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Modeling Chlorophyll (a) and Turbidity in a Eutrophic Lake: the Case of Mansour Eddahbi Reservoir (Morocco)

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Abstract

Eutrophication models purport to management policy and the restoration of water bodies degraded due to eutrophication. The objective of this study is to develop models capable of predicting trophic status indicators (chlorophyll (a), turbidity) in the Mansour Eddahbi reservoir, based on the multivariate statistical analysis.

The database analysed consists of the monitoring of environmental parameters in 2003, which is characterized by a eutrophic trophic status. The results show that understanding the process of eutrophication is related to understanding the interrelationships of trophic status indicators with environmental variables (pH, temperature, dissolved oxygen, Kjeldahl nitrogen).

Keywords: Eutrophication, Mansour Eddahbi, Modeling, Phytoplankton.

1. Introduction

Over the last decades, the quality of surface water has been severely degraded due to human activity in the catchment areas: agriculture, land appropriation changes and wastewater discharges. This adds to the climate change that affects the temperature and the chemical characteristics of water bodies [1].

Indeed, human activity has altered the biogeochemical cycling of nutrients which has increased its concentration in the aquatic environment [2].

All these conditions accelerate the aging of these water bodies, a phenomenon referred to as eutrophication. This is a drastic algal proliferation caused by nutrient enrichment, such as nitrogen and phosphorus [2]. This algal proliferation is one of the major ecological problems of freshwater [3], with harmful effects on public health and ecosystem biodiversity [4].

Eutrophication has for long been an issue for water managers and researchers alike and their major task has been to identify the symptoms of this multifaceted pathology in aquatic environments [5].

To develop a better understanding of the process of eutrophication, it is important to study the link between the evolution of related environmental variables and dynamics of phytoplankton [6-7].

However, the phytoplankton biomass in terms of the concentration of chlorophyll (a) was one of the most widely accepted in the study of organic production methods [8-9].

Improving the quality of surface waters is a general objective in Morocco, in particular the water of Mansour Eddahbi dam. In this context, the water quality monitoring systems are essential for the success of management programs and restoration of these aquatic environments. Reliable data, measured continuously for long periods of time are needed to determine the state of water resources, implement effective conservation and rehabilitation programs and properly assess their performance [10].

The objective of this study is to investigate different correlations of the indicators of the trophic status in the Mansour Eddahbi reservoir (chlorophyll (a), turbidity) with environmental variables during the year (2003), which was characterized by eutrophic trophic status and the development of models that allow us to predict each trophic status indicator (chlorophyll (a), turbidity) depending on environmental variables.

2. Materials and methods

2.1. Dam Mansour Eddahbi

The Mansour Eddahbi dam is located on the Draa Valley (Figure 1), 25 km south of the city of Ouarzazate immediately downstream of the confluence of Oued Dades and Ouarzazate to the input of a very narrow gorge 45 km long. This dam was designed to fight regional disparities and desertification and to improve the particularly disadvantaged people's living standards along the Deraa Valley. The watershed of Oued Draa with an area of 15000 Km^2 is characterized by a highly variable hydrological regime. Indeed, the annual contributions vary from 68 to 1800 million m^3 per year with an average of 420 million m^3, while rates may range from 0.1 m^3 / s to 5300 m^3/s observed during the flood of 1949 [11]. The dam supplies drinking water to the population of the region as well as electrical energy (20 million kW/h per year). Table 1 shows the hydraulic and technical characteristics of the studied reservoir.

Table 1: Hydraulic and technical characteristics of Mansour Eddahbi Dam.

Area of dam	4.760 Ha
Volume of dam	560 10^6 m^3
Residence time	4 - 16 month
average depth	30 m
Annual average input	423 10^6 m^3

This tank is confronted with various sources of pollution that threaten the quality of water. Indeed, the discharge of sewage, agricultural pollution and waste and Garbage upstream of the reservoir are the main sources of pollution and enhancement of dam minerals salts [12]. These salts (nitrogen and phosphorus) cause the phenomenon of eutrophication, due to the increase of its concentration in water.

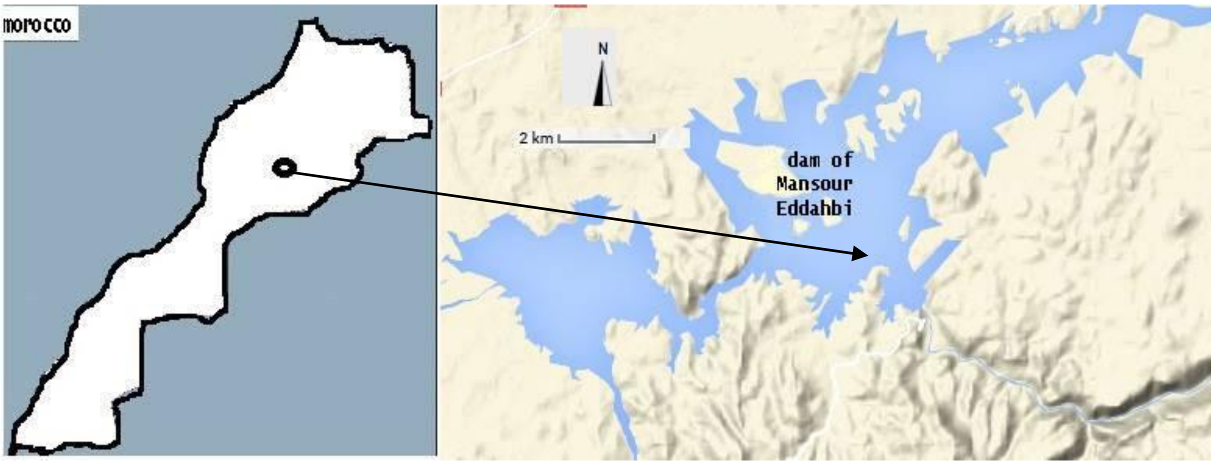

Figure 1: location of the dam Mansour Eddahbi

2.2. Statistical analysis and database

Multivariate statistical analysis is a useful approach to identify relationships of phytoplankton biomass and various environmental variables and assessing the quality of surface water [13-14].

Numerous studies have shown the interaction between algal biomass (chlorophyll a), total phosphorus and turbidity with the physicochemical parameters [15-16-17-18-19].

In this study the method used is the linear stepwise regression. This method is based on the choice of the minimum set of environmental variables that can explain the variation of parameters studied. These methods are widely used in ecological studies and proved to be useful in understanding the interactions between environmental factors [20].

The database analyzed includes:

Temperature (Temp) in ° C, pH, turbidity (Turb) in NTU, dissolved oxygen (DO) in mg/L_Kjeldahl Nitrogen (KN) in mg/L, Total Phosphorus (TP) in mg/L, chlorophyll (Chl a) mg/L, nitrate (NO_3^-) in mg/L and the conductivity (Cond) µs/cm.

This database consists of the daily monitoring of these parameters above the water surface at Mansour Eddahbi dam during (2003) characterized by eutrophic trophic status. The database is in the property of the national office of electricity and the drinking water.
The parameter values are converted into a decimal algorithm ($\log_{10}$) before performing multiple linear stepwise regressions with SPSS.20 software: the independent variables are added to the equation one by one and can be subsequently removed if they no longer contribute significantly to the regression. The process stops when no variable can be inserted or removed.

3. Results and discussion

The results are two models able to predict indicators of trophic state respectively: chlorophyll (a) (Chl a) and turbidity (Turb):

$$Log_{10}\mathrm{Chl\ a} = 10.9 - 12.5\, Log_{10} pH + 0.2\, Log_{10} KN + 0.5\, Log_{10}\, \mathrm{T} \qquad (1)$$

$$Log_{10} Turb = 12.5 + 4.3\, Log_{10} DO + 0.6\, Log_{10} PT - 17.1\, Log_{10} pH \qquad (2)$$

With:
Chl a: chlorophyll (a) in mg/L.
KN: Kjeldahl nitrogen in mg/L.
T: Temperature in °C.
NO_3^-: Nitrate in mg/L.
DO: Dissolved oxygen in mg/L.
Number of analyzed samples: 366

The proportion of the variance of the dependent variables (R-squared) exceeds 97% (from Table 2) in all models and their p-value is less than 0.001. This shows that the results are significant and that they do not result from chance.

Table 2: model parameters

Models	R	R- squared	Adjusted R-squared	Standard error of the estimate
1	0.999	0.997	0.997	0.00131
3	0.989	0.978	0.978	0.00203

Model (1): $Log_{10}\mathrm{Chl\ a} = 10.9 - 12.5\, Log_{10} pH + 0.2\, Log_{10} KN + 0.5\, Log_{10}\, \mathrm{T}$

Chlorophyll is the main photosynthetic pigment of phytoplankton usually used as a phytoplankton biomass indicator in aquatic systems. It is used in several studies of the empirical models linking biomass of phytoplankton to environmental parameters especially nutrients [9-21-22-23].
The nutrients (nitrogen and phosphorus) are made with two light conditions limiting algal growth in the aquatic environment. In freshwaters phosphorus is the limiting nutrient [24-25], while nitrogen is limiting in marine waters [26].
Interaction of chlorophyll (a) (Chl a) and Kjeldahl nitrogen (KN), organic nitrogen and ammonia nitrogen in the model (1) is due to the need to phytoplankton nitrogen uptake for its growth, indeed the nitrogen is assimilated in the form of (NH_4^+ or NO_3^-) [27].
The absence of the effect of total phosphorus (TP) in the model (1) may be due to its high concentration in this year (2003) which is about 0.358 mg/L. Here, we speak of the nutrient limiting of algal growth in state or nutrient concentration is low.
The nitrogen may act as a limiting nutrient of phytoplankton in the freshwater system when the phosphorus concentration is high [28-29].
Interaction of chlorophyll (a) and the pH is due to the role of pH as a regulator of photosynthetic activity in the lake environment. It may vary according to the degree of eutrophication.
Indeed CO_2 assimilation by phytoplankton causes an increase of pH [30]. Thus the pH influences the structure of algal and bacterial community in a given environment [31].

The strong relationship of chlorophyll (a) and the water temperature has been mentioned in several studies of algal biomass [2-3-23]. Temperature plays an important role in diversification of the phytoplankton community [23], because it influences their metabolism:
A high water temperature allows the algae to absorb nutrients at very low concentration thresholds against a cold temperature:

Model (2): $Log_{10}Turb\ =\ 12.5\ +\ 4.3\,Log_{10}DO\ +\ 0.6\,Log_{10}PT - 17.1\,Log_{10}pH$

Turbidity is important parameter in the quality of the water, measuring the reflection light of this water. Otherwise it is a measure of the suspended material regardless of its inorganic or organic nature.
Turbid water meant a decrease in light penetration to the water bottom which reduced the growth of aquatic plant [9].
As the pH regulator factor in algal growth (model 1), the interaction of turbidity and pH in the model (2) is the result of this growth:
Biomass, living or dead, suspended generates an increase of turbidity in the water. This may explain the relationship turbidity-pH.
The interaction of turbidity and total phosphorus is due to phosphorus role as a nutrient that promotes algal proliferation, and the resuspension of phosphorus sediment at the lake bottom can increase turbidity. Indeed the sediment phosphorus release is controlled by pH and bacterial activity [32-33-34].
Moreover, the dissolved oxygen relationship with the turbidity amounts to increase the rate of dissolved oxygen in the production of algal biomass suspension in the water column by photosynthesis [8]. This oxygen is committed by bacterial activity to degrade organic matter [8], which enables the production of colloidal suspension composed as phosphates.

Conclusion

The modeling of eutrophication is an important approach to understanding this phenomenon in the hope of fighting it and in order to ensure good water quality of reservoirs for the production of drinking water.
The models developed in the present study show that algal proliferation in the lake does not only depend on the nutrients (phosphorus and nitrogen) but it is also linked with other environmental variables such as temperature, pH and dissolved oxygen.
It is hoped that these models would give a more elaborate models in the management of water quality retaining in Mansour Eddahbi.

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