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RESEARCH ARTICLE

SUSPENDED SEDIMENT LOAD IN THE WATERSHED OF THE EBDA WADI, ALGERIA

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ABSTRACT

Solids transport is a complex phenomenon; the intensity of this phenomenon varies greatly with the general environment: geology, degree of rock alteration, hydrology, vegetation, climate, etc. The extent of the phenomenon is out of proportion in semi-arid areas or areas with temperate climates. Algeria is one of the countries most affected by this phenomenon and its consequences. To enable a rapid response to demands from engineers for the quantification of bed load transport at the outlet of a catchment area, a simple tool easy to implement has been developed. The principle adopted is based on hydrometric data from gauging stations, seasonal and annual analyses have defined an appropriate method for estimating the sediment yield. This work presents a study of the sediment transport in the Wadi Ebda watershed. In order to understand the sedimentation dynamic in the watershed, an analysis is based on instantaneous flow data and the concentration of suspended sediments transported in the stream. The results obtained were quite satisfactory because the correlation coefficients of the model Q_s= f (Q_l) are between77% and 84%. This method once refined can be generalized to all the watersheds of northern Algeria. In addition, the results show that the annual average of specific degradation is about 809 t km^{-2} $year^{-1}$. This value is comparable to those found in other regions with similar hydrologic regimes.

INTRODUCTION

The surface flows carry with them the products of the weathering of rocks of upland to lowland areas and ultimately to the sea. This section is a brief introduction to the problems of sediment transport; the study has become essential in many areas, the study of erosion and sedimentation studies on the pollution of water ways. And, the search for models connected to the parameters hydroclimatic (precipitations, flowsand/or transport of solid materials) is the subject of many studies (Demmak 1982; Probst and al. 1992; Terfous and al. 2001; Megnounif and al. 2003, 2007; Benkhaled and al. 2003; Achite and al. 2005, 2007; Ghenim and al. 2007, 2008 and Elahcene and al. 2009, 2013…). The objective of these authors is to explain the phenomenon of the flow and solid transport and to highlight relations suitable to be applied to areas or basins slopes where measurements are rare or not-existing. All these parameters are that models differ from one author to another. Each study attempts to characterize the region or basin studied by the model most representatives and most reliable (correlation coefficient) (Bouanani 2004). The sediment transport in Algeria is measured in the watershed gauging stations for almost all episodes of flow.

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Generally, it is limited to the suspension flow. The estimate of the thrust is always a problem whose solution is not complete (Larfi 2006). The parameters (concentration of suspended sediment and water discharge) instantaneous measured in wadi Ebda are designed to quantify the suspended sediment based on the evolution of C and Q_l and Q_s and Q_l. This study aims to develop a simple method for quantifying operational suspended sediment in Ebda wadi (Q_s = f(Q_l)). It is based on data from samples collected by the National Agency of Water Resources (Algeria) between 1989 and 2005.

Area of study

The watershed of the Ebda wadi is located in semi-arid zone. It covers an area of 270 km^2 for a perimeter of 70 km. The basin of the Ebda stream belongs to the catchment of Cheliff, located in the North-West of Algeria. It is bordered to the North by Menaceur, Sidi Semiane and Messelmoun, in the South and South-West by Miliana,Sidi Lakhdar and Ain Defla, in the East by Meurad, Hammam Rig and Ain Torki, and in the West by Elamra and Mekhatria (Figure 1). It has an average altitude of 736 m. The altitude at the outlet, where the hydrometric station Arib Ebda is, is 275 m. It is characterized by a maximum altitude of 1417 m, the length of the equivalent rectangle is 23.5 km, its the torrentiality coefficient is 128 and the length of the principal talweg is 37 km. It is characterized by a semiarid climate with an internal average pluviometry of

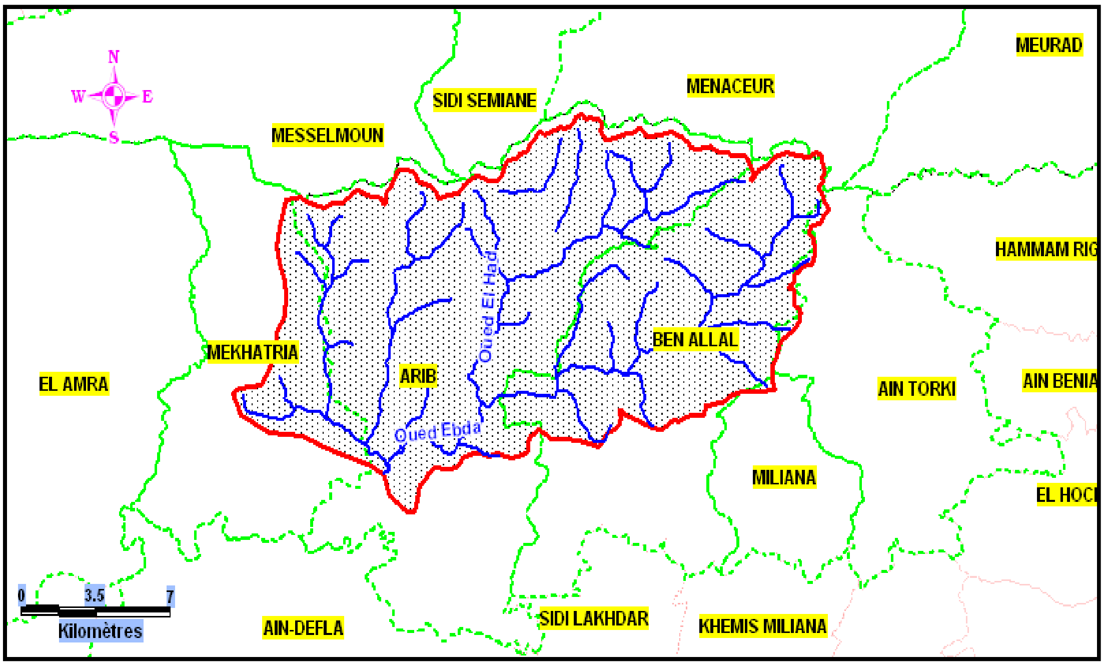

Fig. 1. Situation of Ebda basin, Algeria

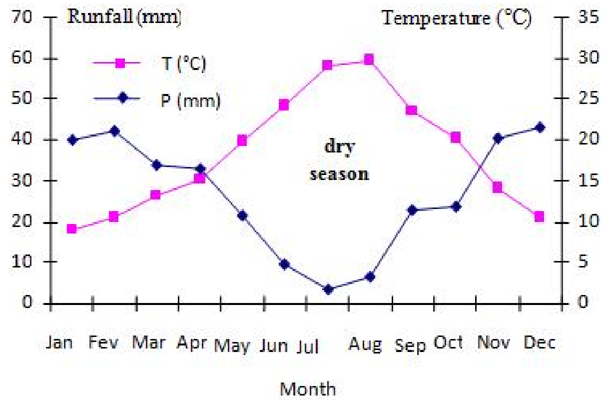

Fig. 2. Ombrothermic diagram, Arib Ebda station, period 1986-2006

571 mm, with irregularities of rains and annual average temperature of 17°C. The station of study of Arib Ebda stream is at the coordinates Lambert (X = 439.65 km, Y = 335.55 km). From the ombrothermic diagram (Figure 2), we found that the dry period in the catchment area of the wadi Ebda is spread over a period of 7 months that is to say the months of May to the month of November.

MATERIALS AND METHODS

The study used instantaneous water discharge values (m^3/s) measured at the hydrometric station of Arib Ebda from 1990 to 2005 (1050 observations), the results were obtained and furnished by the Algerian National Agency of Hydric Resources (ANRH). For measuring values, sediment concentrations (g/l) were evaluated using samples taken from the river. The suspended sediment discharges were calculated by multiplying these concentrations by water discharges. Samples were taken every day or during flood periods, frequently every quarter of an hour. The systematic sampling procedure of the suspended sediments in the Algerian rivers is simple and punctual. The sampling of the charged water is done using bottles from 0.5 to 1 liter capacity, and which are launched either in the current after being ballasted, or hung on a pole or a salmon, according to the conditions of current and of the variations of the dimension of the wadi bed. The collected samples are initially filtered on a Millipore filter and the sediment load is measured by weighing the filters, then the filtered sediments are dried during 30 mn at a temperature of 110°C. Brought back to the unit of volume (1 liter), this load is allotted to the concentration in instantaneous suspension conveyed by the river in g/l. Concerning the evaluation of sediment transport during a rising; it is carried out in the same way that of the water flows, on the basis of examination of recordings. Before the layout of the turbidgamme, the operation of carrying forward on the limnigramme is necessary. The values of concentration in time date are positioned on the limnigramme.

RESULTS AND DISCUSSION

Relationships of models $Q_s = f(Q_l)$

To study the evolution of sediment loads determined from the concentrations and liquid flow rates measured at Ebda wadi, is performed by a timing analysis at different scales. The results (figure 3) show that there is a close relationship between sediment discharge and the liquid flow characterizing the wadi Ebda. This relationship is represented by a law power of in the form $Q_s = a{\times}Q_l^b$. The good correlation in this case can be explained by the effectiveness of the relationship that is to say that the sediment load is a function of liquid flow by the relation $Q_s = a{\times}Q_l^b$. From the figure 3 and the table 1, it is clear that there are good correlations for all scales studied (77% for the series of summer to 84% in spring). The graphical analysis of the figure 3 and the table 1 show good

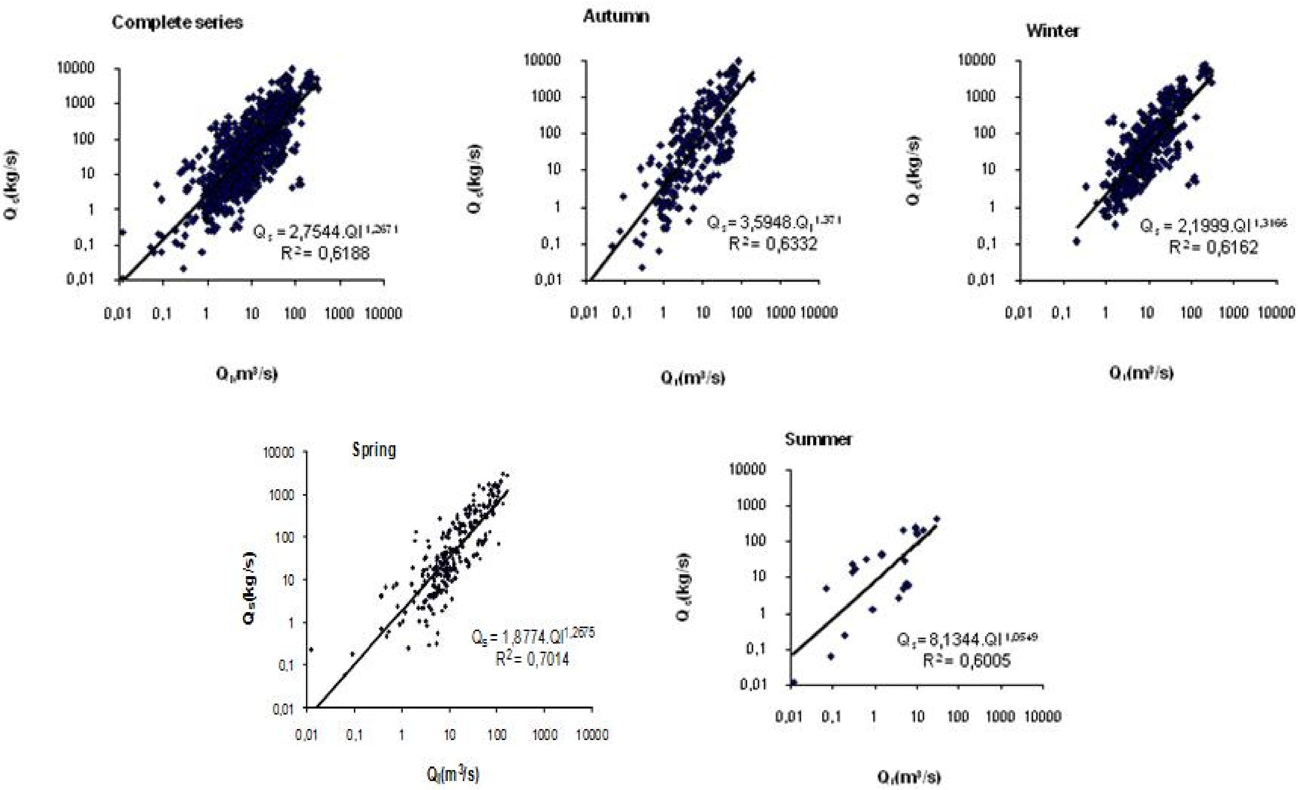

Fig. 3. Correlation between complete series and seasonal solids flow and liquid flow

Table 1. Relationships and determination coefficients of models $Q_s = f(Q_l)$

Temporal scale	Coefficient of determination	Correlation coefficient	Relationships retained
Complete series	0.62	0.79 (79%)	$Q_s = 2.75 \times Q_l^{1.27}$
Autumn	0.63	0.79 (79%)	$Q_s = 3.59 \times Q_l^{1.37}$
Winter	0.62	0.79 (79%)	$Q_s = 2.20 \times Q_l^{1.32}$
Spring	0.70	0.84 (84%)	$Q_s = 1.88 \times Q_l^{1.27}$
Summer	0.60	0.77 (77%)	$Q_s = 8.13 \times Q_l^{1.05}$

Table 2. Some values of the exponent b published for neighboring watersheds

Watershed	Exponent « b »	Authors
Tafna (Algeria)	1,70	Terfous and al. 2001
Haddad wadi (Algeria)	1,45	Achite and Meddi 2004
Mina wadi (Algeria)	1,33	Achite and Meddi 2005
Haute Tafna (Algeria)	1,57	Megnounif 2007
Saida (Algeria)	1,64	Yles and Bouanani 2012
Bellah	1,38	Elahcene and al. 2013
Ebda	1.27	Present study

correlation in the power flow of binder solids in the liquid suspension flows. The points cloud obtained are aligned around the regression line. The power relationship [$Qs = a \times Q_l^b$] has been checked for most rivers of the world (Ferguson 1986; Battala *et al*., 1992; Benkhaled and Remini 2003). The exponent b, based on physical, climatic and hydrological characteristics of watersheds (Bogardi 1974; Vivian 1980; Achite and Ouillon 2007) or hydraulic flow conditions in the course of water (Walling and Webb 1981, 1982; Kattan and Probst 1987) generally varies between 1 and 2. Note that the exponent b in the relationship found in Figure 3 is greater than 1 and less than 2, value similar to that found by researchers who have worked in semi-arid regions (Table 2). For the calculation of daily suspended sediment transport, using the characteristics of Figure 2 for the spring season as their correlation coefficient is closer to unity (R = 0.84). It is reported that this season is season of floods, power is the relationship of the form $Q_S = 1.88 \times Q_l^{1.27}$. This model must be handled carefully to avoid errors that can be generated by the application. The latter being the main factor of sediment transport. The calculation is done on a 16 year period from 1989/1990 to 2004/2005. The results obtained are shown in Table 3.

The table 3 shows that floods are well marked in the watershed of the river Ebda from 1989 to 1990 in 2004/05 are: the flood of January 1992 (2115.153 tons), the flood of September 1994 (682,314 tonnes), flood of April 1992 (643.323 tons), flood March 1991 (618.931 tons) and the flood of February 1996 (615.09 tonnes). The most important sediment transport volumes are concentrated in the months of September to April.

Table 3. Monthly and annual distribution of suspended sediment load in the watershed of EBDA wadi

Year	September	October	November	December	January	February	March	April	May	June	July	August	T_{ss}
89/90	0	0	0	0	0	0	0	1	0	0	15	0	16
90/91	2	123	0	5	3	6	619	7	0	0	0	0	764
91/92	0	340	130	0	2115	271	48	643	55	0	0	0	3602
92/93	0	0	0	0	0	0	0	0	35	0	0	0	35
93/94	0	0	0	0	90	23	0	0	0	0	0	0	113
94/95	682	152	13	285	127	0	388	0	15	0	0	0	1662
95/96	29	72	17	0	22	615	212	378	99	67	0	0	1511
96/97	0	0	0	0	4	0	0	22	11	0	0	0	37
97/98	25	32	230	118	0	37	0	64	818	19	0	0	1043
98/99	0	0	0	0	214	345	477	0	0	0	0	0	1036
99/00	40	0	0	0	0	0	0	0	0	0	0	0	40
00/01	0	0	284	0	539	29	0	0	0	0	0	0	852
01/02	0	22	0	0	0	20	0	0	0	0	0	0	42
02/03	2	2	21	65	400	359	613	65	0	0	0	14	1541
03/04	22	11	36	63	162	17	55	12	18	0	0	0	396
04/05	7	0	73	37	21	54	68	0	0	0	0	0	259
Means	51	47	50	36	231	111	155	74	47	5	1	1	809

Table 4. Some values of specific degradation published for neighboring watersheds

Watershed	Specific degradation ($t\ km^{-2}\ year^{-1}$)	Author's
Maghreb	397	Probst & Amiotte Suchet 1992
Mouilah (Algeria)	126	Terfous & al. 2001
Sebdou (Algeria)	937	Bouanani 2004
Saf Saf (Algeria)	461	Khanchoul & al. 2007
Bellah (Algeria)	610	Elahcene & al. 2013
Ebda (Algeria)	809	Present study

we see that the winter floods and spring floods promote sediment transport because they are not characterized by strong turbulence, due to extreme speeds. We also note that the suspended sediment load is highly variable from one year to another. it varies from 16 t to year 89/90 to 3602 t for the year 1991/92 is a ratio of 1 to 225. The suspended sediment load of wadi Ebda is about 809 t km^{-2} $year^{-1}$. This value is comparable to those found in other regions with similar hydrologic regimes (Table 4).

Conclusion

According to this study, we can conclude that: the transport suspended solids in the river watershed Ebda is mainly during floods. The suspended solids flow rates vary depending on the liquid flow in a law power of in the form $Q_s = 1.88 \times Q_l^{1.27}$. Based on this relationship, we calculated the daily suspended sediment discharge for a period of 16 years from 1990/1991 to 2004/2005.

The results were used to calculate the annual tonnage of material transported in suspension in the Ebda wadi. This model must be handled carefully to avoid errors that can be generated by the application. The results show the existence of relationship between the solid and the liquid flow rate. The importance of the model lies found to fill the gaps. Note that the exponent b of the model is found equal to 1.27, value similar to that found by researchers who worked in areas similar to the site object of the present study hydro-climatic regime. The suspended sediment load of wadi Ebda is about 809 t km^{-2} $year^{-1}$. This value is comparable to those found in other regions with similar hydrologic regimes.

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