of cover and the soil loss is comparable to that of a bare tilled fallow, when C = 0 ,that means a very high coverage effect resulting in no erosion.

The creation of the C factor map requires the existence of Landsat satellite images of high resolution, then we use the unsupervised classification of satellite images using ArcGIS software by classifying the image on 3 classes (bare soil, meager vegetation, Urban area,) giving a specific value for each class.

4.5 Support Practice Factor (P)

Practice support (P) is very important factor in the USLE model for soil loss estimation in the contaminated land and construction of the sites of erosion reclamation because this factor represents practices aimed at reducing erosion. The value of P in the USLE model is the ratio of soil loss with specific support practice for soil loss.

4.6 Sediment Delivery Ratio Module (SDR)

The sedimentation rate (SDR) or (Sediment Delivery Ratio) is the ratio of the sediment of erosion which arrives to the watershed outlet given in a cross section.

The SDR depends on many factors such as slope, watershed length, drainage, land use, soil texture, drainage area, the proximity of the place of erosion compared to the network channel, the amount and intensity of rainfall, the volume and surface runoff speed.

5 Results

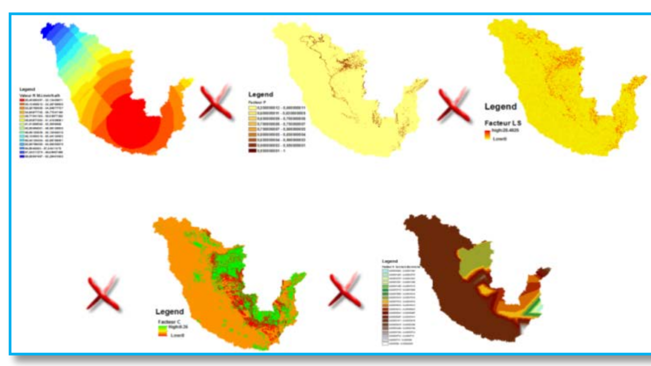
For monthly precipitation data and because of the clear gaps that has been found at The National Water Resources Agency (ANRH). An international database was used, provided by the site (Worldclim.org) Data layers were obtained by interpolation of mean monthly climate data from weather stations on a grid 30 seconds of arc resolution. The values found vary from 28.4086 to 62.2540 MJ.mm/ha/h. As indicated in Table 2:

TABLE 2 EROSIVITY FACTOR FOR EACH WEATHER STATION (WORLDCLIM DATA BASE)

Station	Erosivity (MJ.mm/ha/h)
Beni Abbess	56.39
Igli	25.52
Taghit	28.69
Abadla	11.40
Djorf Torba	26.13
ONM Bechar	25.42
Boukaiss	81.39
Beni Ounif	91.10
Errachidia (Morroco)	89.47

IJSER

In order to use the relation (5) to calculate the K factor and because of deficiency of official data regarding of pedology in the studied area (Watershed Guir), we did a soil sampling campaign in the Guir watershed choosing 16 survey points to bring back a quantity of soil (5kg) to analyze it in the laboratory to draw the granulometric curve for reason to use the relation (5). It was found that the k values vary from 0.02584 to 0.02586 ton.h/ Mj.mm.



For the LS factor it was calculated from DEM of 90m of resolution, and using the classification of the slopes on ArcGis. It was found that the results vary between 0 and 28.4025. The major values of the slopes are usually found in the banks of rivers.

The resulted maps of the USLE model are illustrated in the figure 3.

(a) Erosivity factor map R **(b)** Practice support map P
(c) Topographic factor map LS
(d) Vegetation cover map C **(e)** Erodibilty factor map K.

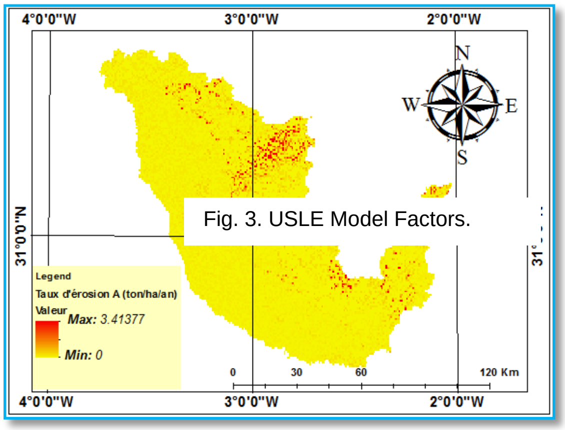


Fig. 3. USLE Model Factors.

6

EROSION RATE CALCULATION (A)

The USLE equation was used to calculate the annual average erosion rate (ton/ha/year) using various USLE factors (R, K, LS, C, P) characterized in layers generated from the previous treatment using ArcGIS raster calculator to multiply the different layers based on equation (3).

Fig. 4. THE EROSION DISTRIBUTION MAP

The Figure 4 shows the result of the model which was used to calculate the erosion in Guir watershed using equation (1). It can be seen from this figure that erosion has occurred on a portion of the watershed, particularly at the slope step.

The result of the modeling of USLE is in a state of image and does not show the extent of soil erosion. Using the function of ArcGis (Zonal statistics) which allow us to calculate the average annual rate of soil erosion.

The result of this option shows that the average value of erosion in the watershed of Guir is (1.73 tons/ha/year), and annual soil loss in the entire watershed (2 003 116 tons / year).

7 THE SEDIMENTATION RATE (SDR)

In this article. it has been used four relations of SDR which are that of Maner 1970; Vanoni (1975); Williams and Berndt's 1972; Renfro (1975) and we have used the EPM and the report (Ru) to choose the appropriate model basing on comparative methods standard error (S.E) and the coefficient of variation (CV). The results are as follows:

TABLE 3
RESULTS OF SDR OF USED MODELS

No	Model	Model Equation	Area (A)	L	R	Slope	SDR
1	Maner (1970)	SDR=1.8768-0.4191log (10 A)	7160.70	…	…	….	-0.1579
2	Vanonin (1975)	$SDR = 0.42\ A^{-0.125}$	7160.70	…	…	…	0.1384
3	Williams et Berndt's (1972)	$SDR = 0.627\ SLP^{0.403}$	7160.70	…….	… ….	2.85	0.956
4	Renfro (1975)	$\log(SDR) = 0.294259 + 0.82362 \log\left(\frac{R}{L}\right)$	…….	194.42	158.4	…….	1.66

IJSER

According to the results obtained from the different used models, we observe that the difference arises because of the diversity of factors used to estimate the value of SDR, so in order to have the most appropriate report we used the sediment (Ru) EPM Model.

$$R_u = 4\frac{(PxD)^{0.5}}{L+10} \quad (6)$$

Ru: Sedimentation coefficient in the watershed;
L: the length of the area which has the same length as of the straight line joining the two ends of the watershed;
P: Watershed perimeter in Km;
D: the difference in mean elevation in the area which is calculated as:

$$D = D_{ar} - D_0 \quad (7)$$

Where
D_0 : Watershed outlet elevation in Km;
D_{ar} : Watershed Average elevation in Km.

Then

TABLE 4
ESTIMATED SEDIMENTATION RATE OF THE WATERSHED USING THE EPM MODEL.

Watershed	A (Km^2)	P(Km)	L(Km)	D(Km)	Ru or SDR

Lower Guir	11524.04	1114.32	185.92	0.158	0.27

Where

$$SE = \frac{[(SDR)_E - (SDR)_B]}{(SDR)_E} x100 \quad (8)$$

SE : Standard error (%);
SDR_B : Basic sedimentation rate ;
SDR_E : Estimated sedimentation rate by the model.

And

$$C.V = \frac{S.D}{X_0} x100 \quad (9)$$

$$S.D. = \sqrt{\frac{(X_e - X_0)^2}{X_0}} \quad (10)$$

C.V.: Variation coefficient ;
S.D. : Déviation standard déviation ;
X_0 : Observed SDR (SDR_0);
X_e : Estimated SDR (SDR_e).

TABLE 4
COMPARAISON OF MODEL RESULTS EVALUATED AGAINST THE BASIC SDR (0.27) AND THEIR RANKS

No	Model	Estimated SDR	Difference between SDR and EPM	S.E (%)	S.D.	C.V (%)	Rank
1	Maner (1970)	>1	…	…	…	…	…
2	Vanoni (1975)	0.1384	0.1316	95.08	0.25	92.59	1
3	Williams et Berndt's (1972)	0.956	0.686	71.75	1.31	100	2
4	Renfro(1975)	1.66	1.39	83.73	2.67	100	3

According to the table. 5. It has been chosen the SDR of the lowest coefficient of variation which is of (Vanoni 1975)

TABLE 5
ABSOLUTE ERROR , S.E. AND C.V OF THE APPROPRIATE MODEL TO ESTIMATE THE SDR IN THE STUDIED WATERSHED

N	Model	Equation	SDR	Absolute Error	S.E(%)	C.V.(%)	Rank
2	Vanoni (1975)	$SDR = 0.42\,A^{-0.125}$	0.1384	0.73	95.08	92.59	1

Applying this model on annual soil loss value in the watershed of Guir, we find that the amount that arrives to the outlet in the watershed of Guir is 277 231.271 tons/year.

8 CONCLUSION

The resulting amount of solid input reaching the outlet of Igli, characterizes 1.35 % of total volume of retention of water of the future dam which is 20,458 666.66 m3, this amount requires 74 years to fill the entire reservoir of the dam. However, the use of anti-erosion facilities is recommended to reduce the erosion rate especially that there's other sources of solid input which arrives from Zousfana's (Bouzouina 2014) river and the wind effect (wind erosion). These facilities are for order to solve the sedimentation problem of the future reservoir and to ensure the service life of service of this dam.

.

REFERENCES

[1] A. Bachir, A. Mazouzi, "Etude de faisabilité d'une retenue d'eau a igli wilaya de bechar", final project study for obtaining a degree in hydraulic engineering, university of Béchar,Algeria, 2009.

[2] G. Verstraeten, J. Poesen, "Estimating trap efficiency of small reservoirs and ponds: methods and implications for the assessment of sediment yield, " in physics and geography progress 2000. [On line]. Available on: http://ppg.sagepub.com/content/24/2/219.short

[3] H, Sik Kim. (2006). Soil Erosion Modeling Using Rusle and Gis On The Imha Watershed, South Korea. (These de master, university of Colorado, United States, [on line].Available on : http://www.engr.colostate.edu/~pierre/ce_old/resume/Theses%20and%20Dissertations/KIMHYOENSIK-Thesis.pdf

[4] GN. Rostami Ali Salajeghe," Selecting the Best Model of Sediment Delivery Ratio Estimation in Ilam Dam Basin," Journal of advancements in environmental biology, vol. 5, N°. 5. pp. 795-802, 2011 [on line]. Available on: http://www.scinet.dost.gov.ph/union/UploadFiles/download.php?b=795802_225116.pdf&f=./Downloads/795-802_225116.pdf&t=application/pdf

[5] S. Huey Teh, " SOIL EROSION MODELING USING RUSLE AND GIS ON CAMERON HIGHLANDS, Malaysia For Hydropower Development," master thesis : Srenewable energy science, university of Akureyri, Iceland,2011.[On line]. Available on: http://www.engr.colostate.edu/~pierre/ce_old/Projects/linkfiles/Thesis%20Soo%20Huey%20Teh.pdf

[6] اميداسدي نليوان (1991) تعيين مناسبت ترين روش تجربي بر أود SDR با استفاده از مدل EPM وخصوصيات فيريكي حوزه (مطالعه موردي : ابخيرقورجاي , استان كلستان) . [على الانترنت]متواجد على :
www.isiwee.ir/files/site1/magazine/10_3.pdf

[7] H. Bouchelkia, F. Belarbi , B. Remini , " Quantification du transport solide en suspension par analyse statistiques : cas du bassin versant de MOUILLAH,"journal de l'aeu et l'environnement, N°19, pp. 29-41, 2011. [En ligne]. Disponible sur : http://www.ensh.dz/files/ljee/19/Article_Boucherkia.pdf

[8] L. Hui, C. Xiaoling, L. Kyoung Jae, L. Xiaobin Cai, S. Myung , " Assessment of Soil Erosion and Sediment Yield in Liao Watershed, Jiangxi Province," Journal of Earth Science, Vol. 21, No. 6, p. 941–953, Décembre 2010 [En ligne]. Disponible sur :

IJSER

www.earth-science.net/ejournal/paper/2010-6-16.pdf

[9] N. Rostami Ali Salajeghe," Selecting the Best Model of Sediment Delivery Ratio Estimation in Ilam Dam Basin," journal des avancements dans la biologie environnemental, vol. 5, N°. 5. pp. 795-802, 2011 [en ligne]. Disponible sur : http://www. sci-net.dost.gov.ph/union/UploadFiles/download.php?b=795 802_225116.pdf&f=./Downloads/795-802_225116.pdf&t=application/pdf

-[[10] N, ROUCHÉ.(juin 2012) .NOTES SUR L'ETABLISSEMENT D'UN FICHIER DE DONNEES DE PLUIES MENSUELLES EN VUE DE LA CONSTITUTION D'UNE SERIE DE PLUIE DE REFERENCE, pp. 40-41. [En ligne]. Disponible sur : http://www.hydrosciences.fr/sierem/produits/biblio/NotesSurCritiqueTome5AfriqueDuNord.pdf

[11] P, Fitte. La vallée de l'Oued Guir (Confins Algéro-Marocains). Une culture primitive inconnue. In: Bulletin de la Société préhistorique de France. 1947, tome 44, N. 7-8. pp. 215-222. [En ligne]. Disponible : DOI : 10.3406/bspf.1947.2180 http://www.persee.fr/web/revues/home/prescript/article/bspf_02497638_1947_num_44_7_2180

IJSER