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SEDIMENT FLUXES OF THE SEBOU RIVER (MOROCCO).

Souad HAIDA

Université Ibn Tofail, Faculté des Sciences, Département de
Géologie

PO. Box 133, Kenitra, Maroc.

E.mail: souad_hs_haida@yahoo.com

Maria SNOUSSI

Université Mohamed V, Faculté des Sciences, Département des Sciences de la
Terre.

B.P.1014, Avenue Ibn Battota, Rabat, Maroc.

Jean-Luc PROBST

Laboratoire des Mécanismes de Transfert en Géologie

UMR CNRS/Université Paul Sabatier n°5563

38 rue des 36 Ponts, 31400 Toulouse, France

ABSTRACT

Annual pre-dam and post-dam data for one of Morocco's largest rivers, the Sebou, were analysed using their water discharge and suspended sediment loads. Results from these analyses indicated significant reduction of water discharge and sediment fluxes by 70 and 95% respectively. Otherwise, the Sebou reservoirs, suffered from siltation due to the high rate of natural and accelerated erosion. In fact, the trap efficiency calculated for the Sebou dams ranges from 85-99%, and their life-span from 42-910 years. For instance, Al Wahda, the second largest dam of Africa, with a capacity of $3.8 \times 10^3 \text{ km}^3$, takes 374 years to be filled with sediments. This huge siltation has a serious environmental and socio-economical impact, since it reduces the reservoirs capacity, and could affect the morphological equilibrium of the coastline. In semiarid region, environmental impacts of dams are particularly emphasised because of the irregular nature of climate and the intensity of erosive forces.

Key words: Sebou river; water discharge; Sediment fluxes; impact of dams; siltation; trap efficiency; life-span; semiarid region.

INTRODUCTION

Under semiarid climate, the scarcity of the rains constitutes a severe limiting factor of economical development. Considering this constrain, Morocco has adopted, since 1975, a vast programme of dam's construction to irrigate one million hectares before the year 2000 (DRPE, 1994) and to produce 5100 GWh year⁻¹ as hydroelectricity potential capacity. Currently, there are 84 large dams, of

with capacity exceeds $10 \cdot 10^9 \text{ m}^3$. Indeed, the high degree of climatic variability, the torrential nature of storm runoff, the low vegetation cover and the intense lithological vulnerability, have an important impact on mechanical erosion and sediment fluvial transport at dam reservoir (Haida et al., 1996; Probst & Amiotte Suchet, 1992, Lahlou, 1996). This paper provides data on the water and sediment fluxes of the Sebou river. The main objective is to determine the impact of the construction of dams on the water and the sediment discharges of the Sebou river.

DATA

Data on water flows and suspended sediment concentrations used in this study were obtained from three gauging stations operated by the Water Planning and Research Directorate (DRPE) which also kindly provided us with information on the status of dams. These stations were Azib Es Soltane, Mechra Bel Ksiri and Mjara (Fig. 1). Pre-dam water and sediment discharges data were for the period 1940-1972, and the post-dam's for 1973-1997, corresponding to the construction of the Idriss 1^{er} (1973), Allal el Fassi (1990) and Al Wahda (1996) dams.

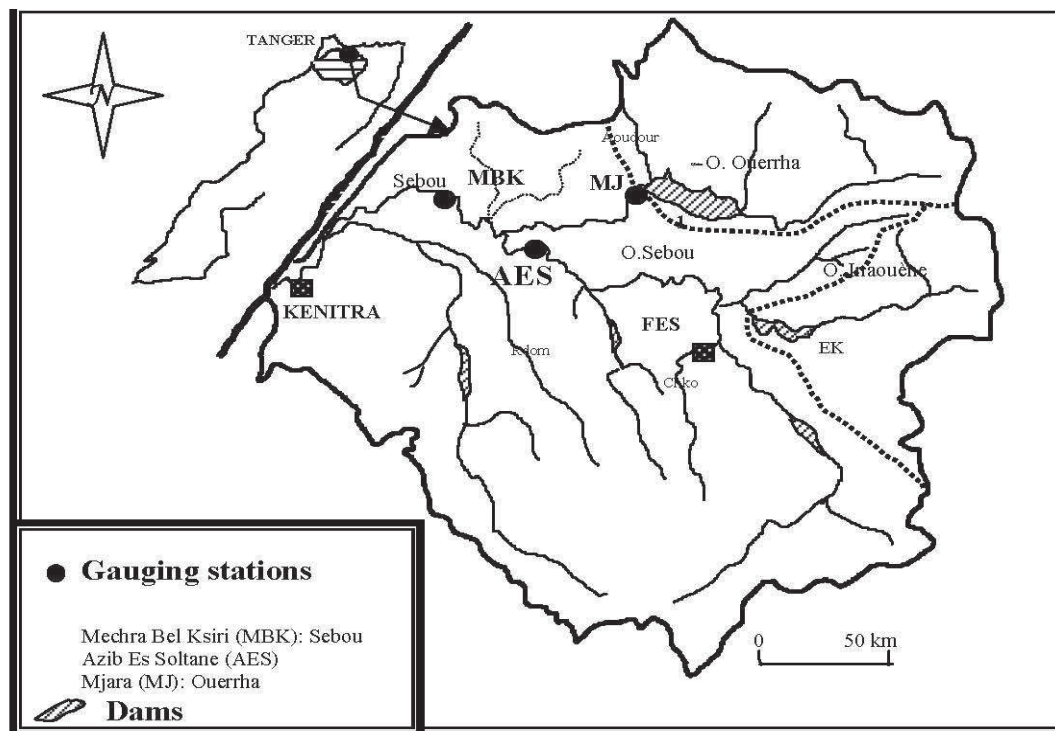


Fig 1. Geographic situation of the Sebou drainage basin showing major dams and gauging stations where data were collected.

METHODS

Sediment fluxes were calculated by the stochastic method based on the product of suspended sediment concentrations weighted by the corresponding water discharges at each outlet station and for each flood period, and the water volume obtained by integrating water flows for the same period. All results on sediment discharges were based on suspended sediment only; no bed load sediment data were available.

Data on the annual water inflows (A) and the storage capacity (C) of the reservoirs were used to calculate the residence time $\Delta\tau_R$ in equation (1) and the trap efficiency (TE) of each reservoir according to the equation (2) (Vörösmarty et al. 1997).

$$\Delta\tau_R = C/A \quad (1)$$

$$TE = 1 - (0,05 / \Delta\tau_{R1/2}) \quad (2)$$

The life-span of the reservoirs was calculated according to Hay's formula (1994) ; Equation (3) where LS is the life-span (in years), W the mean bulk density of sediments ($t\ m^{-3}$), C the storage capacity (m^3), Q_s the average suspended sediment load at a nearby gauging station ($t\ year^{-1}$), and TE the trapping efficiency (%). The bulk density used for calculations is of $1.56\ t\ m^{-3}$ (Sahalash 1982):

$$LS = (W \times C) / Q_s \times TE \quad (3)$$

RESULTS : Impact of dams on water fluxes

As outlined above, the Sebou River system is heavily regulated, thereby significantly altering the flow regime. Haïda (2000) estimated the water discharges before and after the construction of the dams (Table 1). Between 1940 and 1972, the water discharge of the Sebou River and its tributaries was about $5.10\ Mm^3$. The construction of the Idriss 1^{er} (1973), Allal El Fassi (1990) and Al wahda (1996) reduced the inflow volume supply by 56%. Considering all dams, we can estimate that the water discharge of the Sebou River and its tributaries was reduced by approximately 70%.

In order to better show the effect of the dryness on one hand, and the construction of dams on the other hand, on the water flux reduction, we compared the relationship between the annual water discharge and the annual precipitation of the Sebou river before and after damming. The Figure 2 shows a high correlation for the period before the construction of the dams. After damming the water discharges vary independently of precipitation. This indicates that dams regulate the river water flow. This trend could, however, also be caused by the

excessive use of water for irrigation during the drought period, the increase of evaporation caused by higher area of surface water, and the transfer of water to other regions.

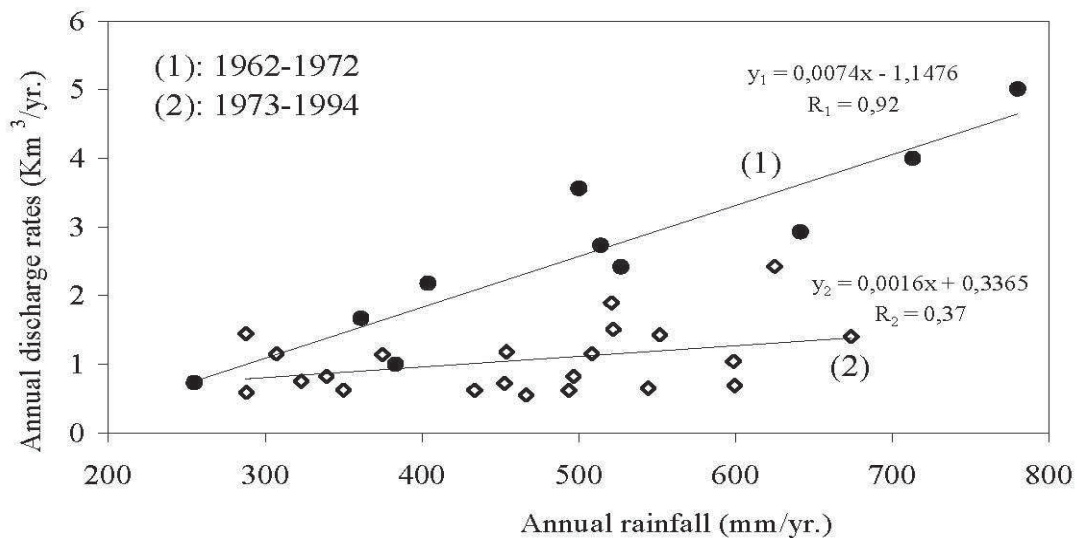


Fig. 2 Relationship between the annual water discharge and the annual rainfall on the Sebou river at Azib Es Soltane before (1962 to 1972) and after (1973 to 1995) dam constructions.

Table 1 : Mean annual water discharges and sediment fluxes measured at Mechra Bel Ksiri Azib Es Soltane, and Mjara stations during the periods before and after construction of dams.

Rivière	Gauging Stations	Surface area Km ²	1940-1972		1973-1997	
			Sediment Fluxes (Mt yr ⁻¹)	water discharge (Mm ³ yr ⁻¹)	water discharge (Mm ³ yr ⁻¹)	Sediment Fluxes (Mt yr ⁻¹)
Sebou	Mechra Bel	26 100	5.10	34.3	2.25	6.57
	Ksiri Azib Es Soltane	16 150	2.55	11.3	0.89	1.73
Ouerrha	Mjara	6190	2.93	25.9	1.64	8.26

Impact of dams on sediment fluxes

The Sebou River basin provides an interesting case study for examining the effects of the construction of reservoirs on river sediment fluxes (Table 1). Before the dam's construction (1940-1972), the average suspended sediment input of the

Sebou River to the Atlantic Ocean was about 34. Mt year⁻¹. After construction of the Idriss 1^{er} and Allal El Fassi dams (1973-1995), the suspended sediment flux was reduced by about 73%. In 1996, when the Al Wahda dam was completed, the sediment discharge measured at the downstream gauging station was no greater than 1.6 Mt year⁻¹. Hence, considering all the reservoirs, more than 95% of the total sediment load has been trapped. In fact, the trap efficiency (TE) calculated for the dams built on the Sebou and its tributaries ranges from 85-99%, and their life-span (LS) from 42-910 years (Haida 2000).

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