SEASONAL DYNAMICS OF TOTAL SUSPENDED SEDIMENT IN WADI EL HAMMAM BASIN (NORTHERN ALGERIA)

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ABSTRACT

The suspended particulate matter (SPM) fluxes temporal variabilities are even more complex than water flows and are therefore very difficult to estimate. Solid transport in Algeria reaches the highest values. The watershed of wadi El Hammam one of the biggest in the northern part of Algeria, is subject to strong water erosion. The present paper is based on discharges and suspended particulate matter concentrations from a 12-years database for the Wadi El Hammam river covering contrasted hydrologic years, Annual SPM fluxes in wadi El Hammam range from 0.5 10^6 t /yr to 7.8 10^6 t /yr.The climate of the catchment is characterized by a marked contrast between dry and humid conditions, with the occurrence of heavy downpours during only a few days of the year. As a consequence, the suspended sediment loads are transported during these events.

Keywords: Erosion, wadi El Hammam, sediment transport, flood, concentration, discharge.

1 INTRODUCTION

The fluxes of sediment into water courses are the reflect of the process of soil erosion and particle transport across the watershed. This sediment transport is performed by different processes, we distinguish in particular the transport of coarser materials (pebbles or gravel, for example) on the bottom of water courses and transport of suspended fine particles (clay, silt or fine sand). This study will only concern the transport of fine particles in suspension.

In arid and semi-arid areas, the quantification of sediment transport by water courses is difficult, because of the irregular nature of the hydrological regime in these basins. Often, most of the discharge occurs during very brief violent floods, and getting samples during these quick events is not easy. However, many studies on the soil of Algeria have shown that they are particularly susceptible to runoff and erosion (Achit et al., 2005; Bouannani, 2004, Chebbani et al., 1999; Demmak, 1982 ; Meguneni et al., 2008; Roose et al., 1999; Terfous et al., 2001; Tixeront, 1960), apart from the high sensitivity of rocks to erosion, large rainfall variations and variations hydrological, the presence of rugged terrain and the poverty of vegetation, are the conditions for training and transportation of materials (Gartet et al., 2005). The materials transported represent a constraint for most rivers equipped with dams . The important sedimentation in reservoirs has led to their progressive silting up (Bouvard, 2004; Remini et al., 2008).

This study investigates the sediment fluxes in wadi El Hammam basin (northwestern Algeria). Our approach is based on an examination of the relationships between discharge and total suspended solid (TSS) concentrations.

2 DATA AND METHODS

2.1 Study location

The Wadi El Hammam basin is located in the north western part of Algeria, draining an area of 8348 km^2 . It belongs to the whole of the coastal basins oranais, particularly to the large basin of Macta (Fig. 1). The basin of the Oued El Hammam, located on the northern flank of the high plains Oranaise, has an elongated shape and its average altitude is 790 m. Around 65% of the area of the basin of the Oued El Hammam stands below 1000 m, 3.6% are more than 1200 m, the highest point exceeding the 1400 m near the confluence of the Macta. The Oued El Hammam is crossed at two points paleo-geographically located in the groove South Tellian: tectonic complex region where sedimentation has produced only waterproof and compressible rocks (marl and clay) or very permeable and inconsistent with the exception of a few hard benches (sandstone, conglomerate and sand more or less cemented) in the northern edge (mountains of Beni Chougrane). Here we find the predominance of marnes colors black, gray and ocher yellow (sandy). The border is (mount of Saida) consists of dolomites overlying limestone. In the center of the plain of Ghriss, there is a filling of clay marl and gray and green. The south (mounts of Dhaya) is covered with marl and sandstone on a rigid base ranging from Tlemcen mountains to those of Saida.

The climate reigning on the basin, typically semi-arid, with an average of 280 mm of precipitation. The pluviometric variations are particularly contrasting rainfall, both in terms of intra-annual qu'interannuel, with years of severe drought. The hydrological regime of the river at the station of Trois Rivières is characterized by its extreme irregularity, both spatial and temporal; the regime is characterized by high water mark of autumn, a winter and spring with moderate flow and a very pronounced summer low flow (Meddi et al.,2009).

2.2 Discharge and suspended sediment data

Suspended sediment concentrations were measured in the Three Rivers station which is located upstream of the dam Bouhanifia and downstream of the dam of Ouizert , during different hydrological conditions (low discharge to severe flood events. The Oued El Hammam has three major tributaries: the Oued Hounet, Oued Melrir and Oued Sahouat (Fig.1). The choice of the Three Rivers station, located at the confluence of three main branches, was based on the availability of instantaneous data discharge and sediment discharge obtained from the National Agency of the Hydraulic Resources (ANRH), the fact that fluid intake is limited to downstream, and because of its smooth operation.

3 RESULTS AND DISCUSSIONS

3.1 Hydrologic regime

The hydro-systems (rivers and streams) are part of the water cycle and as such are influenced by climate and weather conditions (precipitation, evaporation, temperature) and vice versa. Monitoring long-term of the flows on some stations is used to calculate a mean annual flow and highlight changes in flow from one year to the other around this value.

Flows are indirectly related to rainfall. If evaporation is constant over time, the flows follow so the variations of precipitation during this period. The major problem in modeling the rainfall-runoff relationship is the fact that the rainfall does not always flow directly and can be stored in aquifers.

Fluctuations in flows (ΔQ) and precipitations (ΔP) show periods of deficit in red and other excess periods in blue (fig. 2). Generally speaking, changes in precipitation are not perfectly synchronized with those of flows, this "opposition" is probably inherent to the natural characteristics of the basin under study, the river receives support of low water from the dams that store water upstream, or more naturally from the groundwater which are a function of geology, for example. The fig.2 shows also an alternation of humid periods (mid 70s) and dry periods (the late 80s, early 90s).

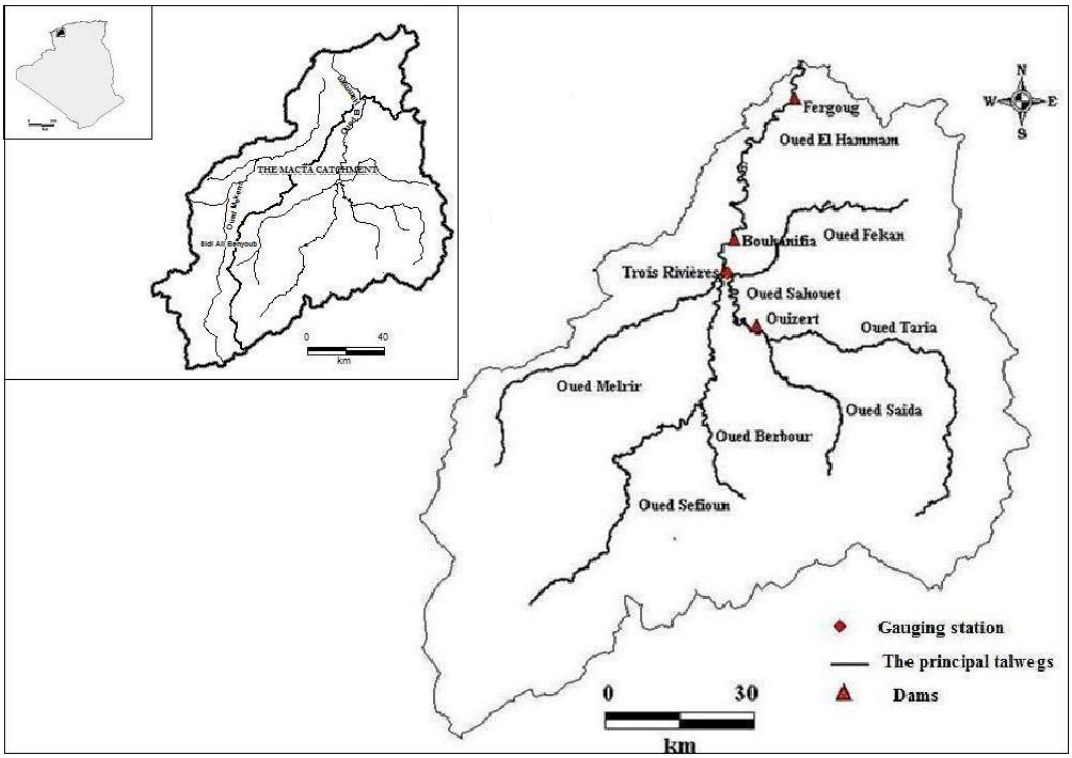

Figure 1. Location of the Wadi El Hammam catchment

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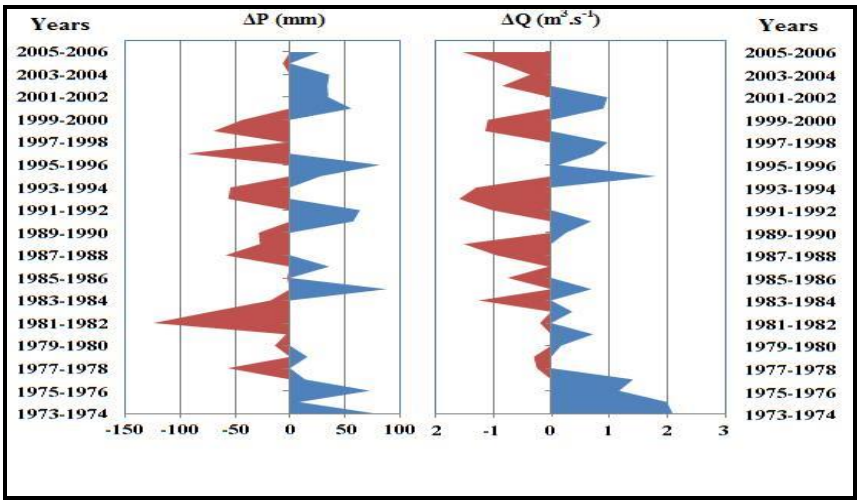

Figure 2.Interannual variations of rainfall and flows around the average interannual for the watershed of Wadi El Hammam(1993-2006)

3.2 Sediment regime

The mean of specific flux over the period 1993-2005 is 256 t/km^2/yr. However, Fig. 3 shows over a period of 12 years a highly irregular interannual sediment yield, these fluctuations are associated with irregular rainfall and thus liquid flows. So the relationship between liquid flow and solid flow shows that in most cases when liquid flows are low, sediment transport is almost non-existent. It may be noted also that the years 1994-95, 2000-01 and 2001-02 have the exceptional peaks representing more than half (67.30%) of total tonnage. Furthermore, it should be noted that although the year 1996-97 has been considered a dry year (rainfall relatively low did not exceed 113 mm), the tonnage of transport in suspension registered is remarkable. This important sediment yield is probably due to the

flood of August 25, 1997 with a maximum liquid flow rate of 1578.4 m^3 / s and a solid flow instantaneous 37802.68 kg / s obtained during the flood peak (Fig.3).

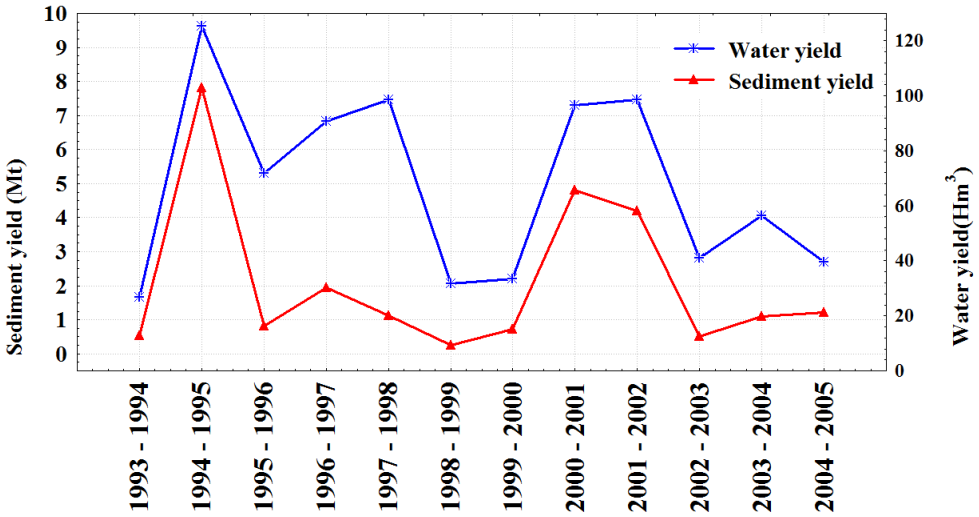

Figure 3. Liquid and solid flow to the station of the Three Rivers (1993-2005)

The highest monthly flows occur in autumn, especially in October (fig.4). Flows that we observe in this season generally come from storms occurring in the basin. During the months of June, July and August, rainfall is low or nil, but summer storms contribute significantly to increasing sediment transport. As an indication 87% of the sediment load is transported in four months: 22.35% in September, in October 50.32%, 8.34% in November and 6.6% in August. During the months of December, January and February, the soil is saturated and cohesive, so that the sediment transport stops during this period due to lack of available.

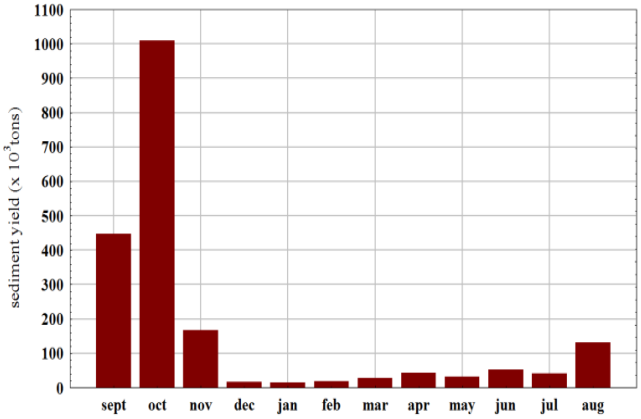

Figure 4.Monthly flows of suspended sédiment in the watershed of the Oued El Hammam (1993-2005)

3.3 Evolution of concentrations of suspended solids during floods

It has often assumed that the flood study can highlight the importance of surface runoff, flow responsible for triggering the process of erosion of soil mechanics. During the hydrological cycle, rainfall of showers occurred in the catchment area play a predominant role in the export of flux of suspended solids. In addition, for a given flow value, the concentrations of TSS may be higher during the climb phase of the flood, resulting in a hysteresis clockwise or orthograde (Bogen, 1980; Walling & Webb, 1981; Asselman, 1999; Sammori et al., 2004) or be more important during the flood recession, while describing a counterclockwise hysteresis or retrograde (Heidel, 1956). The hysteresis clockwise may be related to the exhaustion of the stock of material available before the peak flow

(Williams, 1989) while the counterclockwise hysteresis would be consequent with the existence of distant sources (Heidel, 1956, and Williams, 1989) or the collapse of riverbanks immediately after the passage of the flood peak (Sarma, 1986; Ashbridge, 1995).

3.3.1 Examples of hysteresis during extreme events

Our instantaneous data have allowed to establish hysteresis relationships between flows and TSS concentrations. We have selected some cycles, showing different responses to hydrological changes. In Fig.5 gives as an example the curves corresponding to the floods of 04/11/1994, 27/09/1994, 05/09/1995 and 10/10/2001. Three floods showed hysteresis orthograde, one flood is a retrograde (flood 04/11/1993) .The curves were observed systematically retrograde when the wadi El Hammam shows a flood discharge important. The phase shift between the liquid flow and solid flow may indicate a distant source of TSS from the gauging station. In a manner more fine, hysteresis curves, explaining the dispersion of the scatter plot for flow rates equivalent of orthograde type or the form of eight due to the presence of two buckles. the first loop (fig.5 floods : 05/09/1995 and 10/10/2001) can be attributed to contributions in TSS substantial increase in leaching rates, the second loop correspond to an additional source (resuspension) that seems to appear when the flow exceeds a certain threshold(Mano, 2008).

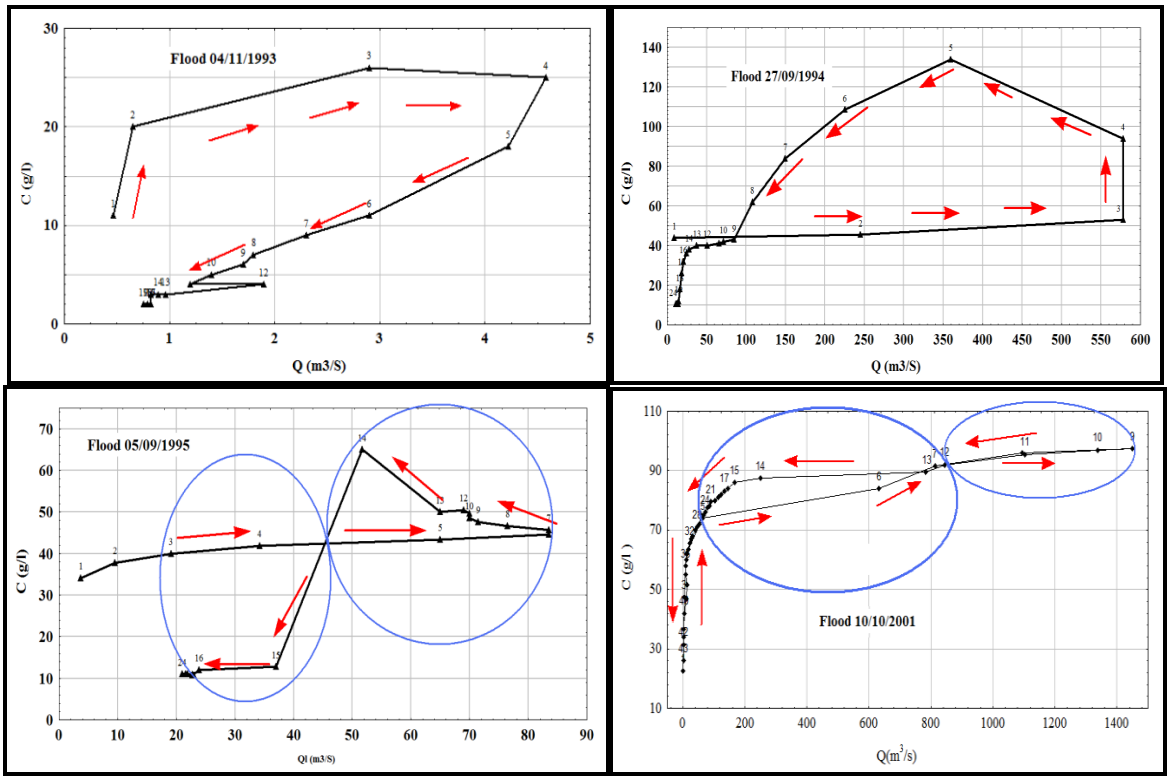

Figure.5 Example of variations of instantaneous concentrations in TSS with instantaneous flows (Q)during floods

4 CONCLUSIONS

In this study, a great number of data on the transport of total suspended solids in the Têt River have been explored in order to get an estimation of the sediment export from the river . For the period (1993-2005), our results indicate a sediment yield for the entire basin of Oued El Hammam in the range of about 256 $t \cdot km^{-2} \cdot yr^{-1}$. This average sediment yield can be compared to the basin of Wadi Sikkak 170 $t \cdot km^{-2} \cdot yr^{-1}$, the Wadi Isser 180 $t \cdot km^{-2} \cdot yr^{-1}$ (Bouanani (2004) [8]). Nevertheless, one has to point out that the temporal variability, both in terms of seasonal and inter-annual variability, of the sediment transport in wadi El Hammam is very high, making it difficult to get more reliable estimates, unless the river is not continuously surveyed with automatic sampling and monitoring equipment.

The identification of a relationship between liquid and solid discharge at instantaneous scale, from data analysis, is not straightforward. The chronological evolution of TSS concentrations and flow rates associated during flood can observe hysteresis loops, clockwise and anti-clockwise, at the basin.

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