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Estimation of Sediment Concentration Using Sediment Rating Curve Approach in Isser Watershed (North-West of Algeria)

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ABSTRACT

This paper was elaborated in order to estimate suspended sediment in Isser watershed located in North-West of Algeria. Power functions models by least squares regression were developed to establish rating curves. In total, 2026 pairs of instantaneous water discharge (*Q*) and instantaneous suspended sediment concentration (*C*) from the period 1988–1989 to 2003–2004 were used. In order to reveal the temporal impact, four subdivision data are elaborated: all, annual, seasonal and monthly scales. Better estimation of the total suspended sediment yield was obtained by application of the power linear model in monthly division data (-0.16%). When considering efficiency, both models with seasonal scale offered coefficients in order of 0.95%. The approach of correction for models did not improve accuracy of the estimation. The results have indicated for the 16 years of the available data, that the Isser watershed has drained a total of 194.37 million m^3 of water and 1.4 million tons of suspended sediments, with a specific degradation of 77 tons/km^2/year.

Keywords: suspended sediment, sediment-rating curve, power linear model, power nonlinear model, efficiency coefficient, error of estimation, Isser watershed, Algeria.

INTRODUCTION

Soil degradation is a global phenomenon. The total area eroded in the world is estimated at 25 million km^2, or 16.8% of the Earth's surface (Xiaoqing, 2003). About 28% of this degradation is attributed to wind erosion and 56% to water erosion (Gratiot, 2010). This phenomena is unevenly distributed (Musy and Higy, 2003), due to the sensitivity to variations in stream flows and watershed characteristics. According to Fournier (Xiaoqing, 2003; Campbell, 1977) maximum suspended solids is obtained in arid and semi-arid zones. This is induced by a very contrasting and aggressive climate, poor vegetation cover, steep slopes (Campbell, 1977; Probst and Amiotte, 1992; Bravard and Petit, 2000; Achite and Meddi, 2005), the high vulnerability of the land (soft rocks, fragile soils), overgrazing and the adverse impact of human activities (Roose, 1991; Antipolis, 2003). At this scale, there is a clear predominance of the solid suspension contribution, which sometimes represents nearly 90% of the total solid input (Bravard and Petit 2000; Asselman, 2000). In Algeria, the western part is the most affected with 47% of the land, followed by the Center with 27% and the East with 26% (Achite et al., 2006).

Estimation and quantification studies of suspended solid transport have increased since the 1970s for a variety of reasons (Horowitz, 2002). This is important for projects planning, such as erosion and soil loss assessment, environmental impact assessment, water treatment and the association of pollutants with sedimentary particles as well as the estimation of dead volumes of dam reservoirs and their influence on the under- or over-estimation of the latter's capacities (Walling, 1977; Kisi, 2007). In Algeria, many studies are established at different watersheds for the purpose of understanding, evaluating and estimating solid transport (Demmak, 1982; Arabi, 1991; Terfous et al., 2001; Bouchelkia and Remini, 2003; Achite and Meddi, 2004–2005; Achite and Ouillon 2007; Ghenim et al., 2008; Elahcene andRemini, 2009; Elahcene et al., 2013; Bouchelkia et al., 2013; Gliz et al., 2015; Remini et al., 2015; Berghout and Meddi, 2014-2016; Balla et al.,2016; Selmi and Khanchoul, 2016; Tachi et al.,2016; Bouzeria et al., 2017; Belarbi, 2018). All this studies reflect the complexity and a high variability of the phenomenon in time and space.

The solid charge is deduced generally from direct measurements or based on solid transport equations. Although, on one hand direct measurements are the most reliable way, they are very expensive and not available in all rivers (Bouchelkia et al., 2014). They are difficult to operate during important, infrequent and unpredictable events in arid and semi-arid climates (Lewis, 1996), in addition to the conditions of access and security. On other hand, solid transport equations require information on particle characteristics and flow. They must take into account morphological and hydro-climatic conditions of the study area (Dogan, 2005).

For these reasons, it become a necessity to opt for another approach that aims to exploit available data of the liquid flow, which is frequent measure, and the concentration of suspended sediment less frequent in order to model and estimate sediment yield (Smart et al., 1999). This estimate is established frequently by sediment rating curves, which represent the average relation between discharge and suspended sediment concentration at a specific watershed (Glysson, 1987; Asselman, 2000). The form of power function is the most employed, (Walling and Webb, 1981; Webb et al., 1997; Bednarczyk and Madeyski, 1998; Asselman, 2000; Li et al., 2003). It is in the following form:

$$C = a \cdot Q^b \tag{1}$$

where: C is suspended sediment concentration (mg/l);
Q is water discharge (m^3/s);
a and b are regression coefficients.

In this paper, the authors sought which model provides a good accuracy in estimation of sediment suspension in the study area. The subdivision of data series and application of correction factors were tested in order to improve this accuracy.

STUDY SITE AND DATA COLLECTION

The drainage basin is situated in the north west of Algeria (Fig. 1). Its drainage area is about 1140 km². The length of the principal talweg is about 66 km. The basin is characterized by a Mediterranean climate. Mean annual precipitation is about 389 mm. Average annual water load is 194×10^6 m^3, while the average annual suspended sediment load is 0.087×10^6 tons with specific degradation about 77 tons/km²/year.

Slope is a major factor in water erosion; steepest slopes are concentrated in the northwestern and southern part of basin. Moderate, low and

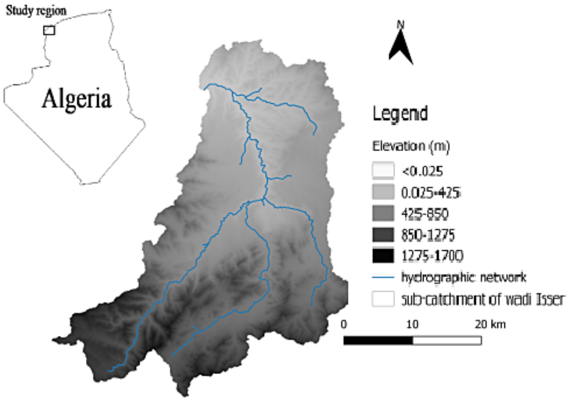

Figure 1. Location of the Isser watershed

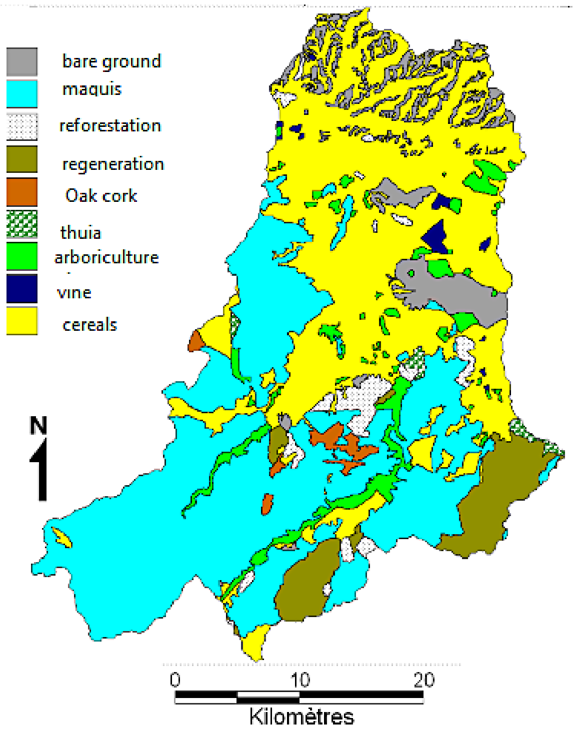

Figure 2. Lithology of the Isser watershed (Boughalem, 2013)

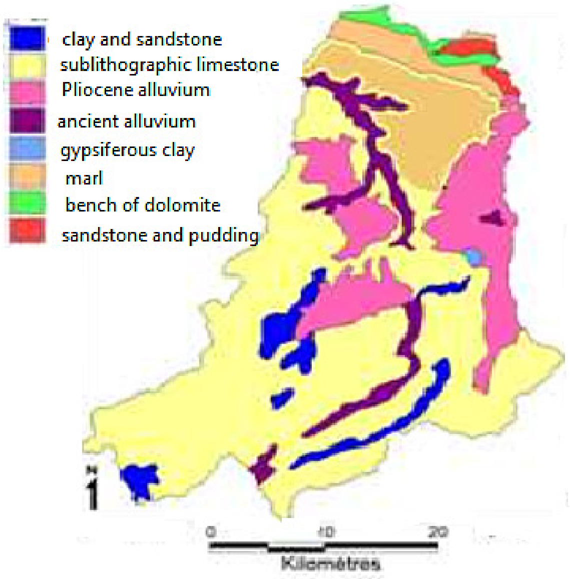

Figure 3. Vegetation cover (Boughalem, 2013)

very low slope occupy the rest of basin. The lithology of this basin indicates a large occupation by limestone and marl (Fig. 2).

Figure 3 reflects a very poor vegetation cover. The northern part of land is occupied by cereals, while the southern portion is in majority maquis.

The available data for suspended sediment concentration (*C*) and liquid flow (*Q*) for the period 1988–1989 to 2003–2004 at the Hydrometric station of Sidi Aissa are provided from the services of the National Agency of Hydraulic Resources (ANRH). These results in 2026 instantaneous data from (*Q*, *C*) collected at varying time intervals.

Suspended sediment concentration (C) was measured cross the wadi-section. Samples were taken by 1 L plastic bottles. Results were deduced by the filtration method.

The frequency of sampling during flood periods varies between 5 minutes to 1 hour. However, at stable events, samples are taken once every two days. During the low season generated by a scarcity of flow, measures are taken once in month or more. The average catches are 126 taken per year, the most intensified month in measurements is that of March, while the least sampled month is August.

Table 1. Data characteristics

Parameter	Q (m^3/s)	C (kg/m^3)
Average	4.80	4.20
Standard deviation	20.34	12.35
Min	0.001	0.01
Max	295.4	102.6

METHODS

Sediment-rating curve is developed using the power function model with two forms:

1) Power linear model that comes from logarithmic transformation:

$$logC = loga + blogQ + log\varepsilon \tag{2}$$

Which is then back-transformed to obtain:

$$C = a \cdot Q^b \cdot \varepsilon \tag{3}$$

where: *a* and *b* – are model parameters obtained by least squares regression on logarithmic transformed data,
ε – a lognormally distributed error.

This induce according to several authors underestimation, or bias of suspended sediment concentration estimated by least square regression of log transformations variables [Duan 1983; Jansson 1985; Walling et al. 1988; Newman 1993; Janson 1996]. In order to correct this bias, data will be multiplied by correction coefficients.

The first coefficient proposed by Duan (1983), Walling and Webb (1988), and Newman (1993) is given by:

$$C_d = \frac{1}{n\sum 10^{\varepsilon_i}} \tag{4}$$

where: C_d – Duan correction factor,
ε – residue of observation.

$$\varepsilon_i = \log(C_{obs}) - \log(C_{est}) \tag{5}$$

then:

$$C = \left(aQ^b\right)C_d \tag{6}$$

2) Power function model, using nonlinear regression at the form:

$$C = aQ^b + \delta \tag{7}$$

where: δ – a normally distributed error.

Kao et al. (2005) proposed the second correction coefficient. C_k applicable with non-transformed data, it can be adapted for the both models linear or nonlinear. It is given by the following expression:

$$C_k = \frac{\sum_i^n(\varepsilon_i)}{\sum_i^n aQ^b} \tag{8}$$

$$\varepsilon_i = C_{obs} - C_{est} \tag{9}$$

then:

$$C = (1 + C_k)aQ^b \tag{10}$$

Finally, four sets of rating relationships were constructed, using data sets: all data, years, seasons and months.

The accuracy of each model at different temporal scale is evaluated by:

- Error of estimation:

$$E(\%)=\left(\frac{ESL}{MSL}-1\right)\times 100 \qquad (11)$$

where: ESL – is the estimated sediment concentration; MSL – is the measured sediment concentration.

- Efficiency criterion:

$$R^2=\frac{\sum_{i=0}^{N}(C_{obs}-C_{avr})^2-\sum_{i=0}^{N}(C_{obs}-C_{est})^2}{\sum_{i=0}^{N}(C_{obs}-C_{est})^2} \qquad (12)$$

where: C_{obs}, C_{avr} and C_{est} – are suspended sediment concentration observed, average and estimated.

Evaluation of water and sediment yield in the Isser watershed

The average liquid contribution through the hydrometric gauging station for the period between times t_i and t_{i+1} is given by the relation:

$$Al_i=\frac{1}{2}(Q_i+Q_{i+1})(t_{i+1}-t_i) \qquad (13)$$

The arithmetic sum of the element liquid contributions during a given period (year, season, month and flood event) will give the liquid contribution of this period:

$$Al_i=\sum_0^t\frac{1}{2}(Q_i+Q_{i+1})(t_{i+1}-t_i) \qquad (14)$$

It is the same for the solid contribution for a period, which is given by the relation:

$$As_i=\sum_0^t\frac{1}{2}(C_iQ_i+C_{i+1}Q_{i+1})(t_{i+1}-t_i) \qquad (15)$$

where: Q, C – water flow and sediment concentration; $t_{i+1}-t_i$ – the measurement gap.

RESULTS AND DISCUSSION

Sediment rating curve

Sediment rating curves were plotted for the study area using the two power functions: linear and nonlinear models. Figure 4 shows a scatter plot from the instantaneous suspended sediment concentration (*C*) versus water discharge (*Q*) at Sidi Aissa station and the difference between the two models for all data. Regression coefficients and determination coefficients are given in Table 2.

Figure 4 reflects a large dispersion of the points for the complete series, accompanied by a low correlation for the both models ($r = 0.61$ for linear model, $r = 0.42$ for nonlinear model). This dispersion necessitated proceeding for division data at different temporal scales.

According to Table 2, for the monthly scale, significant coefficients of determination r^2 have obtained in November and August. Its values have not exceeded 0.65 at the annual scale. Lower correlations were observed at seasonal scale.

The data of the study area are characterized by height values of sediment concentration (*C*) associated with low values of discharge (*Q*) (Fig. 4). Their relationship is obscured by the sudden arrival of sediment produced by occasional rains in dry periods, leading to the first emergence of the solid load (Ghenim, 2008; Elahcene and Remini, 2009; Berghout and Meddi, 2016).

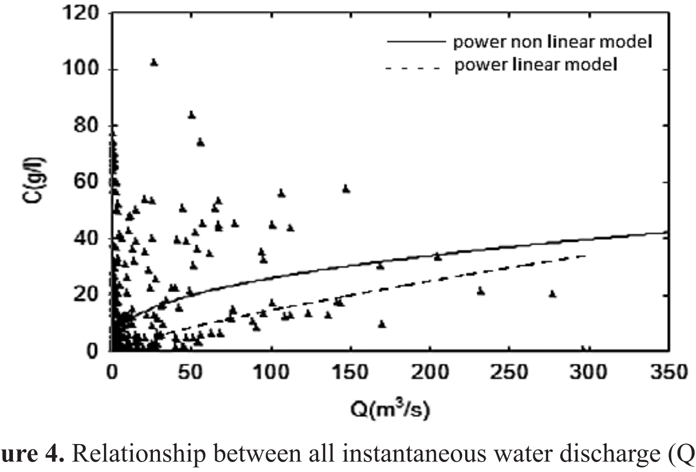

Figure 4. Relationship between all instantaneous water discharge (Q) and sediment concentration (C) using linear and nonlinear models

Table 2. Model parameters, regression coefficients and number of data (N) at different scales

Scale	Data	*N*	Linear model			Nonlinear model		
			A	*b*	R^2	*a*	*b*	R^2
	All	2026	0.401	0.79	0.377	3.816	0.419	0.174
Annual	1988-89	180	0.703	0.504	0.191	0.34	0.014	0.002
	1989-90	124	0.581	0.826	0.436	2.633	0.535	0.22
	1990-91	178	0.362	0.77	0.443	3.396	0.424	0.397
	1991-92	145	0.192	0.808	0.309	0.32	0.7	0.268
	1992-93	130	0.094	0.51	0.26	0.676	0.888	0.39
	1993-94	88	0.089	0.338	0.145	0.222	1.272	0.38
	1994-95	91	0.889	1.003	0.538	0.328	0.356	0.234
	1995-96	169	0.193	0.863	0.526	0.492	0.668	0.444
	1996-97	79	0.15	0.678	0.284	0.842	0.989	0.123
	1997-98	122	0.377	0.66	0.222	3.29	0.226	0.041
	1998-99	84	0.687	1.323	0.572	8.292	0.613	0.525
	1999-00	96	0.692	0.912	0.523	4.402	0.51	0.726
	2000-01	152	0.616	0.75	0.311	4.604	0.409	0.26
	2001-02	135	1.115	0.966	0.656	5.78	0.527	0.654
	2002-03	122	0.448	0.526	0.091	2.418	0.538	0.11
	2003-04	131	0.705	1.138	0,609	3.502	0.566	0.627
Seasonal	Autumn	405	1.527	0.858	0.397	12.171	0.295	0.248
	Winter	747	0.332	1.068	0.465	1.686	0.585	0.153
	Spring	724	0.271	0.706	0.492	1.151	0.545	0.366
	Summer	150	0.117	0.212	0.033	9.234	2.133	0.622
Monthly	September	89	7.022	0.488	0.177	30.50	0.085	0.056
	October	117	1.521	0.853	0.481	9.486	0.306	0.33
	November	199	0.804	1.113	0.673	6.038	0.4977	0.61
	December	238	0.4	1.125	0.42	1.356	0.533	0.16
	January	280	0.358	1.15	0.51	2.734	0.503	0.17
	February	229	0.233	0.908	0.404	0.90	0.52	0.066
	March	313	0.303	0.745	0.594	1.394	0.505	0.358
	April	189	0.212	0.52	0.127	1.624	0.707	0.088
	Mai	222	0.186	0.498	0.284	0.492	0.637	0.195
	June	106	0.034	-0.15	0,079	0.06	-0.102	0.014
	July	33	0.014	-0.25	0.029	0.232	0.633	0.016
	August	11	21.95	1.45	0.825	19.81	0.69	0.91

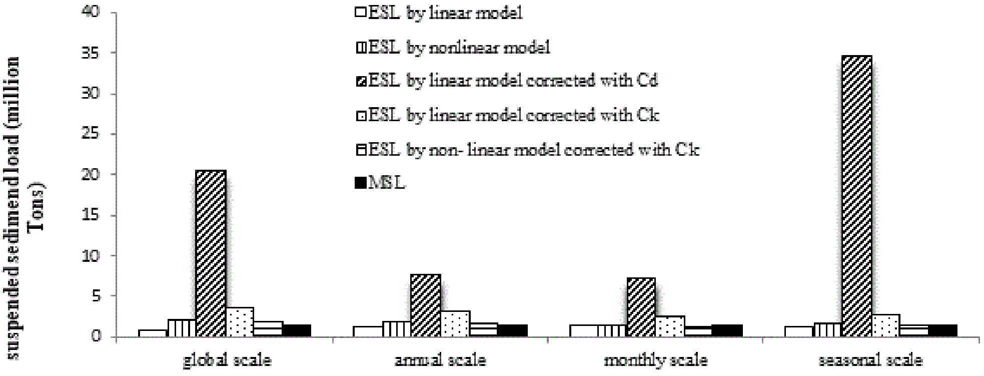

Figure 5. Representation of suspended sediment loads measured and estimated by linear, nonlinear and corrected models

Figure 5 revealed the difference between observed and estimated suspended sediment load from different techniques. It has showed the great gap induced by application of the linear model after correction by Duan coefficient.

To evaluate the accuracy of each model, Table 3 summarizes errors induced from adaptation of sediment rating curve at different scales with and without correction. It has been found that the linear model underestimated sediment load at different scales, while nonlinear model overestimated. These findings were compatible with previous research of estimation of suspended sediment load (Walling, 1977a-b; Jansson, 1985-1996; Asselman, 2000).

It was noted that application of different correction coefficients did not improve the accuracy of estimation of the linear model; something that is similar with other findings (Walling and Webb, 1988; Sadeghi et al., 2008). However, error values decreased after correction in the case of the non-linear model.

Good estimation is obtained when monthly division is applied, with an appreciable error value (-0.16%) for the linear model.

Contrary to what has been found by other authors who have studied basins under temperate climates (Walling, 1977a-b; Glysson, 1987; Asselman, 2000); seasonal grouping does not improve estimation, since seasonal effect is not the same in watersheds under arid and semi-arid climates. In temperate zones, much of the suspended solid transport is generated by precipitation or runoff, so large runoff volumes are generally associated with high solid loads (Campbell, 1977; Glysson, 1987). In turn, in the considered case (Figs. 8 and 9) winter which generates only 15.61% of total water loads is responsible for nearly 50% of the sediment yield.

Considering efficiency of models, Table 4 summarizes the values of Nash coefficient obtained by application of power models established at different temporal scales. Value that tended to 1, means good estimation of instantaneous sediment concentration, negative value indicates bad estimation by the model (Asselman, 2000). The results indicated that the best values are obtained by the nonlinear model at monthly and seasonal scales, which improved slightly after correction.

Annual, seasonal and monthly variability of water and suspended sediment loads

On the basis of instantaneous water discharge Q (m^3/s) and suspension sediment concentration C (g/l), during 16 years in the study area, the total water yield of 194.4 Hm^3, corresponding to 1.4 million tons of sediment was evaluated. The sediment transport phenomena in the Isser watershed are characterized by a great temporal variability (annual, seasonal and monthly), which is illustrated respectively in Figs. 6–9.

Table 3. Errors (%) in estimated suspended sediment load at the Isser watershed during the period of 1988–1989 to 2003–2004 using sediment rating curve

Model / Data	Linear model			Nonlinear model	
Temporal scale	Before correction	After correction by *Cd*	After correction by *Ck*	Before correction	After correction by *Ck*
All	-42.80	1358.77	153.28	41.72	28.40
Annual	-5.78	435.98	129.20	34.09	17.12
Seasonal	-16.23	2372.27	86.91	13.49	5.79
Monthly	-0.16	410.39	76.09	2.71	-9.81

Table 4. Model efficiency in estimated suspended sediment load at the Isser watershed during the period of 1988–1989 to 2003–2004 using sediment rating curve

Model / Data	Linear model			Nonlinear model	
Temporal scale	Before correction	After correction by *Cd*	After correction by *Ck*	Before correction	After correction by *Ck*
All	0.06	-30.45	-0.27	0.172	0.17
Annual	0.45	-77.37	-4.24	0.29	0.55
Seasonal	0.70	-3509.47	-1.72	0.94	0.98
Monthly	0.83	-26.10	0.14	0.93	0.93

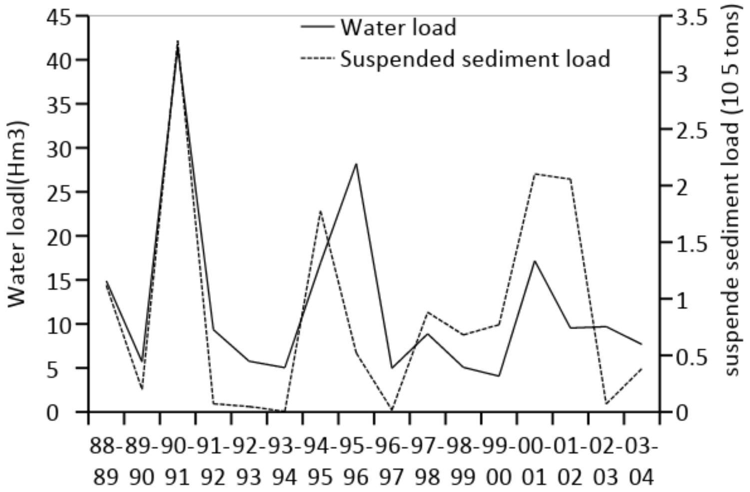

Figure 6. Annual variation of water and sediment loads

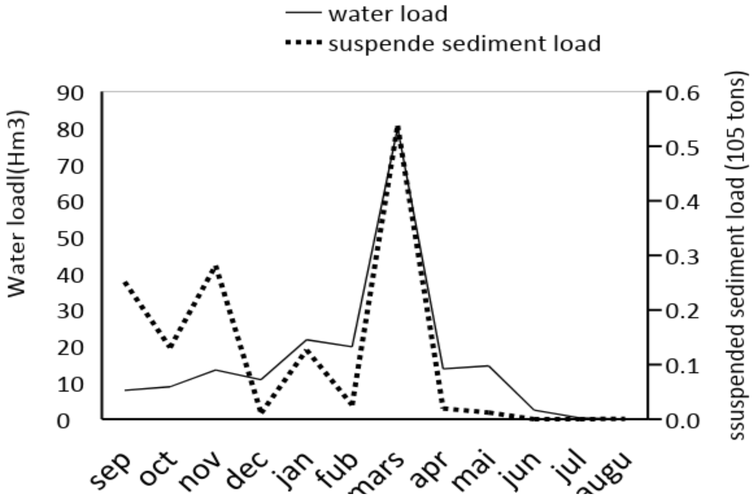

Figure 7. Monthly variation of water and sediment loads

The annual variation showed that the most water productive year was in 1990–91 with 41.4 Hm^3 (21.3% of global water load), generating the greatest solid contribution of 0.33 million tons (23.43% of global solid load). The specific degradation in this year was 288 tons/

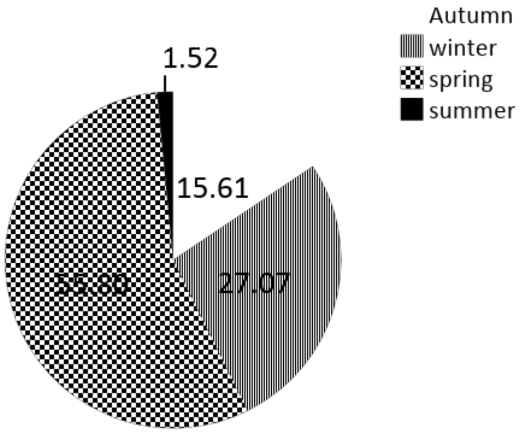

Figure 8. Seasonal contribution (%) of water load

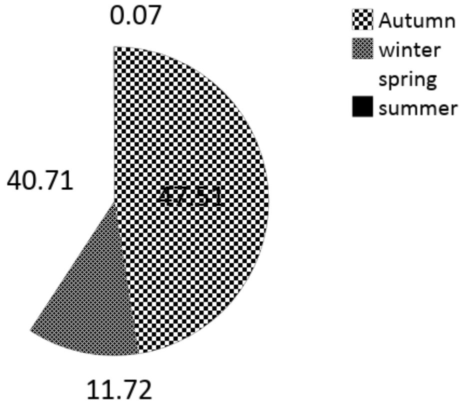

Figure 9. Seasonal contribution (%) of sediment load

km²/year, due to important flood events. However, the poor water contribution occurred in 1999–2000, and the lowest sediment yield was estimated in 1993–1994.

Figures 8 and 9 reflected a considerable water liquid of spring season; this was due to the important flood events especially in march. This month; nevertheless its solid contribution was not the largest. In turn, important sediment yield was provided in autumn, which is characterized by aggressive rainfall. On the one hand, the low vegetation cover and dry soil during the summer season (preparation period of sediment supply stocks) (Roose, 1991; Selmi and Khanchoul, 2016). In summer, the sediment contribution was insignificant because of the low liquid load (low value of water discharge).

Monthly variation (Fig. 7) showed peak in March with maximum water and sediment load (water load of 41.13% and 38.43% of sediment load), which decreases to reach the lowest value in August.

CONCLUSIONS

This paper presents the development of sediment rating curves using power function model to establish the relationship between water discharge (Q) in (m^3/s) and suspended sediment concentration (C) in (kg/m^3) over a 16-year period in the Isser watershed.

Results showed very satisfactory in estimation of sediment transport rates from the power linear model obtained by least square regressions on logarithmic transformed data with underestimate about 0.16% at the monthly scale. In the case of rating curves plotted by a power function, based on nonlinear least square regressions, the best accuracy was about 2.71% at the same monthly scale.

Corrections factors and seasonal scale did not improve the precision of estimation in the study area. During the period of record, Wadi Isser drained 194.4 million m^3 of water yield and 1.4 million tons of suspended sediments yield, with a specific degradation of 77 tons/km²/year.

This approach significantly contributes to the understanding and modeling of solid transport phenomena in the study area. The methods discussed in this study offer a straightforward and efficient means of estimating solid inputs carried by Wadis in arid and semi-arid regions.

REFERENCES

1. Achite A., Meddi M. 2004. Estimations du transport solide dans le bassin-versant de l’Oued Hadda (Nord-Ouest Algérien). Sécheresse, 15(4): 367-73.
2. Achite M., Meddi M. 2005. Variabilité spatio-temporelle des apports liquide et solide en zone semi-aride. Cas du bassin versant de l’Oued Mina (Nord-Ouest Algérien). Revue des Sciences de L’eau, 18: 37-56.
3. Achite M., Ouillon S. 2007. Suspended sediment transport in a semiarid watershed, Wadi Abd, Algeria (1973-1995). Journal of Hydrology, 343: 187-202.
4. Achite M., Touaibia B., Ouillon S. 2006. Erosion hydrique en Algérie du Nord: Ampleur, Conséquences & Perspectives. 14th international soil conservation organization conference water management and soil conservation in semi-Arid environments. Marrakech, Morocco, May 14-19, 2006, 6 p.
5. Antipolis S. 2003. Les menaces sur les sols dans les pays méditerranéens. Etude bibliographique. Plan Bleu. Centre d’activités régionales, 70 p.
6. Arabi M., Kedaid O.E., Bourougaa L., Asla T., Roose E. 2004. Bilan de l‘enquête sur la défense et restauration des sols (DRS) en Algérie. Science et changement planétaires. Sécheresse, 15(1): 87-95.
7. Asselman N.E.M. 2000. Fitting and interpretation of sediment rating curves. Journal of Hydrology, 234: 228-248.
8. Bednarczyk T, Madeyski M. 1998. Assessment of suspended load tapped in a small reservoir related to the erosion in a loess basin. IAHS Publ., 249: 241-247.
9. Balla F., Kabouche N., Khanchoul K., Bouguerra H. 2017. Hydro-sedimentary flow modelling in some catchments Constantine highlands, case of Wadis Soultez and Reboa (Algeria). Journal of Water and Land Development, 34, 21–32. DOI: 10.1515/jwld-2017-0035.
10. Belarbi F., Bouchelkia H., Remini B., Benmansour A. 2018. Quantification and study of monthly variation of suspended sediment loads in Tafna basin – Algeria. Journal of Water and Land Development, 37, 29–38. DOI: 10.2478/jwld-2018-0022.
11. Berghout A., Meddi M. 2016. Sediment transport modelling in wadi Chemora during flood flow events. Journal of Water and Land Development, 31, 23–31. DOI:10.1515/jwld-2016-0033.
12. Bouchelkia H., Belarbi F., Remini B. 2013. Estimated flows a solid suspended by the statistical analysis of outfall drainage basin of Tafna (Algeria). Soil and Water Research, 8(2), 63–70.
13. Bouchelkia H., Belarbi F., Remini B. 2014. Quantification of suspended sediment load by double

correlation in the watershed of Chellif (Algeria). Journal of Water and Land Development, 21, 39–46.

14. Bouchelkia H., Remini B. 2003. Quantification du transport solide dans le bassin versant algérien du Chellif [Quantification of sediment transport yield in the Algerian basin of Chellif]. Ingénieries, 33, 45–56.
15. Boughalem, M., Mazour, M., Grecu, F., Abdellaoui, A., Hamimed, A. (2013). Evaluation par analyse multicritères de la vulnérabilité des sols a l'érosion: cas du bassin versant de l'Isser – Tlemcen, Algérie. Analele Universității Bucureşti, 5-26.
16. Bravard J.P., Pettit F. 2000. Les cours d'eau : dynamique du système fluvial. Paris Colin, 2e edition, 222 p.
17. Campbell I.A. 1977. Stream discharge, suspended sediment and erosion rates in the Red Deer river basin, Alberta, Canada, 244-259.
18. Demmak A. 1984. Recherche d'une relation empirique entre apports solides spécifiques et paramètres physico-climatiques des bassins: application au cas Algérien. Challenges in African hydrology and water resources. IAHS Publ., 144: 403-414.
19. Dogan O. 1993. Cartographie de I 'érosion et les recherches sur la conservation des sols en Turquie. Institut de Recherches des Services Ruraux Ankara Turquie, 7996.
20. Duan N. 1983. Smearing estimate: A non parametric retransformation method. Journal of the American Statistical Association, 78(383): 605-610.
21. Elahcene O., Remini B. 2009. Corrélation entre la concentration en matières en suspension et le débit liquide dans le bassin versant d'Oued Bellah (Algérie). European Journal of Scientific Reseach, 26(1): 139-146.
22. Elahcene O., Terfous A., Remini B., Ghenaim A., Poulet J.P. 2013. Etude de la dynamique sédimentaire dans le bassin versant de l'Oued Bellah (Algérie). Hydrological Sciences Journal, 58(1), 224–236. DOI 10.1080/02626667.2012.742530.
23. Ghenim A. 2008. Etude des écoulements et des transports solides dans les régions semi-arides méditerranéennes. Thèse de Doctorat Université de Tlemcen, 134 p.
24. Gliz M., Remini B., Anteur D., Makhlouf M. 2015. Vulnerability of soils in the watershed of Wadi El Hammam to water erosion (Algeria). Journal of Water and Land Development, 24, 3–10.
25. Gliz M., Remini B., Anteur D., Makhlouf M. 2015. Vulnerability of soils in the watershed of Wadi El Hammam to water erosion (Algeria). Journal of Water and Land Development, 24, 3–10.
26. Glysson D. 1987. Sediment-transport cuves. U.S.Geological suvey. Reston, Virginia, 87(218): 2-47.
27. Gratiot N. 2010. Impact des sédiments cohésifs sur l'écosystème. Habilitation à diriger des recherches école doctorale terre univers environnement. Chargé de Recherches à L'ird (UMR 5564), Equipe river Cermo. Grenoble Cedex, 9, 92 p.
28. Horowitz A.J. 2002. The use of rating (transport) curves to predict suspended sediment concentration: a matter of temporal resolution. Turbidity and sediment surrogates workshop, April 30 – May 2, 2002, Reno, NV.
29. Jansson M. 1985. A Comparison of detransformed logarithmic regressions and power function regressions. Geografiska Annaler .Series A, Physical Geography, 67A(1-2): 61-70.
30. Jansson M. 1996. Estimating of sediment rating curve of the Reventazon river at Polomo using logged mean loads within discharges classes. Journal of Hydrology, 183: 227-241.
31. Kao S.J., Lee T.Y., Milliman J.D. 2005. Calculating highly fluctuated suspended sediment fluxes from Mountainous Rivers in Taiwan. TAO, 16(3): 653-675.
32. Kchanchoul K., Jansson M. 2008. Sediment rating curves developed on stage and seasonal means in discharge classes for the Mellah Wadi, Algeria. Swedish Society for Anthropology and Geography, 90A(3): 227-236.
33. Kisi Ö. 2007. Development of stream flow-suspended sediment sating curve using a range dependent neural network. International Journal of Science and Technology, 2(1): 49-61.
34. Lewis J. 2001. Turbidity threshold sampling for suspended sediment load estimation. Proceedings of the Seventh Federal Interagency Sedimentation Conference, March 25 to 29, 2001, Reno, Nevada, III: 110-117.
35. Li H., Lee J.H.W., Cai M. 2003. Nutrient load estimation methods for rivers. International Journal of Sediment Research, 18(4): 346-351.
36. Musy A., Higy C. 2003. Hydrologie: une science de la nature. Presse Polytechniques et Universitaires Romandes, 314 p.
37. Newman M.C. 1993. Regression analysis of log-transformed data: statistical bias and its correction. Environmental Toxicology and Chemistry, 12: 1129-1133.
38. Probst J.L., Amiotte Suchet P. 1992. Fluvial suspended sediment transport and mechanical erosion in the Maghreb (North Africa). Hydrological Sciences Journal, 37(6): 621-637.
39. Remini B., Bensafia D., Nasroun T. 2015. Impact of sediment transport of the Chellif River on silting of the Boughezoul reservoir (Algeria). Journal of Water and Land Development, 24, 35–40.
40. Roose E. 1991. Conservation des sols en zones

méditerranéennes synthèse et proposition d'une nouvelle stratégie de lutte antiérosive. Cah Orstom, sér. Pédol., XXVI(2): 145-181.

41. Sadeghi S.H.R., Mizuyama T, Miyata S., Gomi T., Kosugi K., Fukushima T., Mizugaki S., Onda Y. 2008. Development, evaluation and interpretation of sediment rating curves for a Japanese small mountainous reforested watershed. Sciencedirect. Geoderma, 144: 198-211.
42. Selmi K., Khanchoul K. 2016. Sediment load estimation in the Mellegue catchment, Algeria. Journal of Water and Land Development, 31, 129–137. DOI: 10.1515/jwld-2016-0044
43. Smart T.S., Hirst D.J., Elston D.A. 1999. Methods for estimating loads transported by rivers. Hydrology and Earth System Science, 3(2): 295-303.
44. Tachi S.E., Ouerdachi L., Remaoun M., Derdous O., Boutaghane H. 2016. Forecasting suspended sediment load using regularized neural network: Case study of the Isser River (Algeria). Journal of Water and Land Development, 29, 75–81. DOI: 10.1515/jwld-2016-0014.
45. Terfous A., Megnounif A., Bouanani A. 2001. Etude du transport solide en suspension dans l'Oued Mouilah (Nord Ouest Algérien). Revue des Sciences de L'eau, 14(2): 173185.
46. Walling D.E. 1977a. Assessing the accuracy of suspended sediment rating curves for a small bassin. Water Resources Research, 13(3): 531-538.
47. Walling D.E. 1977b. Limitations of the rating curve technique for estimating suspended sediment loads, with particular reference to British rivers. IAHS publications, 34-48.
48. Walling D.E., Webb B.W. 1981. The reliability of suspended sediment load data. Erosion and sediment transport measurement. Proceedings of the Florence Symposium. IAHS Publ., 133: 177-194.
49. Walling D.E., Webb B.E. 1988. The reliability of rating curve estimates of suspended sediment yield: some further comments. Sediment budgets (Proceedings of the porto-alegre symposium). IAHS Publ., 174: 337-350.
50. Walling D.E., Webb B.W. 1996. Erosion and sediment yield: a global overview. IAHS Publ., 236, 94 p.
51. Webb B.W., Phillips J.M., Walling D.E., Littlewood I.G., Watts C.D., Leeks G.J.L. 1997. Load estimation methodologies for British rivers and their relevance to the LOIS RACS(R) programme. The science of total environment. Journal of Hydrology, 194/195: 379-389.
52. Xiaoqing Y. 2003. Manual of sediment management and measurement. World meteorological organization operational. Geneva. Switzerland, 948: 159 p.