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Water quality of a recent lake reservoir in a semi-arid climate; Yacoub El Mansour (Morocco)

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Abstract

A spatiotemporal study of the water physico-chemical quality was realized on the reservoir Yacoub El Mansour, located in the Province of El Haouz, on the N'fis River, 65 km South of Marrakesh. According to the bi-monthly sampling at the station 'dam' at different depths (0, -1, -2.5, -5, -10, -15, -19.5m, 1m of the bottom and the bottom), using a Van Dorn bottle, and on two littoral stations located at the entrance of reservoir. The trophic level of the reservoir lake was examined using enriching nutrient (phosphorus), transparency of water and chlorophyll *a*. The data related to these indicators during this study helped to establish the trophic level of the reservoir lake.

Keywords: trophic level; Reservoir Lake; physico-chemical quality.

I. Introduction

In Morocco, the general hydrological context remains mainly influenced by an annual irregularity and an inter-annual variability of rainfall with an alternation of strong hydraulicity as well as sequences of drought, this alternation being a dominant hydrological regime.

Because of the lack of water resources, the only way to master and store the surface water is using dams [3]; the dam reservoirs are subjected to serious anthropic and climatic impacts often due to dysfunction but also, in some cases, to the threat of total destruction. The scientific and socio-economic interests of the natural environment is not demonstrated as an area with rich and varied natural 'wetland' resources (within the meaning of the RAMSAR Convention, 1971). Therefore, an ecological study of these vulnerable areas is required.

In the region of Marrakesh, the main plan for the integrated development by the water resources of Tensift El Haouz's pond recommended the establishment of the Wirgane dam in N'fis River upstream of Lalla Takerkoust dam [17]. This lake reservoir has been recently built (2008), for this reason there is almost no hydrologic data. However, similar studies were applied on different dams in Morocco (Tifnouti, 1993, Cherifi and Loudiki, 2002 …). The objective of this work is to study the water quality in the Yacoub El Mansour reservoir through monitoring the physical and chemical descriptors (transparency, temperature, pH, conductivity, dissolved oxygen, suspended matter, total phosphorus, orthophosphates, Nitrites, Nitrates, Ammonium and chlorophyll *a*). The analysis of the results concluded from this study enable us to minimize the impact on the environment and to manage the dam effectively.

II. Materials and methods

1. Study area

The Yacoub EL Mansour dam is located in N'fis' river, 65 km south of Marrakesh city. It is about 20 km upstream Lalla Takerkoust dam and 1.5 km north of Wirgane village. Thanks to its reserve of 70 million m^3, the dam allows improving the capacity of regulating the N'fis' River in Lalla Takerkoust dam as well as decreasing the loss of water which used to go towards downstream. The dam is set in a concrete which is compacted with a ruler. It is 70 m in height and 233 m in crest length. This dam enables us to increase the volume of N'fis inputs, this volume being 68-85 million cubic meters per year (figure 1).

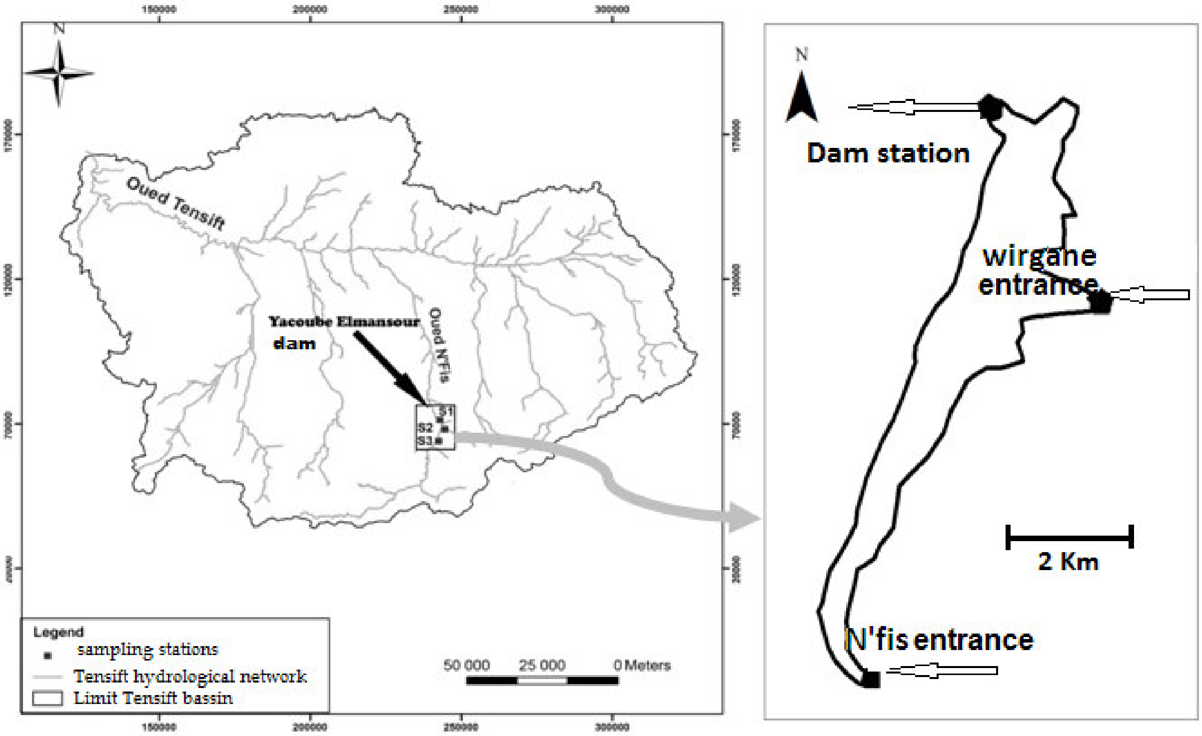

Fig1 : Geographical location of the dam Yacoub El Mansour in the Tensift El Haouz basin (a) catchment area of the Tensift River and (b) the reservoir lake with the different stations.

2. Sampling

The measurement spots are distributed among several stations in the same area and on several depths of the same station. In our study we analyzed two axes of variation: the spatial axis is related to the depth, the thermal and physico-chemical stratification of the lake, and the temporal axis during a biannual cycle. The different sampling stations are as follow:

- ✓ A dam station (S1), located at the bridge that was sampled at different depths:
  Surface area, -1, -2.5, -5, -10, -15, -19.5m, 1m of the bottom and the bottom.
- ✓ Littoral stations: (S2) located at the entrance of the Wirgane River and (S3) located at the entrance of the N'fis River.

3. Analysis in situ

Temperature, pH, dissolved oxygen and conductivity are measured in situ using a multi-parameter probe (wtw.multi 340i/SET). The water transparency was evaluated using Secchi disk (CLARKE, 1941). The depth at which the disk is not any more visible indicates the transparency of the water which is expressed in meter; this depth makes it possible to calculate the thickness of the euphotic zone (Zeu). This later is determined using the equation (1):

$$\mathbf{Zeu = DS \times 2,56} \qquad \mathbf{(1)}$$

4. Laboratory analyses

Suspension substances were determined after the filtration on a 0, 45µm Millipore membrane (T90-105 AFNOR). The nitrogen ammoniac ($N\text{-}NH_4$), Nitrites ($N\text{-}NO_2$) and Orthophosphates ($P\text{-}P0_4$) were measured using a standard AFNOR (T90-015,013,022). Nitrate ($N\text{-}NO_3$) was measured by colorimetric after reduction on a column of cadmium (RODIER 7éme ed.).

The total phosphor (P-PTot) is determined in the field water after the mineralization (AFNORT 90-023). The method we used to measure chlorophyll *a* was recommended by ISO (1992): a sample of 500 ml of water, taken on the same levels as those retained for the physicochemical indicators, is filtered though a Whatman membrane GF/C (porosity 0, 45 µm and 4.7 cm in diameter). The extraction of the collected pigments was obtained by immersing the filter in 10 ml of ethanol 95% after boiling it, then the sample was incubated for 24 hours at a temperature of 4°C in the dark. The sample was put into a centrifuge of 4000 G for 15 minutes. The optical densities of the extract are measured at 665 and 750 nm before and after acidification with HCl (1 mole/L). Chlorophyll content was determined by the formula (2):

$$\mathbf{Chlorophylle}\ a = \mathbf{29.62\ (665a\text{-}665b)^{*}Ve/\ (Vs^{*}L)\ en\ \mu g/l\ (2)}$$

- 665 a = corrected absorbance DO 665 - DO 750 before acidification.
- 665 b = corrected absorbance DO 665- DO 750 after acidification.
- Ve = Volume of ethanol extract (ml).Vs = Volume of the filtered sample (l).
- L = width of the cuvette (cm).

III. Results and discussion

The temperature of the water lake is one of the main factor explaining the biological behavior of the ecosystem; figures 2(a) and 2(b) which represent the evolution of temperature profiles during 2012 and 2013. Water was colder in February 2012, with a minimum of 13.8°C and 12°C in January 2013 and higher in August with a maximum of 35°C in 2012 and 28.9°C in 2013. Concerning the vertical water profile, it was slightly colder at the bottom compared to the surface. In January 2012, the lake thermal homogenization was observed; however, from the beginning of July to September, there was a remarkable increase in air temperatures as well as in the durations of insolation. This leads to the installation of a thermal stratification at the surface. As a result, the vertical mixture was gradually blocked. In 2013, the warming of the surface water and the stratification started from April until August. The thermocline was established between 2.5 and 10 m over all the period of stratification (April-August). Takerkoust dam Lake had also a period of thermal stratification in spring and summer (Tifnouti, 1993), while there was no observed thermal stratification at Daourat lake reservoir (Benzha, 2005). The temperature had the same seasonal evolution in the two littoral stations and varied between 14.7°C in January and 35°C in August. Let us note that the inputs of the N'fis River and Wirgane River present frequent periods of drought. The pH was slightly alkaline. It was between 7 and 8.8 at the dam station and did not exceed 8.5 in Wirgane station and 8.8 in N'fis station (figure 3). The minimum values were recorded in February, while the highest value was recorded in September, at - 10 m from the surface. This value was due to the consumption of CO_2 by photosynthesis, the acid-base balance of the surrounding was changed and the pH increased. When the later increases it modifies the calco-carbonic balance and supports the precipitation and the sedimentation of calcium carbonate [2]. Dissolved oxygen content varied between 2.3 mg/l in November and 8.35 mg/l in January (Figures 4(a) and 4(b)).This content gradually decreased with the depth. Lower values are related to the biological activity of the degradation of an organic substance and to the strong stratification limiting epilimnion-hypolimnion exchanges, and leading to the deoxygenation in the hypolimnion [2]. This deoxygenation is very low at Yacoub Elmansour reserve which is probably due to the strong wind and dropped dam allowing the mixing of the water column. This mixture helps re-oxygenate the bottom from the surface layers. In the surface layers (0 to 10 m) oxygen supersaturation appears, due to an intense photosynthetic activity. This supersaturation was first observed on the surface, gradually sinked with the thickening of the epilimnion as well as the evolution of dynamics of algal populations between spring and summer [10].

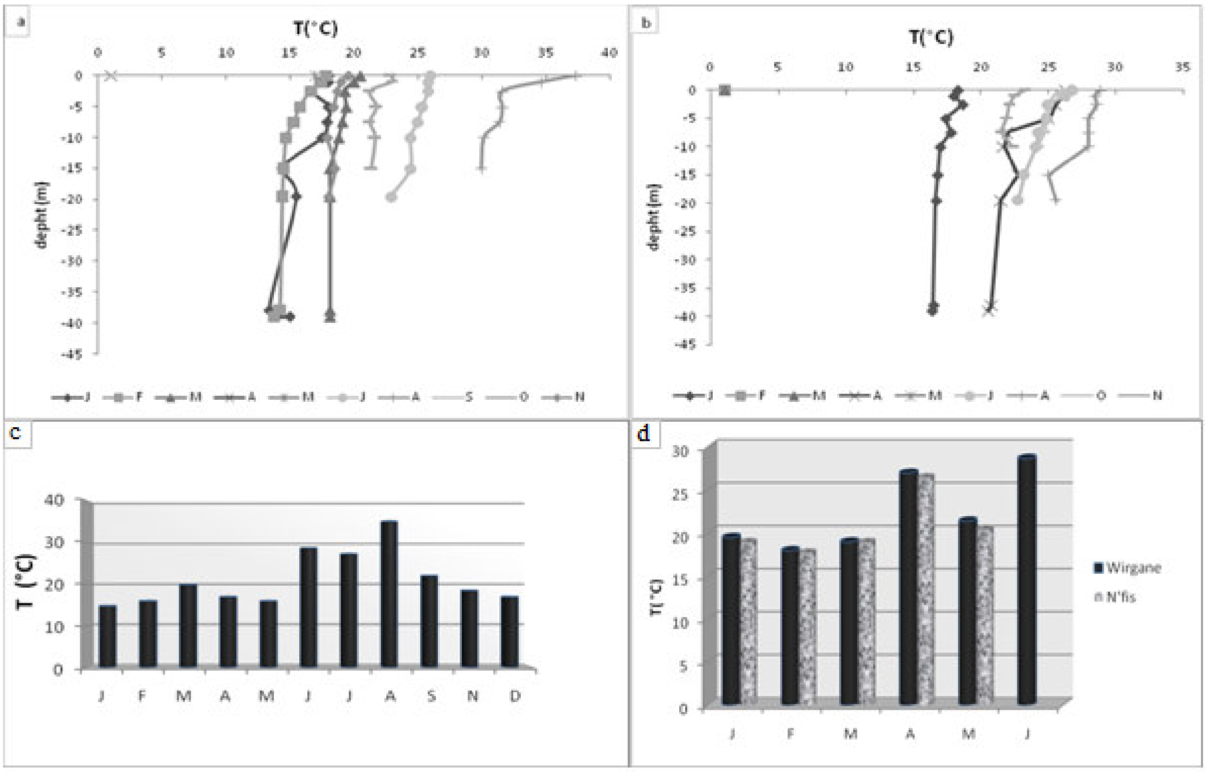

Fig 2: vertical profiles of water temperature at the dam station S1: (a) in 2012 and (b) in 2013 and variation of T° at littoral stations (c) in 2012 and (d) in 2013

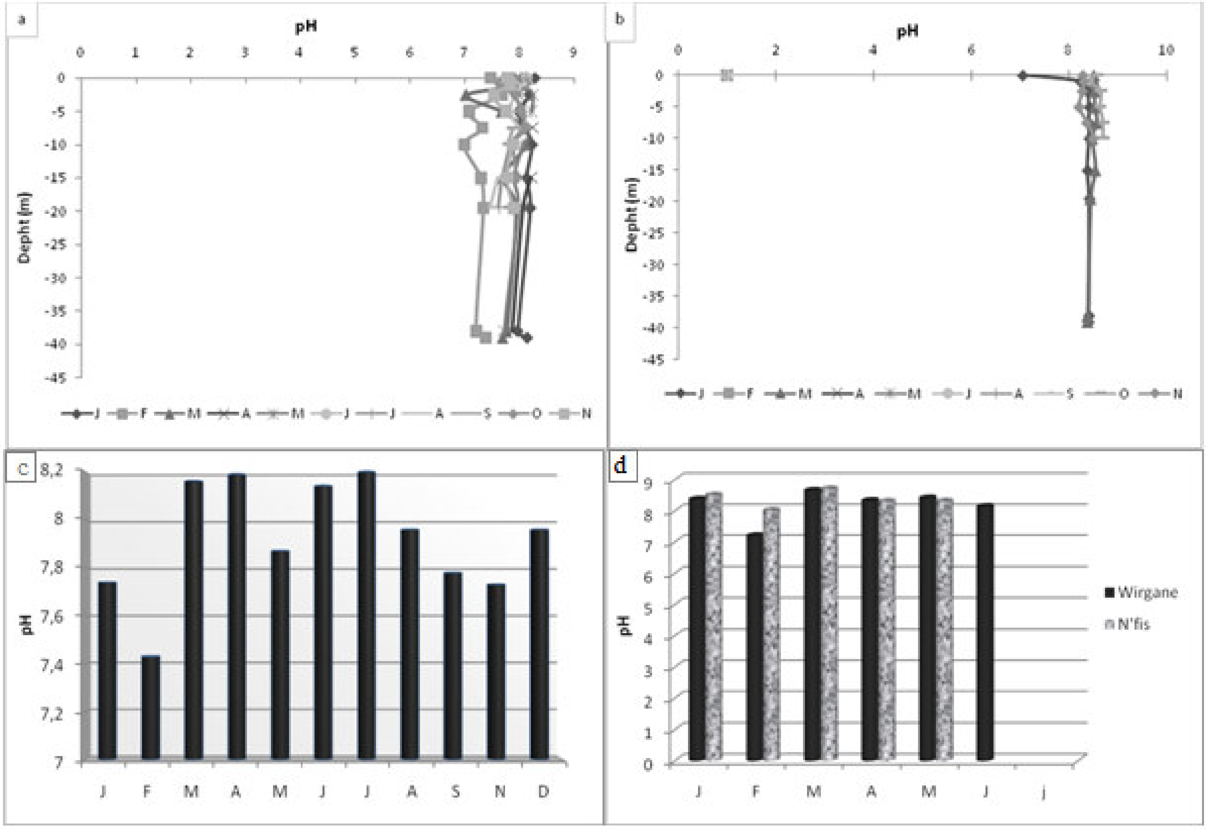

Fig 3: vertical profiles of the pH at the dam station S1 : (a) 2012 and (b) 2013 and variation of the pH at littoral stations (c) 2012 and (d) 2013.

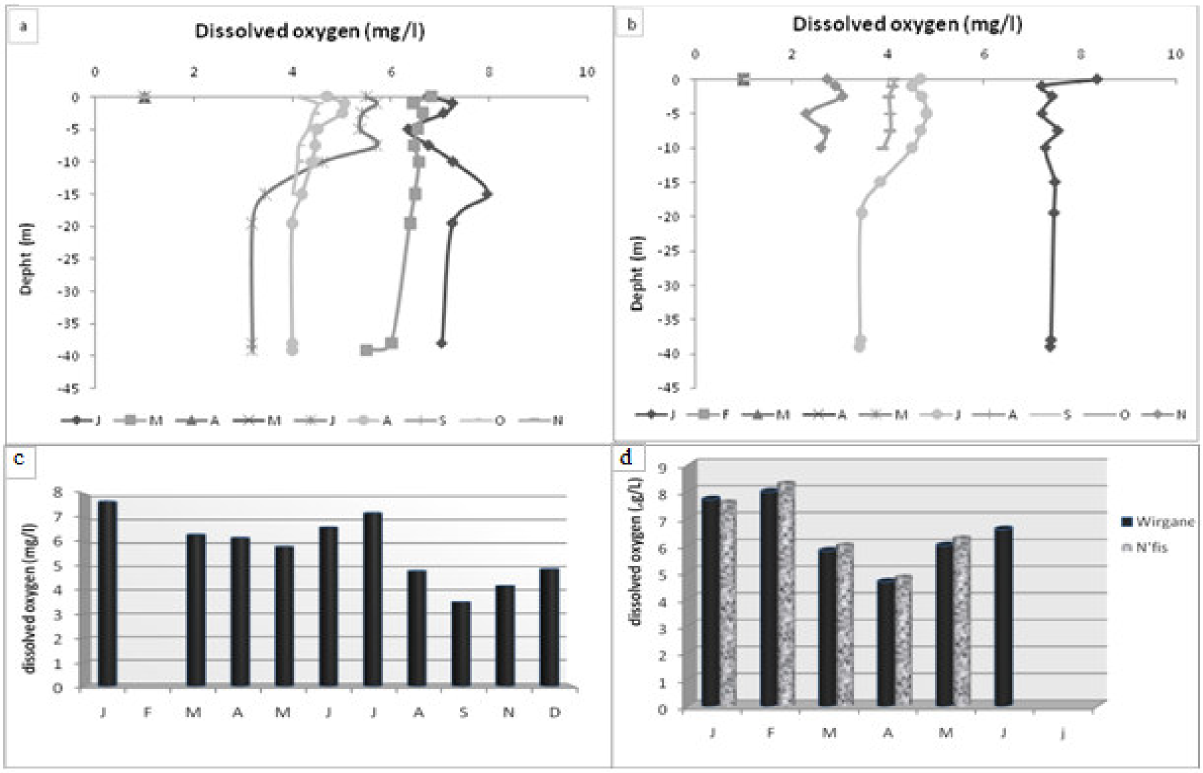

Fig 4: vertical profiles of dissolved oxygen content at the dam station S1: (a) 2012 and (b) 2013 and variation of dissolved oxygen content at littoral stations (c) 2012 and (d) 2013.

The Figures 4(c) and 4(d) show that the two littoral stations are more oxygenated in January (7.76 mg/l) and less oxygenated in September (3.5mg/l). Conductivity values recorded during the study period, ranged from 299µS/cm to 600µS/cm at the dam station (figures 5(a) and 5(b)) and between 177µS/cm and 512µS/cm at littoral stations (figures 5(c) and 5(d)). The highest values were recorded during October-November. It is due to the mineralization of organic substance by bacterial activity and deoxygenation, which causes the release of several salts [2]. The conductivity values were almost homogeneous in the entire water column but there was a decrease in mineralization at -15 m in May 2012. This homogenisation was also observed at Lalla Takerkoust dam reservoir (Chérifi 1992). On the contrary, there was a sudden increase of the conductivity at -5 m in October 2012. All the inorganic nitrogen was formed essentially of $N0_3^-$ which varied between 10 µg/l in August and 1162.3 µg/l in October at the dam station (figures 6(a) and 6(b)) with a maximum value of 1260.9 µg/l in May for the N'fis station and 865.8 µg/l for the Wirgane station (figures 6(c) and 6(d)). The Nitrites varied between 49.2µg/l in November and 446µg/l in September during the year 2012. In 2013 their values varied between 19.68µg/l in October and 1548 µg/l at the bottom in June (figure7). The concentration of ammoniacal nitrogen was high in the reserve during August (1074µg/l) in the first year of study; however, it was high in the second year both in August and September (485µg/l) (figure8). These high values were probably related to the degradation of organic material process which released ammoniacal nitrogen that accumulated without continuing its oxidation to nitrite, and then into nitrate, because of lack of sufficient oxygen [2]. During winter, the mixing induced a decrease of the nutrient stock throughout the water column. It also produced the homogenization of this element in the water column. Ammoniacal nitrogen was very dynamic in the epilimnion because it was rejected, by the zooplankton. In the hypolimnion, it is formed by the reduction conditions. In 2013, the ammoniacal nitrogen concentration increased continuously at the bottom. Phosphorus was present in various forms in the lake. We analyzed the reactive soluble form: orthophosphate, total phosphorus, the latter including dissolved phosphorus and particulate phosphorus. In general, the evolution of orthophosphate during the period of study showed high concentration during the floods. These contents ranged from 72.6 g/l in February and 487.08 g/l in January (figure 9(b)). In spring and summer, the contents were very low or absent because of the absorption by the algae. The reservoir Yacoub El Mansour had high concentrations of total phosphorus which varied between 20 g/l in May and 524.8 g/l in September (fig9 (a)). The measure of chlorophyll *a* is the indicator of the phytoplankton biomass. The maximum chl *a* content was 2.7 mg/l; it was recorded during June. The annual average of chlorophyll *a* in the reservoir was 0.6 mg/l. The vertical evolution of chl *a* at the dam station (figure11) showed a decreasing gradient to the bottoms. Yet, on the level of the littoral stations, the contents were under the limit of detection. At the oligotrophic Bin El Ouidane dam lake the annual average of chl *a* was below 2 $\mu g.L^{-1}$ (Chérifi and Loudiki 1999).

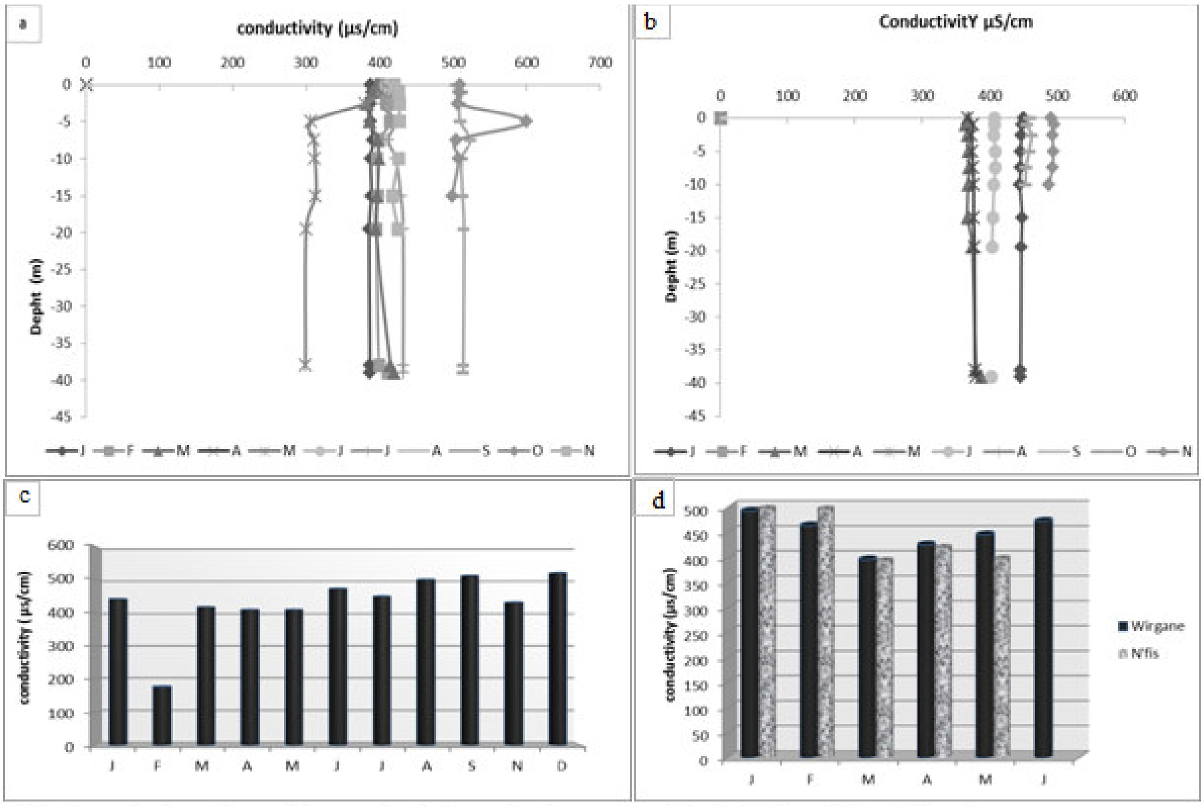

Fig 5: vertical profiles of the conductivity at the dam station S1: (a) 2012 and (b) 2013 and variation of the conductivity at littoral stations (c) 2012 and (d) 2013.

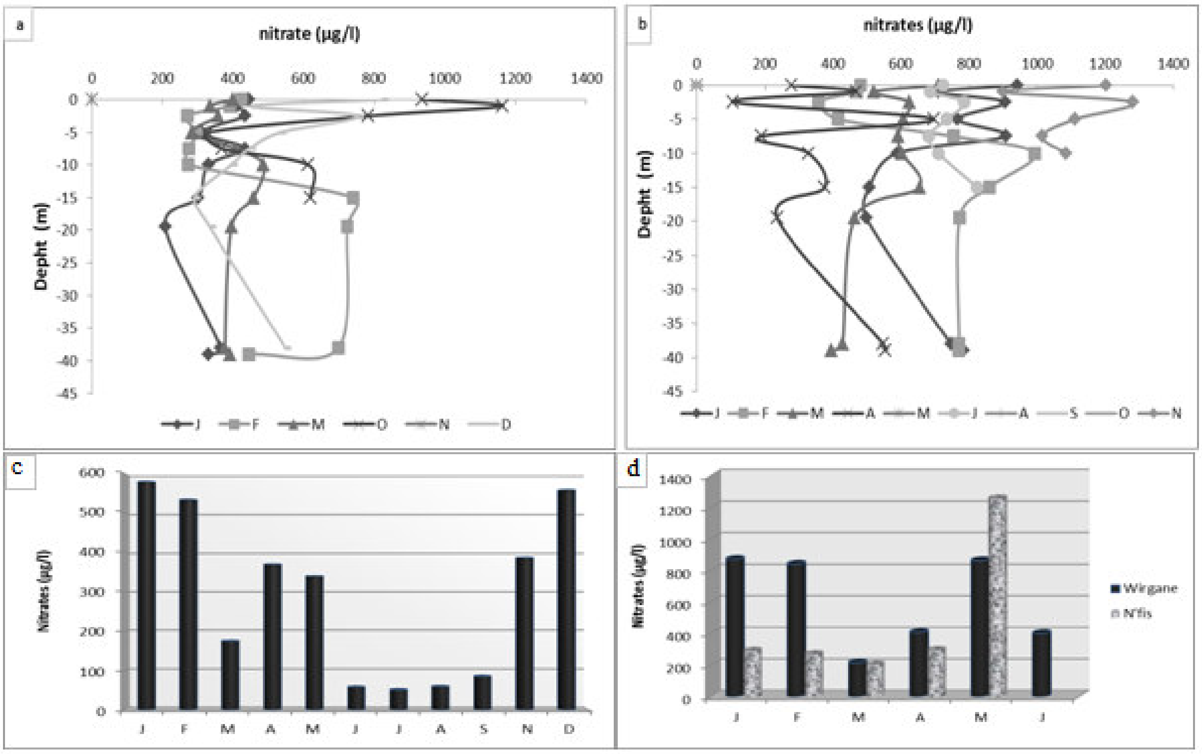

Fig 6: vertical profiles of NO_3^--N at the dam station S1: (a) 2012 and (b) 2013 and variation of NO_3^--N at littoral stations (c) 2012 and (d) 2013.

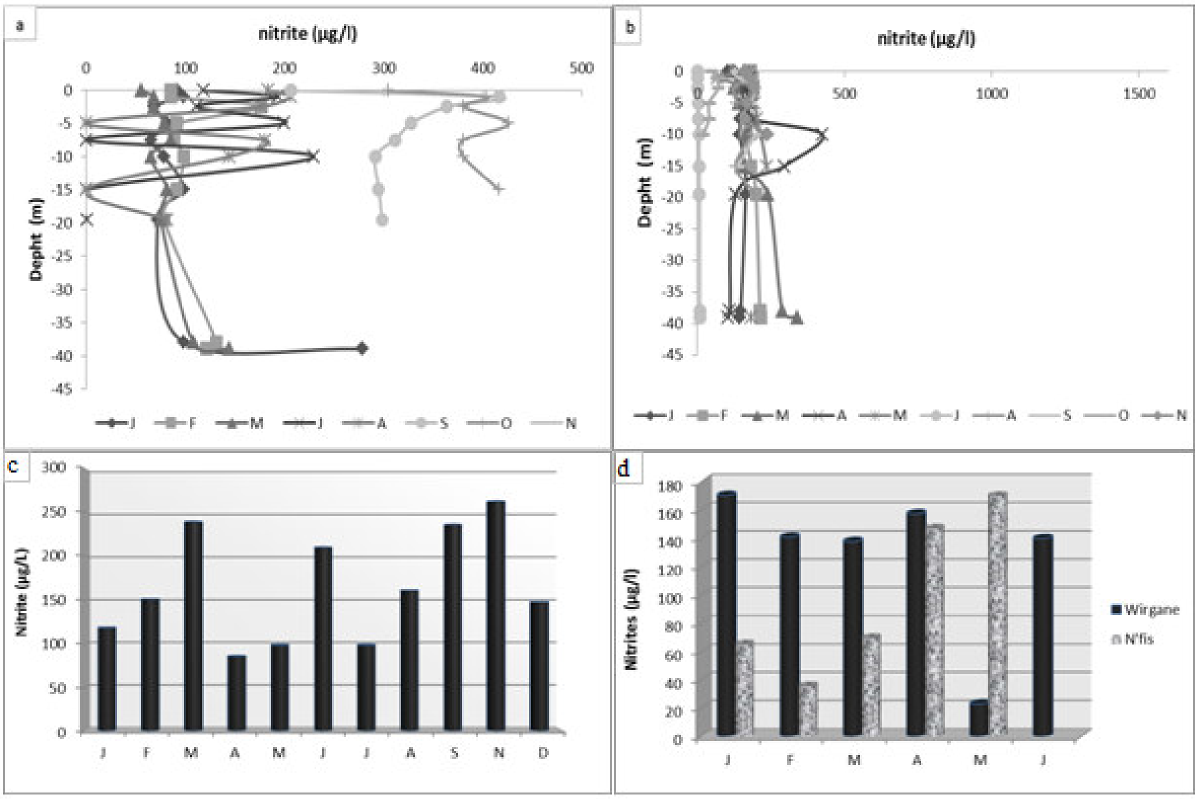

Fig7: vertical profiles of NO$_2^-$ - N at the dam station S: (a) 2012 and (b) 2013 and variation of NO$_2^-$ - N at littoral stations (c) 2012 and (d) 2013.

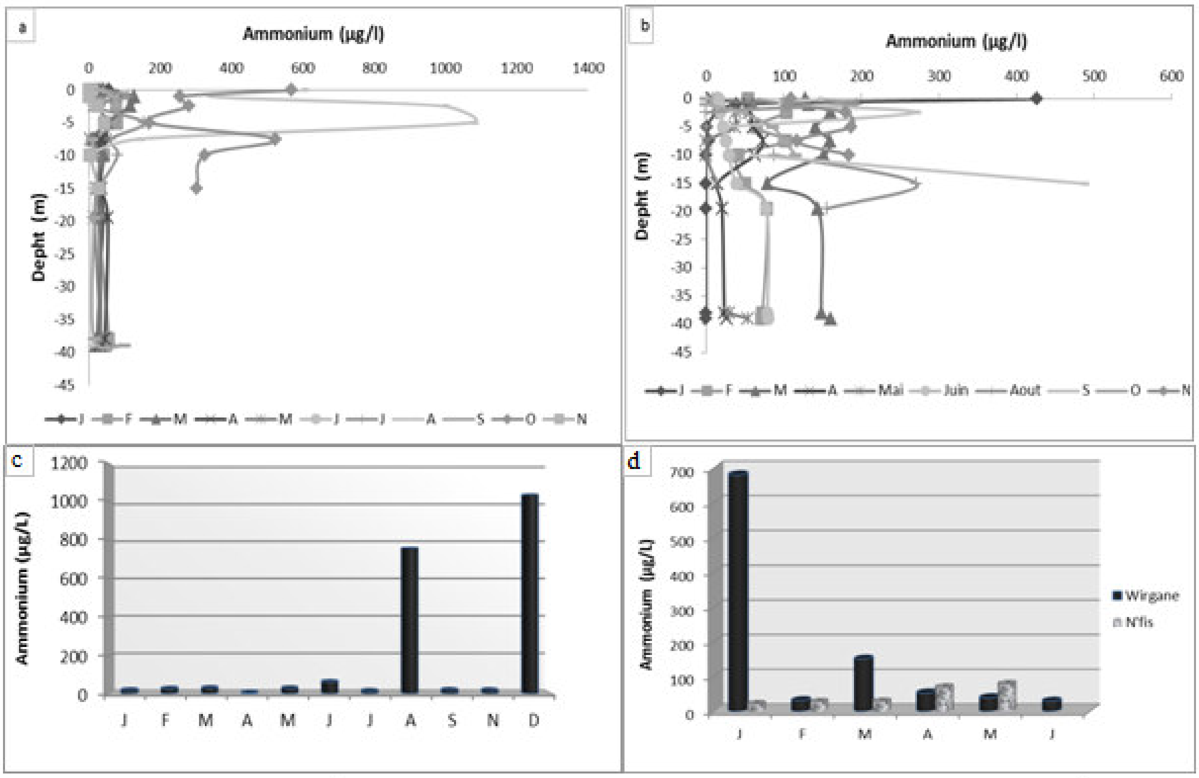

Fig8: vertical profiles of NH4$^+$- N at the dam station S1: (a) 2012 and (b) 2013 and variation of NH4$^+$- N at littoral stations (c) 2012 and (d) 2013.

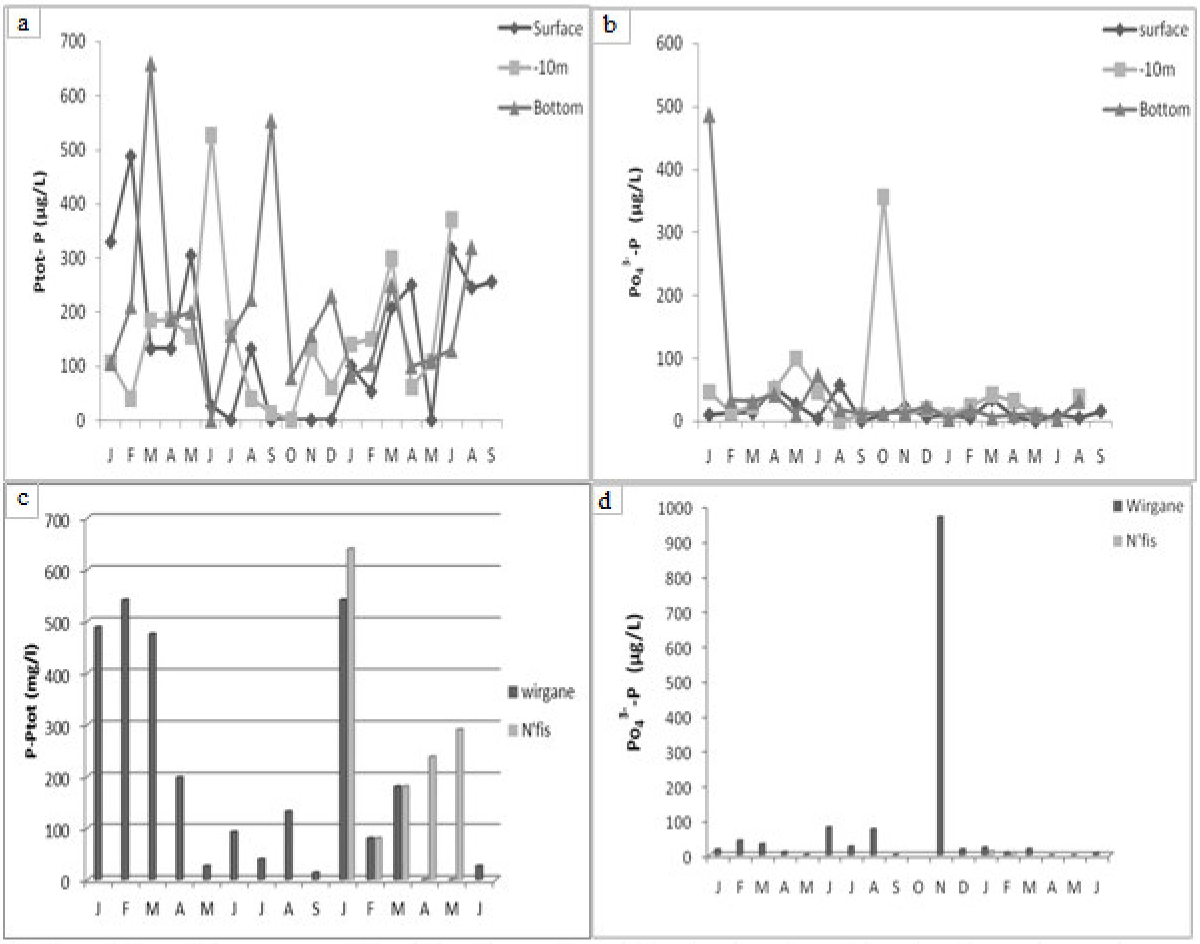

Fig 9: variation of the contents of total phosphorus (a) and of orthophosphates (b) at the dam station, and at littoral stations (c) Pot-P and (d) Po$_4^{3-}$-P.

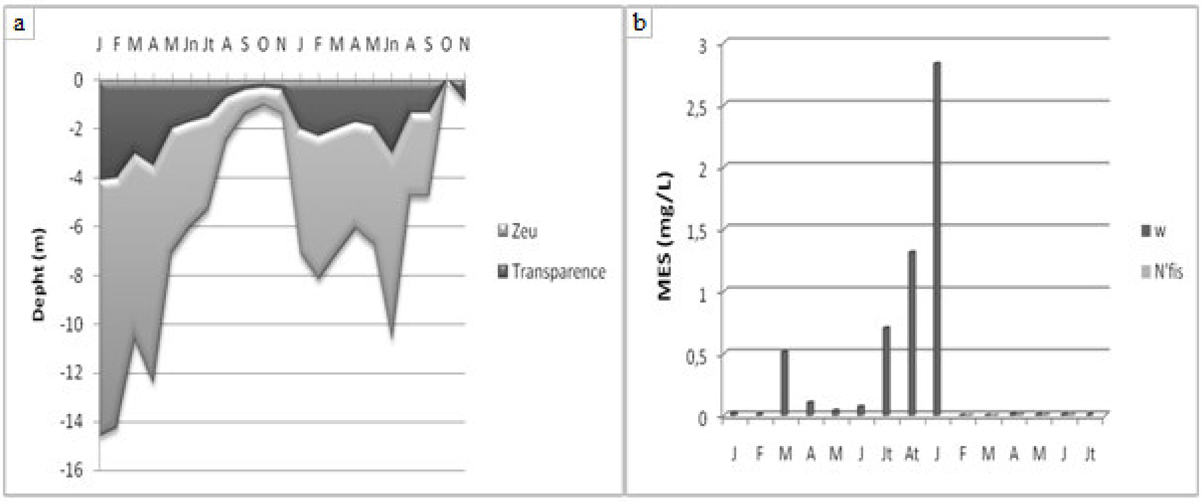

Fig 10: variation of the depth of the sechi disc (Transparence) at the dam station (a) and variation of the contents of the suspended matter at littoral stations (b).

The annual average measured using a Secchi disc, was 1, 9 m, with a maximum of 4.1 m in January and a minimum of 0, 9 m in November. The high values were mainly due to the suspended matter and to the development of the phytoplankton in the water column. The contents of suspension matter generally did not exceed 3 mg/l for the two littoral stations, whereas they were very weak at the dam station.

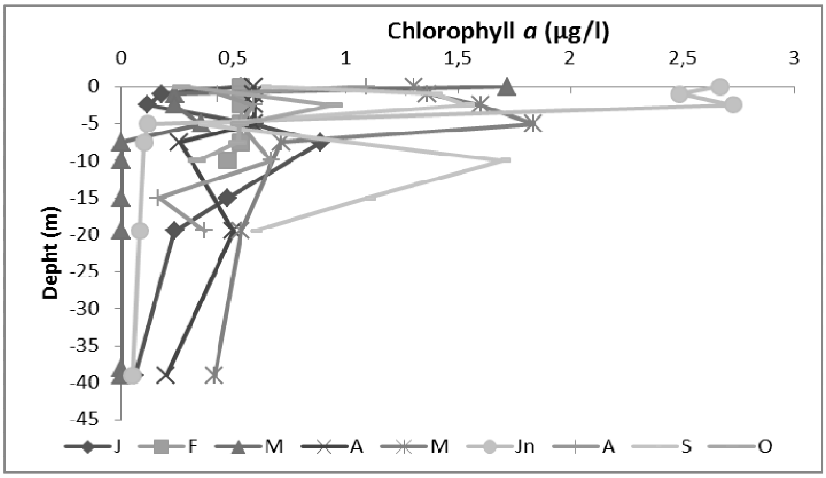

Fig11: vertical profiles of the contents of chl *a* at the dam station in 2013

Table1: Pearson Correlation between physical and chemical variables.
* Correlation is significant at the 0.05 level (bilateral).
** Correlation is significant at the 0.01 level (bilateral).

	N-NO^{3-}	**N-NO^{2-}**	**N-NH^{4+}**	**ORP**	**PT**	**pH**	**T**	**COND**	**OD**	**MES**	**Chla**
N-NO^{3-}	1,000										
N-NO^{2-}	,004	1,000									
N-NH^{4+}	-,055	,093	1,000								
ORP	-,069	,073	-,019	1,000							
P T	-,248**	-,137	,094	-,014	1,000						
pH	,023	-,073	-,047	-,113	,008	1,000					
T	-,303**	-,009	,337**	-,070	,024	,246**	1,000				
COND	,030	,251**	,310**	-,036	-,154*	-,061	,081	1,000			
OD	-,027	-,347**	-,131	-,028	,091	-,121	-,465**	-,246**	1,000		
MES	-,416*	,461*	,173	,124	-,246	-,222	,303	,284	-,583**	1,000	
Chl a	-,294**	-,019	-,060	,009	-,011	-,029	,219**	,092	-,102*		1,00

The Correlation analysis of the various variables (table 1) shows that, N-NH$_4^+$ is significantly correlated with T as well as COND, as well as the pH with T. We also found that T and chl *a* were negatively correlated with DO and N-NO$_3^-$. This can be explained by the fact that when the water column temperature is higher, the phytoplankton grows. This leads to a greater consumption of oxygen to oxidize the nitrogenous elements within the environment. Consequently, a reduction of N-NO$_3^-$ and DO is observed. The latter, is also negatively correlated with the suspended matter (MES), N-NO$_2^-$and COND whereas the ORP has no correlation with other physico-chemical factors. The trophic status of the dam was examined using nutrient enrichment (total phosphorus), chlorophyll *a* and water transparency. The data collected with regard to these three indicators, showed according to the O.C.D.E model (1982), that the reserve is hypereutrophic, based on phosphate concentrations and eutrophic when transparency is considered, while it's oligotrophic according to chl *a* values. The physico-chemical factors do not seem to be good descriptors of water quality of the reserves located in semi arid areas because of the particulate solid charge which is not bio-available for phytoplankton. In contrast, the concentration in chl *a* seems to be representative of the trophic status because it gives a more reliable idea of the algal development. Similar results were already demonstrated in Morocco, in some lake reservoirs (Smir and Sahla, El Ghachtoul 2005). However, in France, in the Marne lake reservoir, the ecological characteristics of the reserve resulting from the phosphate concentrations are always better for the trophic level evaluation than that provided by the concentrations in chl *a* (Roland and Jacquet 2010).

IV. Conclusion

Most of the work related to the evaluation of the dam trophic level involves mainly temperate areas, and mathematical models are established for these regions where the phenomenon of mechanical erosion in catchments is less important than in semi-arid areas. However, the study conducted in this work to determine the trophic level of the Yacoub El Mansour reservoir dam which is located under a semi-arid climate, seems to be mainly determined by changes in environmental conditions, especially climatic conditions. Therefore the pre-established mathematical models are not adapted to this type of environment. Thus, for future studies, it would be desirable to develop classification criteria for this type of vulnerable environments in order to get a more exact representation of their trophic level. This representation would be adequate if we integrate, several descriptors: physico-chemical, biological, hydrological and climatic variables in order to have a global biotypology integrating several specific mathematical models for each type of environment.

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