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MORPHOLOGICAL EFFECT OF FLOOD WATER PATHWAY IN RESERVOIRS ON THE DISTRIBUTION OF SEDIMENTATION

Nsiri Ines[1*], Tarhouni Jamila[1], Irie Mitsuteru[2] and Ben Ali Hassen[1]

[1] National Institute of Agronomy, nsiriines@gmail.com

[2] University of Tsukuba, irie.mitsuteru.fu@u.tsukuba.ac.jp

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Abstract: In the North Africa countries, sediments deposition in the reservoir dams reduces the available surface water resources by 2 to 5% per year. In Tunisia, even many efforts are made to protect reservoir dams against soil erosion, the sedimentation still very important and constitute a limitation their time duration. In order to better understand these phenomena, bathymetry, turbidity, suspended soil particles and sediments were monitored for two reservoir dams in Tunisia: Joumine and Sejnane. These data will be interpreted in order to better characterize the sedimentation process and identify the determinant factors. Geostatistical Technics are applied to the bathymetric data in order to simulate the evolution, in time and in space, of the morphology of the reservoir dams and to estimate the distribution of the sediments deposits. The results for the two dams will permit to better understand the influence of the initial geometry of the reservoir dams on the sedimentation process and to deduce the main water flow path lines. Turbidity, suspended particles and sediments particles size profiles established for fixed stations in the reservoir dams will be interpreted in order to better understand the sedimentation process in the reservoirs dams and to characterize the influence of the initial reservoir geometry.

Keywords: Bathymetry, Geostatistical Technics, reservoir dams, Turbidity, sedimentation, soil erosion, suspended particles

* Correspondence to: Nsiri Ines. E-mail: nsiriines@gmail.com

INTRODUCTION

The studies of erosion, sediment transport and reservoir sedimentation in North Africa, have progressed considerably during the last years because of their effect on the reduction reservoirs' storage capacity and water resources threats.

The degradation of surface water resources in North African country such as Tunisia, due to sedimentation on reservoir, reaches nearly 1% (Irie *et al.*, 2011). Therefore, monitoring, protecting, and improving the quality of water in reservoirs is critical for targeting conservation efforts and improving the quality of the environment (Nellis *et al.*, 1998).

To assess the impacts of sediments on the surface water, two dams were chosen namely Joumine and Sejnane; these are representative of the north dams in Tunisia.

In this study, at first, the localization and characteristics of Joumine and Sejnane dams are defined. Secondly, the interest was focused on the bathymetry measurements and their spatialization on the basis of variograms and kriging techniques. Finally, the profiles of turbidity and suspended solids were established.

SITE DESCRIPTION

This study concerns two dams located in the north part of Tunisia: Joumine and Sejnane, at Mateur – Bizerte basin (**Fig. 1**).

Joumine and Sejnane are earthen dams. The water of Sejnane's dam is used for drinking water supply, irrigation and water transfer towards Cap Bon as well as to the center of the country. Besides, the water of Joumine's dam is used for irrigation of 1500 ha in the plains of Mateur, for drinking water supply of the regions of Bizerte, Tunis, Cap Bon and Sahel and provides agricultural water needs at Cap Bon area. The main characteristics of these reservoirs dams are summarized in the **Table 1**.

This work is focused on the interpretation of the sedimentation process in the reservoirs dams by the interpolation of bathometric data and the establishment of turbidity and sediments particles profiles.

BATHOMETRIC DATA

Bathometric measurements were carried out in September 2009 in Joumine's reservoir dam and, in June 2011, in Sejnane's reservoir dam. Simultaneously, the X and Y coordinates were determined by GPS and the water depth with the Sonar of HDS-7 (Lowrance USA).

To produce a continuous bathymetric map, it is necessary to interpolate the survey data. The bathymetric surface was interpolated with kriging as Triangular Irregular Network (TIN). Kringing is a geostatistical method for interpolating a surface from point data. Elevations are interpolated from the original data points to regularly spaced grid. The interpolation is based on a global weighting scheme derived from the data variance. The graph relating the variance of the difference in value of a variable at pairs of sample points to the separation distance between those pairs define the variogram. This relationship can in addition be calculated for different direction.

Let Z be a random function of punctual supports S_i such as {i = 1 ... n}, h any vector and any angle θ, the experimental variogram γ * can be directional or omnidirectional, it is written, according to Matheron (Elkamel, 2009):

$$\gamma * (h) = \frac{1}{2n(H,\theta)} \sum_{i=1}^{n(h,\theta)} [Zi - Zi + h]^2 \qquad (1)$$

where n(H, θ) is the number of pairs whose points are spaced by h and direction θ and Zi represents the random function Z in point S_i. This equation is usually called estimator "Matheron" or estimator "classic". Using the bathymetric data measurements, experimental variogram was calculated by the Variowin software 2.21 and fitted with one of several equation, such as linear, spherical, Gaussian, exponential or circular, a modeled variogram is then established. The modeled variogram constitute the basic function of interpolation by kringing. Furthermore, the comparison of directional variograms constitutes a useful tool to characterize the heterogeneities; in the case of reservoir dams, this will indicate the flow path lines and the solid deposits area.

Table 1: Characteristics of the dams

Dams	Local authority	Date of construction	Area of catchment (km^2)	Water level (NGT)	Surface (ha)	Volume (Mm^3)
Joumine	Bizerte	1986	418	86,5	660	130
Sejnane	Bizerte	1994	367	95,1	790	138

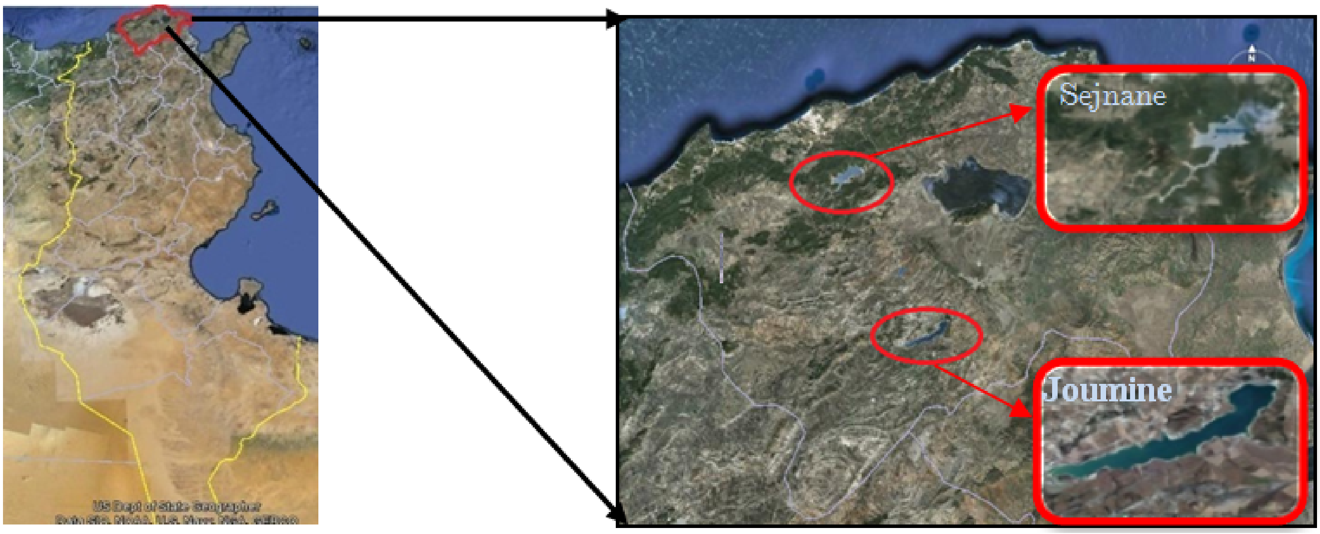


Fig. 1 Localisation of the sites.

TURBIDITY AND SUSPENDED SOLIDS

As water turbidity is mainly induced by the presence of suspended solids, turbidity measurement has often be used to calculate fluvial suspend sediments concentrations (Wass *et al.*, 1997).

The multi-parameter water quality meter permit the measurement of vertical profile of several kinds of water quality parameters in a few minutes by just descending the meter from water surface. The surveys were carried out monthly in some points along longitudinal transect for each dams: Joumine and Sejnane .The measurement of turbidity was one of these parameters. Indeed, turbidity is a reduction in water clarity because of the presence of suspended matter absorbing or scattering downwelling light (Grobbelaar, 2009).

From the depth of the highest value of turbidity, water sampling was collected to determine the suspended solids. Turbidity as a surrogate measure of suspended solids has several limitations. Conventionally, suspended solids were quantified directly through collection of a sample of water followed by filtration of this sample through a dried and pre-weighed 0.7 mm pore-size glass fiber filter (Bilotta & Brazier, 2008). Suspended solids are operationally defined as the mass retained on the filter per unit volume of water (mg L^{-1}).

Turbidity and suspended particles profiles established for fixed stations in the reservoir dams (**Fig. 2**) give an idea about the sedimentation process in the reservoirs dams and permit to characterize the influence of the initial reservoir geometry.

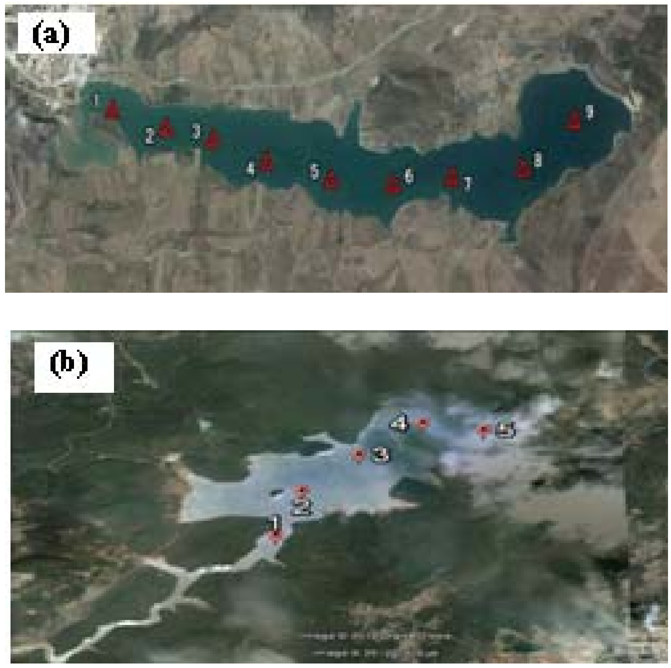


Fig. 2. Stations of sampling in Joumine's reservoir dam (a) and Sejnane's reservoir dam (b).

RESULTS

Bathometric data interpretation

In the case of Sejnane reservoir dam, the global and the directional variograms are modeled by bounded models with spherical type which is indicative of depth continuity in space. The pairs of points whose distance < 500 m, are practically in the same depth. Beyond 500 m, there are large variations in depth (**Fig. 3**).

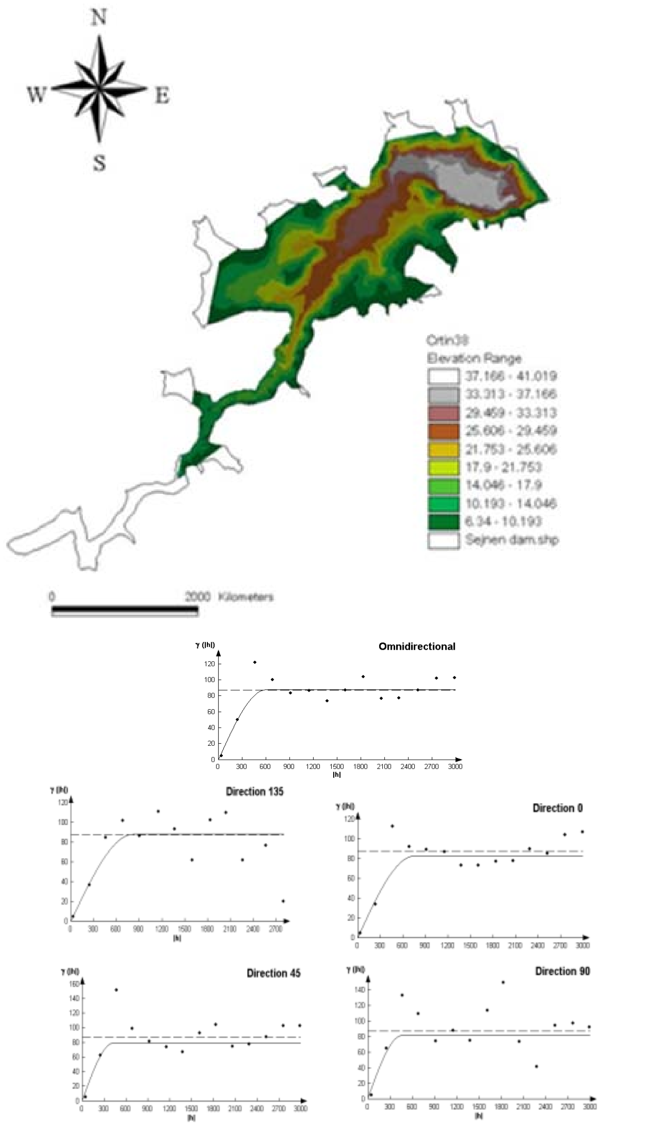


Fig. 3 TIN Map and Global and Directional variogram of bathymetry (Sejnane's dam).

In the case of Joumine reservoir dam, the global and the directional variograms are modeled by unbounded models with power type which is indicative of the presence of derive in all directions. The directional variograms show fluctuations specially the vaiogram with direction, north-east/south-west, It shows that the depth has a spatial variation (**Fig. 4**).

By the comparison between the current bathometry and original topography for each reservoir dam, thickness of sedimentation is estimated. For Joumine reservoir dam, the channel of original topography was firstly covered by the sediment from upper to lower. In addition, sedimentation spreads on the upper side and lower side separately though the middle area has thinner sedimentation. Especially, on the lower side, there is notable sedimentation near by the intake tower. (**Fig. 6**)

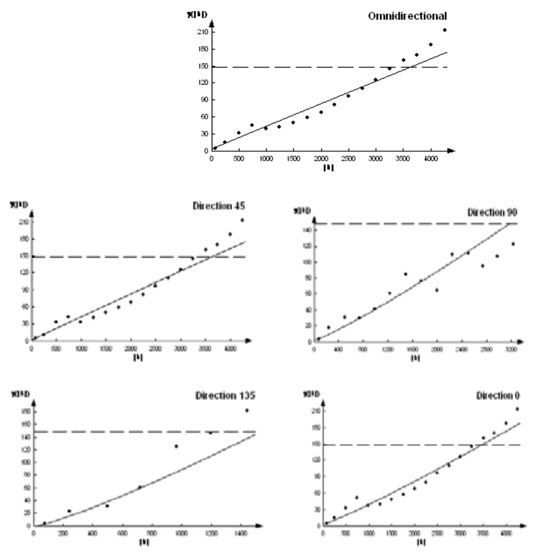


Fig. 4 Global and Directional variogram of bathymetry (Joumine's dam).

After calculating and constructing variograms, the interpolation of bathymetric data was carried out by the use of the global variogram for each dam. The bathymetric maps were drawn by the use of the software surfer 8. (**Fig. 4**)

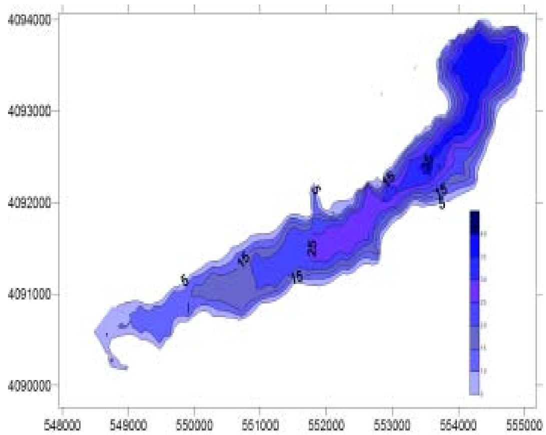
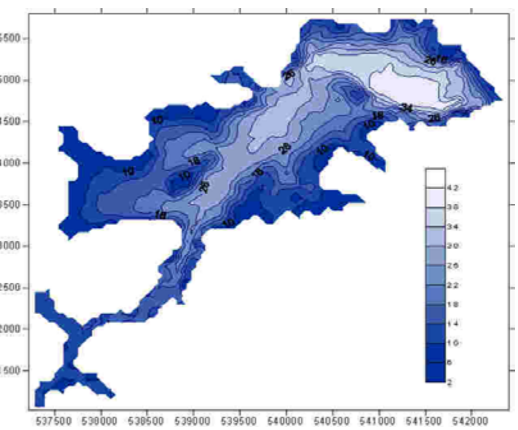


Fig. 5 Bathometric maps of Joumine (2009) and Sejnane (2011).



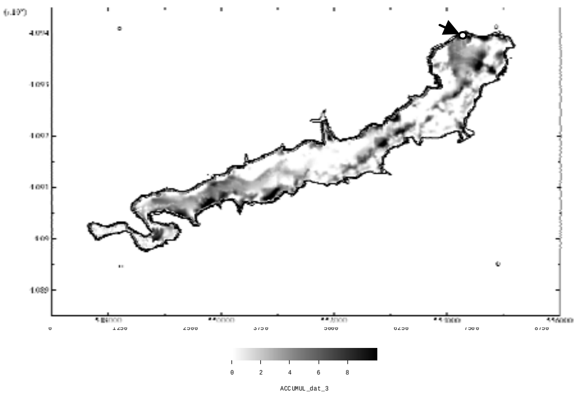


Figure 6. Sedimentation map of Joumine (2009).

The current in the reservoir was driven only by wind or natural phenomena. But since 1999, in Joumine reservoir, the environmental flow has been discharged only when big flood occurs in rainy season. The objective of this water discharge is the environment conservation of Ichkel. The water intake for the environmental flow makes a current near the bottom because water intake gate of the tower is placed just above the bottom. Therefore, the turbid water from the upper river, which had high density flows nearby the bottom and it was easily conveyed to the lower side with the current by the intake. In case of Joumine reservoir which has a longitudinal shape, and the distance from inflow to the intake gate is so long (3 km), the movement of turbid water and particle settlement is more complicated than the case of Sejnane reservoir. Sejnane reservoir is characterized by rounded shape and short distance from the inflow to the intake gate. The higher sedimentation is near by the intake tower.

Comparing the current bathymetry and topography of the initial restraint, sediment thickness is determined for each dam. The sedimentation in reservoirs shows a notable soil loss in the watershed of Joumine and Sejnane. Such as, the Joumine watershed losses about 123 mm of superficial layer due to erosion and about 96 mm in Sejnane watershed.

Table 2. Water loss due to silting

	Joumine		Sejnane	
	1986	2009	1994	2011
Capacity of the dam (Mm^3)	120,5	108,7	138	132
Volumes of sediments (Mm^3)	11,8		6	
Annual water volume loss (Mm^3)	0,513		0,352	
Average loss of soil (m^3/ha/year)	1227,27		959,13	
The thickness of the layer eroded per year (mm)	123		96	

TURBIDITY AND SUSPENDED SOLIDS PROFILES

Individual events are identified with different symbols, illustrating changes in the nephelometric turbidity-sediment concentration relationship from March to September for Joumine reservoir dam and Sejnane reservoir dam.

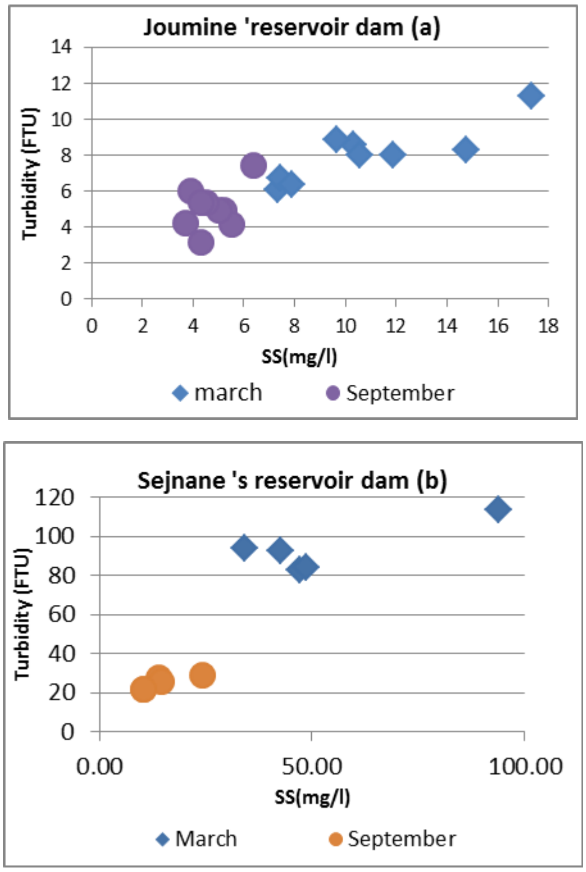


Fig. 7 Plot of in situ turbidity and sampled suspended sediment in Joumine reservoir (a) and Sejnane reservoir (b).

An approximately linear relationship between suspended sediment concentration and turbidity can be estimated for both of dams (**Fig. 7**). Spatial and temporal variation in the physical character of the sediment will introduce a degree of disperse to the relationship between suspended sediment concentration and turbidity (Bilotaa & Brazier, 2008)

Turbidity and SS values decrease from the inflow to the intake gate. A high turbidity reading can be recorded without necessarily involving a high SS concentration. Since turbidity readings are influenced by the particle size and shape of SS, the presence of phytoplankton, the presence of dissolved humic substances and the presence of dissolved mineral substances (Bilotaa & Brazier, 2008).

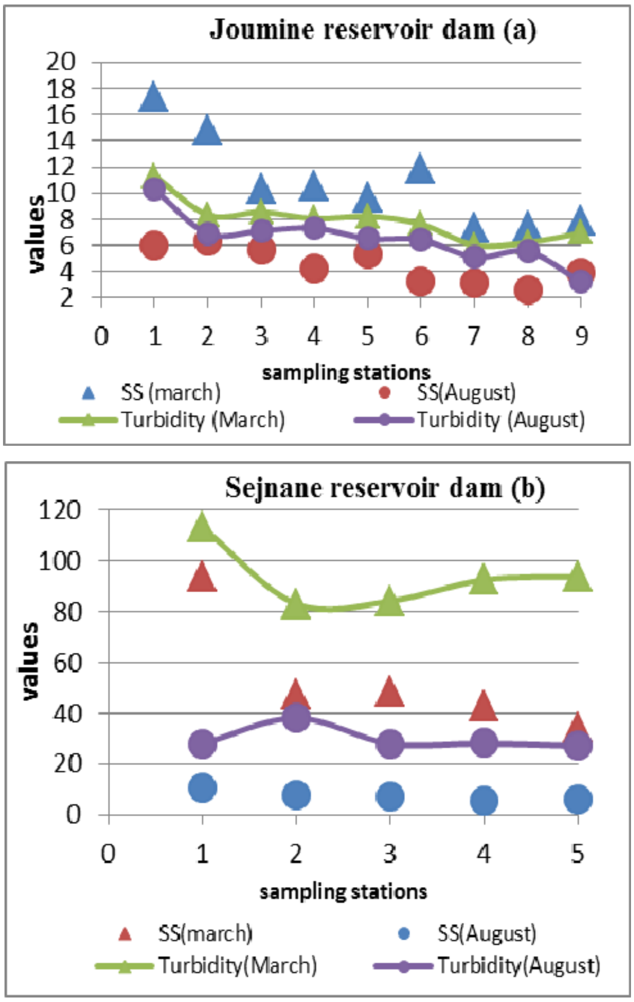


Fig. 8 Profiles of the evolution of turbidity and sampled suspended sediment in Joumine reservoir (a) and Sejnane reservoir (b).

Suspended solids become stable and decrease in the dry period due to the absence of precipitation. Thus, bathometric surveys can be done.

CONCLUSION

To control the storage water capacity of reservoirs, bathometric surveys are crucial. It should be done during the dry season since there is a stabilization of the suspended solids. Therefore the water quality parameters should be observed to discuss the mass transfer in the water body and to assess the sedimentation risks and its impacts on surface water availability. Indeed, the accumulation of sediments in reservoirs is related to environmental parameters such as land use, soil characteristics and thermal stratification of the water body as well as plankton blooms and suspended solids in the reservoir dam.

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