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Research Article

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Spatial Distribution of Nutrients and Risk of Eutrophication of Lake Tengrela In the Municipality of Banfora In Burkina Faso

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Abstract

The study characterises the spatial distribution of a selection of nutrients from the literature review. A relationship is also established between the selected nutrients and chlorophyll a, which is characteristic of the trophic level of a water body. We used data from water withdrawals during the high and low water seasons, linked to specific coordinates, but also surveys of 36 producers around the shores of the lake.

Our results show different levels of nutrients in the water body, modelled according to the lake's right of way. The spatial distribution of aquatic species is also disparate, as they are strongly correlated with these nutrients, and the distribution of nutrients in the water body depends on seasonality and parameters and the presence of macrophytes according to the presence of nutrients. As for the farmers, 100% of them use chemical fertilisers and organic manure in their production. These practices increase the presence of nutrients in the water body.

Our results confirm the fact that the spatial analysis of the distribution of nutrients in the water body is, on the one hand, strongly linked to the agricultural activities around the shores of the lake and that they have an impact on the health of the lake. This analysis will make it possible to understand and know the most influential and problematic nutrient for the proper management of this water body.

Keywords: Macrophytes, Trophy, Nutrients, Modeling, Tengrela

1. Introduction

Eutrophication is a "syndrome" that affects the biotope and the aquatic biocenosis [1]. It results from excessive plant production in watercourses, exacerbated by natural interactions and various human activities. The trophic level of water bodies can be categorised according to the studies of, who described several levels of classification of water bodies according to their qualities [2]. Nutrients are overloaded with water and lose their self-purifying capacity. The inability of these rivers to self-purify then breaks their trophic state, which can lead to eutrophication of the watercourse, starting with dead arms, i.e. the level or interaction with biota is almost zero, and stagnant water (Brahy, http://environnement.wallonie.be). This trophic state of watercourses includes nitrogen compounds such as phosphorus and carbon compounds (Brahy, http://environnement.wallonie.be), Mama, which must be taken into account in the process of water enrichment [3].

In wetlands, as elsewhere, there is a strong interaction between land and water. They form neutral or buffer zones against pollution and the effects of climate variability by absorbing excess water, but also by providing a microclimate that moderates the local climate. They are also a reservoir of water, biodiversity and organic matter, and an important habitat for a wide variety of fauna and flora [1]. Globally, wetlands occupy an estimated area of between 5.3 and 1 million km2, according to cited in [4]. estimate the areas to be between 7 and 9 million km2, or 4 to 6% of the land area [5]. However, these estimates of the areas identified in the world represent a relatively small proportion compared to their use and the high demand, which is also threatened by human activities [6]. The high demand for water has a number of consequences for water bodies, the most obvious of which is eutrophication. This symbol is the most visible water degradation caused by human activities: the development of primary production in rivers: eutrophication.

Our study is intertwined with the issues of pollution and macrophyte development in water bodies. At the national level, water management policies are not properly enforced. These policies to protect water or even water bodies in general create breaches for more catastrophic consequences for the ecosystem. Important policies such as IWRM, PAGIRE are not highlighted. For example, limiting production to less than 100 metres from the banks of water bodies [7]. Yet these resources are essential to the socio- economic activities of people in Africa. According to the FAO Africa has renewable fresh water of around 3,936 km3/year, while the water used is of the order

of 215 km3/year, and the sectors of levy are mainly agriculture, industry and domestic needs. According to the same data, Africa has a low rate of water abstraction, as do other continents such as Asia, Europe and the Americas. The low abstraction rate is explained by the low availability of means for water abstraction. This low rate of water withdrawal is also explained by the poverty of the African population, which cannot afford basic social services, including water, but also by the lack of accessibility to water due to long distances, or the lack of means for boreholes, which can require enormous resources given the distance to the source, as explained by and let (8). Indeed, in Mali, according to this author, many challenges related to access to drinking water are among the concerns of the population. The situation is similar in Burkina Faso, where the inhabitants of the city of Ouagadougou, as in most other Burkinabe cities, have difficulties in accessing water [9].

Against this background, policies are being implemented in Africa to improve the management of available water. These policies include sub-regional policies such as those of ECOWAS. From these sub-regional organisations, local common water management policies are developed by the member countries. Burkina Faso, a Sahelian country, is not left out of these water management policies. In fact, this country has a fairly large surface and groundwater resource that is difficult to access due to lack of resources.

The purpose of our study is to analyse the spatial distribution of physico-chemical parameters such as temperature, PH, conductivity, COD, BOD5, dissolved oxygen, chlorophyll a, ammonium, nitrates, ortho-phosphate in the eutrophication process of the water body and to analyse them according to the national standards in force in terms of algal development in the lake.

2. Materials and Methods

2.1 The Study Site

The study area was selected according to several criteria. These criteria were taken into account according to the information available on the study area. Lake Tengrela was chosen on the basis of the various geographical information obtained from the Ramsar databases and the socio- economic information obtained from the literature review. This information and the choice of this site were made in the light of the objectives of our research and the likely resources available. Knowledge of the drivers of change and the location of land use in the study area is important. Data from the Ramsar site show that Lake Tengrela is an area threatened by the proliferation of opportunistic species and the cultivation of riparian populations.

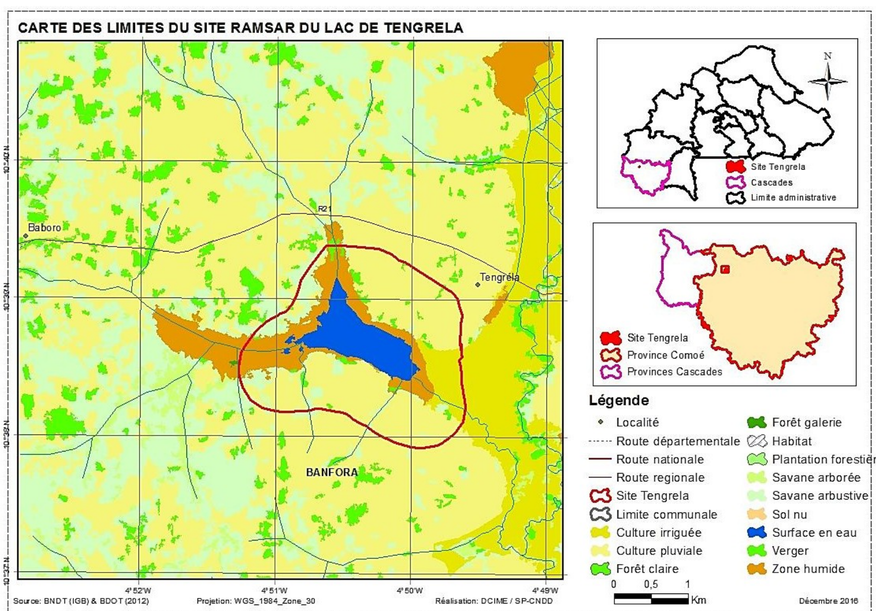

Figure 1: *Map showing the location of the lake*

2.2 Watercourse Sampling

The field phase concerns the collection of data in the field. This collection concerns physico- chemical parameters. These parameters will be measured according to the standards in force. In order to be able to compare these data, the data collected will be subject to the levels set by the and the national standard.

2.3 Physical Parameters

The main physical parameters of our analysis are: temperature, PH, conductivity, DCO, DBO5, dissolved oxygen, chlorophyll a, nitrogen and its variants, phosphorus and its variants.

2.4 The Water Sampling Period

All water samples were taken using a pre-defined sampling transect. This transect is obtained thanks to a good knowledge of the morphology of the site (lake and dam), integrated in the GIS tool for a delimitation by a sampling grid. The work of the DGRE (Direction Générale des Ressources en Eaux /Burkina Faso) on certain rivers has made it possible to understand the impact of seasonal variations on the quality of water resources. This sampling grid is useful in terms of the methodology used in the study. Water samples are taken at different times of the year, particularly during the periods of high water (August/September) and low water (May/June and December/January).

2.5 Frequency and Transect of Water Sampling

The data collection, i.e. the sampling in Lake Tengrela, will follow a tortuous path in these waters. The sampling points are known in advance by the treatment, as far as we know the surface of the water bodies. A systematic step of 100 metres is chosen for water sampling. The area report for each systematic step gives us the number of samples to be taken at each point. The points that are known in advance are integrated into a differential GPS for the reconnaissance of watercourses and facilitate the work downstream. In other words, each sample is already associated with an information point (X, Y, Z) that will be used for all treatments, taking into account the spatial analysis. A total of 123 duplicates samples were taken during the high water period and 78 duplicate samples were taken during the low water period according to the systematic step method shown in the figure.

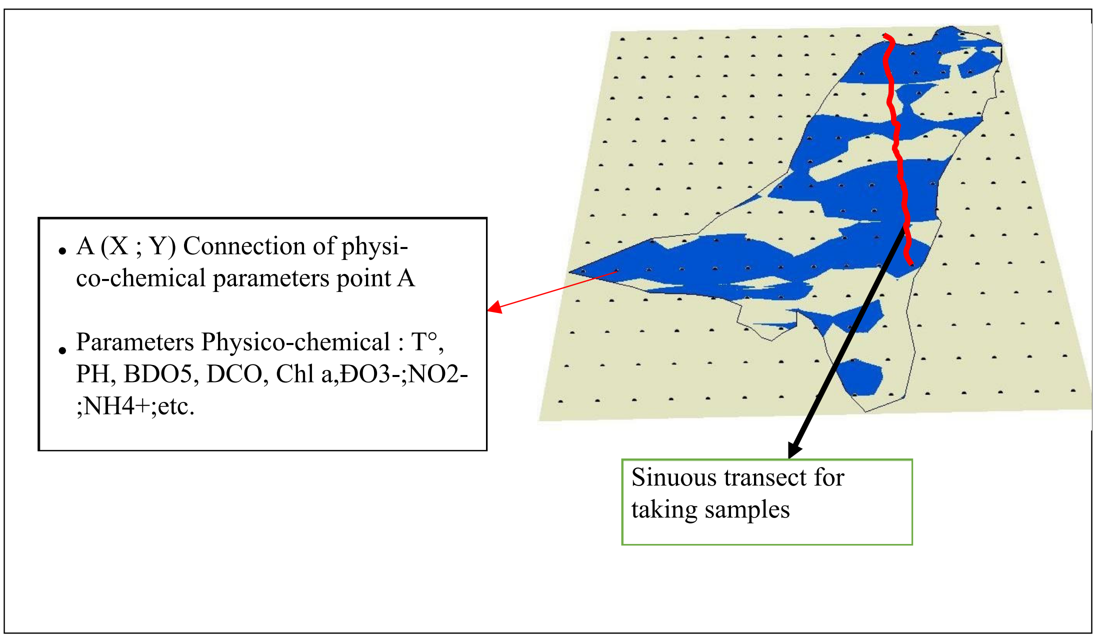

Figure 2: Sampling Method for Taking Samples from The Lake

2.6 How to Collect and Store Samples

For each sampling point, a water sample is taken from a double 1 litre bottle. The water sample is stored in a (new) plastic bottle rinsed with the water from the site (lake or dam) so as not to interfere with the physico-chemical analyses. After the samples were taken, they were kept cool in thermo bags and placed in coolers. The samples were sent to the Environmental Analysis Laboratory (EALA) within 48 hours. A sampling prototype was developed at the research laboratory (LABOSH) to take into account the depth of water sampling.

2.7 The Survey of Lakeshore Operators

In order to understand the causes of nutrient inputs to the water, we carried out a survey of farmers around the lake to identify the causes of the presence of certain nutrients. In total, we identified 36 farmers around the lake. These are the farmers who have resisted the eviction of the local population in order to preserve the site.

3. Results

3.1 Global Status of Stakeholders Around the Lake

The lakeshore agriculture is practised by 36 owners who are heads of households. These owners are heads of families, which gives a family character to the perimeters exploited around the shores. These 36 owners have returned to family farms, 34 of them individuals and 02 of them groups. Of the 2 groups, one is a structured group (Pépinière villageoise de la Comoé) and the other is made up of farmers. As for the family farmers, most of them are male (31) and the rest are female (03). Without taking into account the pairing of activities, the operators have three types of activity: agriculture (depending on the season), trade, fishing. In fact, 33 (89.19%) farm during the rainy season, 32 (86.49%) farm during the dry season, 11 (29.73%) trade and 3 (8.11%) fish. These activities are also the source of income for the operators.

In general, without taking into account the status of the operators, the activities are carried out during the two seasons of the year, but most farmers combine agriculture with other types of activities such as trade and fishing. Thus, 22 farmers (62.11%) practise agriculture during the two seasons without other activities, 11 farmers (30.56%) combine agriculture during the two seasons with trade, 2 farmers (5.56%) only combine agriculture during both seasons with fishing and 1 farmer (2.77%) practises agriculture during the rainy season with fishing. The farmers' production is diversified (cabbage, tomato, sorrel, maize, aubergine, onion, chilli, pepper, cucumber, courgette, nursery, etc.).

3.2 Farmers' Perimeters

As a national RAMSAR site, the lake has well-established rules with advisory services. Developed land should comply with the rules relating to the conservation of the lake, including the prohibition of cultivation within the limits of the easement strip. Of the farmers found around the shores, 28 (75.68%) obtained their land through landowners, 2 (5.41%) settled without permission, 2 (5.41%) claimed to have obtained permission for a project without hard evidence, 1 (2.7%) said they leased the land and 3 operators did not answer the question. These operators use the land for an interval of between 3 and more than 5 years. However, during this interval of land use the plots were broken up more than 6 times for some and not at all for others.

This indicates a need for plots and pressure on land that may be family or non- indigenous. A total of 58 plots are cultivated by 36 farmers who earn between 20,000 and an average of 300,000 francs per season, sometimes with surpluses in periods of good production. This income allows 33 farmers (91.67%) to send their children to school, 32 (88.89%) to use the foreign currency from sales for household cooking, 1 (2.77%) to use their own production for family cooking, 3 (8.33%) prefer to reinvest in breeding, construction, purchase of various materials or by paying for more modern martial such as motor pumps to increase production.

3.3 Operators' Tools and Materials

The tools used by the operators consist of watering cans (97.3%), jerry cans (94.59%), motor pumps (94.59%), daba/pickaxes (91.89%), piping (86.49%), seals (72.97%). In addition, all farmers (100%) use chemical fertilisers in their production and 100% use organic manure in their agricultural production. These practices increase the presence of nutrients (pollutants in water). In addition to the use of fertilisers by all farmers, 28 (75.68%) burn waste, 27 (72.97%) throw away waste, 3 (8.11%) dump waste and 1 (2.7%) keeps waste on the farm. All these practices take place on the shores of the lake. All farmers use fertiliser that is fully paid for on the local market and whose quality and suitability to the local climate they do not know. These data are presented in Figure 3.

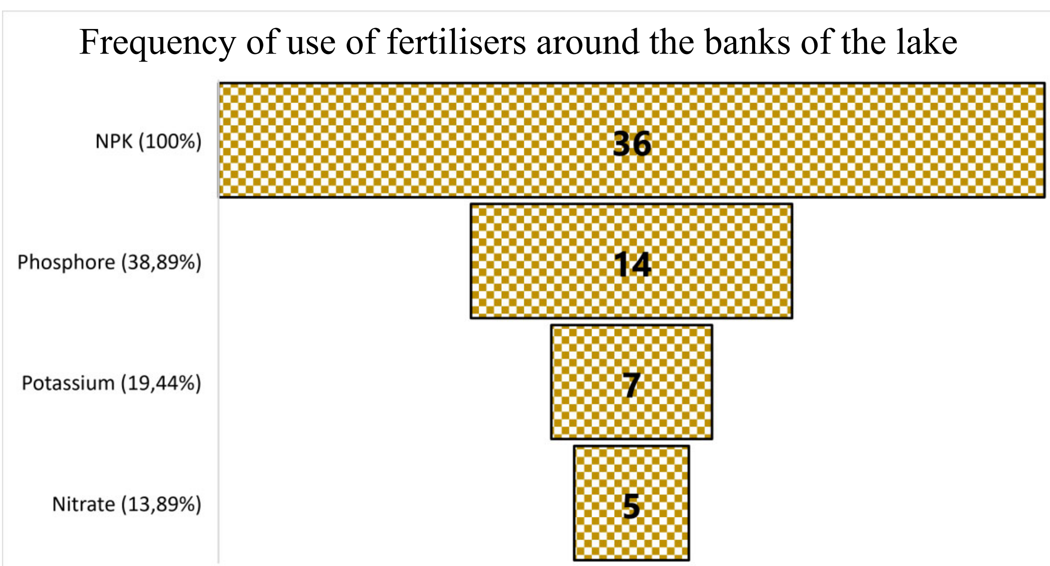

Figure 3: Frequency of use of fertilisers around the banks the lake

These fertilisers are used at different times of the year according to need. In January, February, July, the use of fertilisers is much more increased, in June, December, March, November the use is moderate and the rest of the year the use is low and many farmers practically do not use them at these times of the year. Nevertheless, some operators know the effects of chemical use (28 respondents including 75.68%), 8 operators (21.63%) do not know the effects of their actions on the lake.

Photo Board 1: some tools used by operators around the banks of the lake Source: photos, BOUDA, 2023

3.4 Sustainability and Lake Operations

The lake operators use the chemicals for their farms. In fact, more than half of the farmers, i.e. 31 (83.78%), know the term sustainability, having heard it in an information context such as radio (91.89%), television (18.92%), in training courses (13.51%) and 5.41% during exchanges with agricultural and livestock agents. On the other hand, 5 (13.51%) do not know this term, which is negligible among the operators who are aware of it. The number of operators partly explains the presence of nutrients in the lake. Concerning the distance between the banks, 41.67% of the operators are from the easement strip of the lake, which easement strip of water bodies is established at 100 metres according to the Integrated Water Resources Management (IWRM) (Baron et al., 2022), for more precautionary, the widening of the easement strip up to 600 or even 1000 metres could allow a good management of water bodies if necessary [10].

Also, some measures to protect the banks are not respected, such as the introduction of materials and the non-payment of water abstraction fees as promulgated in the Enforcement Decree. Other activities that may be problematic in terms of introducing nutrients into the water body include leaching with the use of detergents (89.19%) and watering animals (86.49%). The water police, who have a relationship with the water authorities, regularly prohibit activities that could cause damage to the lake. In this sense, 34 (91.89%) have alreadybeen fined, compared to 2 farmers (5.41%) who have been warned but not fined.

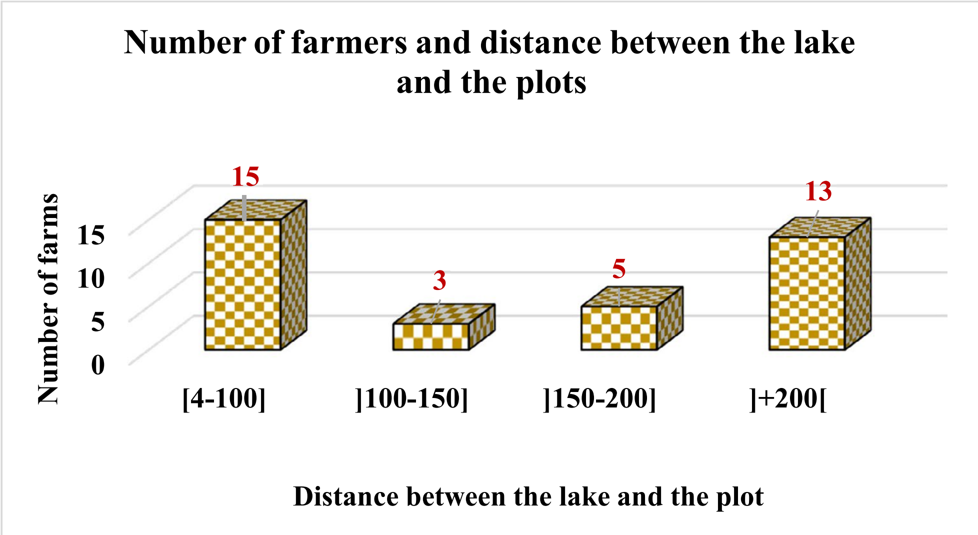

Figure 4: distance of cultivation plots from the water body

3.5 Spatial Distribution of Nutrients in Lake Tengrela During Low Water Season

An analysis of the physico-chemical parameters of water during low water period shows low values. Nitrate data, for instance, indicate results of 2.24 µg/L N-NO3, which fail to meet the OECD standard for waters in oligotrophy situations. In comparison, data for OP42- shows 0.89 µg/L P-PO4, chlorophyll a shows 15.58 µg/L, PH 6.96, turbidity 79.31 NTU, and DCO and DBO5, which are to a lesser extent correlated, substantially conform to the standard. Their values are 47.99 mg O2/L and 37.23 mg O2/L, respectively. This dataset displays Lake Tengrela's water body situation, which meets the standards set by the Ministry. Therefore, during the low water period, Lake Tengrela is considered to be in a normal condition, disregarding the chlorophyll a data (the standard is 10).

As for the remaining standards, i.e. those of the OECD, the lake exhibits a range from oligotrophic to eutrophic conditions based on the data and threshold values. Based on the data collected, the lake is in the oligotrophic to hypereutrophic condition according to the SEG-eau standard set by the French Ministry.

For the data used to interpret the oligotrophic situation, this could be explained by the fact that, although the water level drops during the low-water period, there are still tributaries that continue to feed this body of water. As a result, the amount of nutrients present in this lake does not show the extreme values of this sampling period. The spatial distribution is not uniform for all the physico-chemical parameters (figure 5).

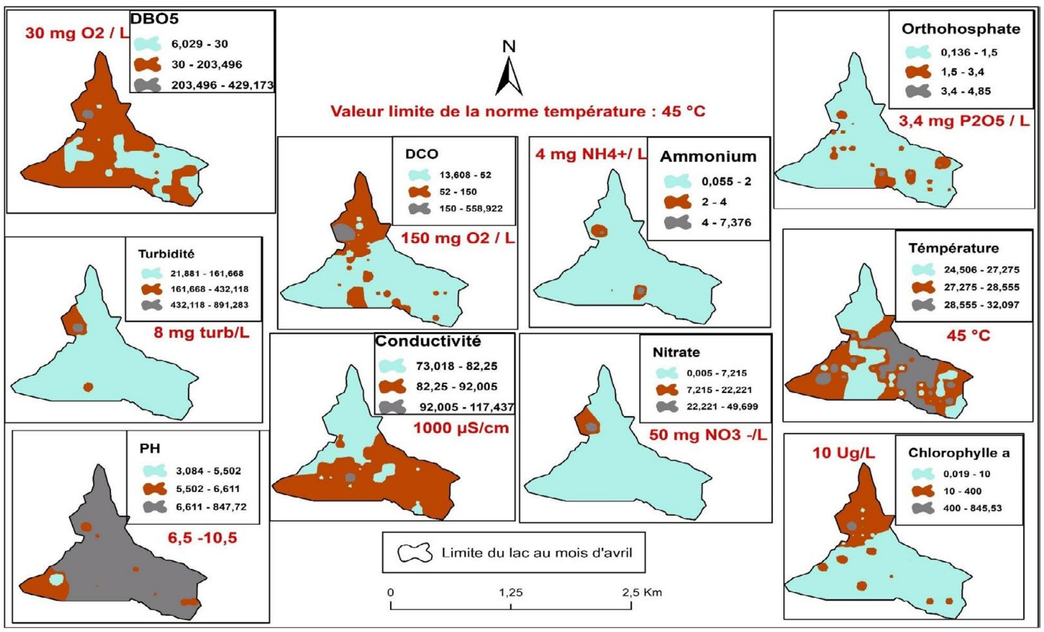

Figure 5: interpolation of physical and chemical water variables at low water period.

3.6 Flood Season

Our analysis will focus on the collected nutrients responsible for highlighting the phenomenon of eutrophication. The literature review has identified two nutrients that are responsible for highlighting the eutrophication of water bodies: nitrogen and phosphorus. In this area, as seen in the previous chapters, there is a rather irregular nutrient dynamics (depending on the different parameters studied). Our sampling took place during both seasons: the rainy season, which corresponds to the period of high water, and the dry season, which corresponds to the period of low water (according to the methodology given by the Directorate General of Water Resources). The data from the analysis show that Lake Tengrela is at an "oligotrophic" to "mesotrophic" level and therefore requires monitoring, active surveillance and maintenance of control activities to prevent it from falling to an "eutrophic" level, which could cause irreversible effects.

Linked data from the OECD and the French Ministry of Health (SEQ-eau) provide this information on the fair water quality of Lake Tengrela during the flood period. This information on Lake Tengrela "oligotrophic" to "mesotrophic" is only valid for the flood season. This implies a very high dilution of the water due to the seasonality and the climate of the area, as it belongs to the Sudanese zone. The data used to highlight the trophic situation of the waters are nitrate, orthophosphate, chlorophyll a and total phosphorus, all of which have been compared with the OECD and French Ministry standards, as well as the national standard of the Ministry of the Environment of Burkina Faso. These data indicate the trophic status of the water bodies according to their nutrient content. Thus, the nitrate data give results of 1.89 µg/L N-NO3, which is below the OECD standard for waters in oligotrophic situations, 0.18 µg/L P-PO4 for OP42-, 0.034 µg/L for chlorophyll a, 6.91 for PH, 46.59 NTU for turbidity. All these data, when applied to the OECD and QES-UAE grid of limits, allowed classification (figure 6).

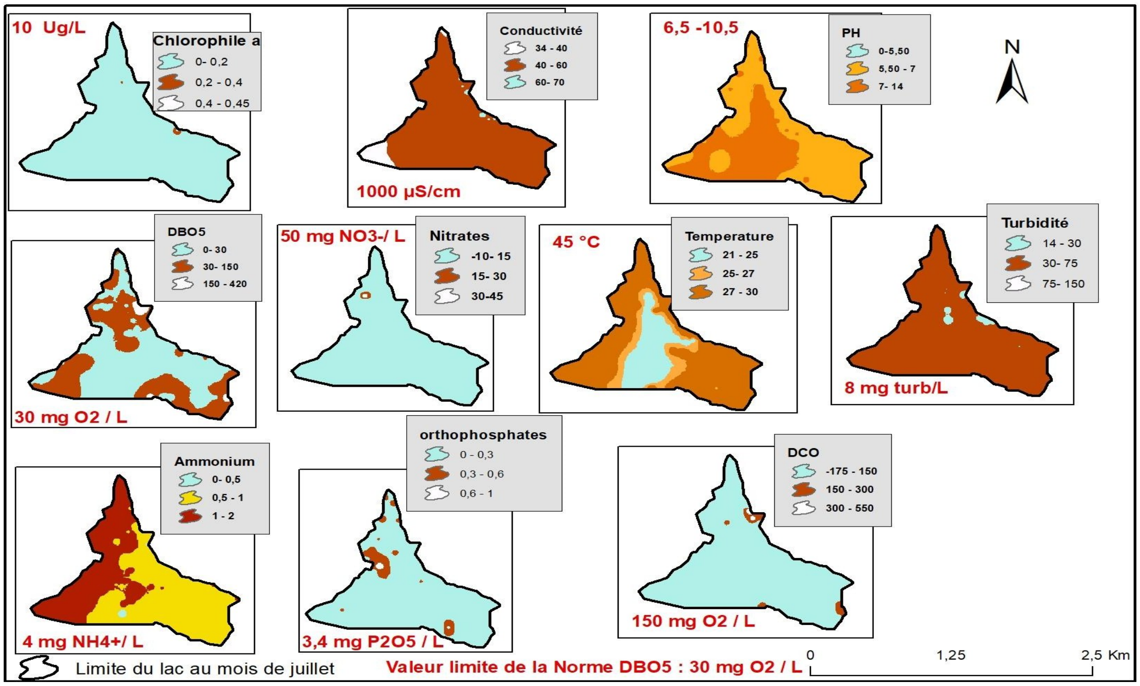

Figure 6: Interpolation of Variables Physical Et Chimical Water at Flood Season

4. Discussion

4.1 Spatial Distribution of Physicochemical Parameters

The spatial distribution is a function of several factors. This spatial distribution is correlated with the presence or absence of macrophytes in the lake. In fact, according to studies on the spatial distribution in water bodies, models seem to be more realistic regarding the correlation between nutrients and algal development [11]. For other authors, such as Souissi et al. spatial distribution is also due to temperature, wind and pseudovacuoles in algae that allow them to float on the surface and thus be pushed by the wind of growing water bodies [12].

The significance of the model also depends on seasonality. The model results show greater activity during the high water season, even though most of the water body remains homogeneous. Mama discusses the spatial distribution of macrophytes during the flood season using the Integrated Macrophyte Index [3]. In fact, according to the same author, during periods of high water, the effect of salinity is a parameter that inhibits the development of certain macrophytes; during the period of high water, dilution with the input of fresh water cancels the inhibiting effect of salinity on the growth of water hyacinth. On the other hand, during the low-water period, the presence of water hyacinths remains visible in streams where the salinity is lower.

The presence of more chlorophyll a during the low-water period than during the wet period is also the result of the lack of dilution of the water in the lake [13-15]. It is also due to the reduction of water arriving from tributaries. As a result of these processes, plants select dead branches or the absence of certain limiting factors for their growth, such as salinity, which inhibits the growth of hyacinths, as shown in the study by [16].

4.2 Agriculture and Nutrients in The Lake

Agriculture is the most widespread activity in the communes of Burkina Faso and particularly in the commune of Banfora [17,18]. The community of Banfora is not on the margins of this activity. Many people practice it to the detriment of the rules of water management. The different nutrients correlated with chlorophyll a are correlated with the two parameters most often of anthropogenic origin [19]. More than half of the farmers use organic and chemical fertilisers in their production. Their proximity to the easement strip also poses a threat through the introduction of nutrients.The nutrients dispersed in the lake are partly due to the presence of farmers around the shores of the lake, as it is possible that the food web of this body of water acts by increasing the nutrients present in the lake through biological processes, most of the nutrients coming from outside the lake [20-21].

5. Conclusion

In this article we have shown that it is possible to use the spatial distribution of nutrients obtained from sampling and laboratory analysis, correlated with survey data, to know the trophic state of a water body. This allows us to know which nutrient is representative and quantitative compared to other nutrients in the lake, but also if this nutrient is related to agricultural activities in the lakeshore. Not only are there correlations between the analysed data that are not entirely homogeneous. Our results can be used by the local authorities to improve the water quality of the site, as it is not only a RAMSAR site but also a popular tourist destination. Our results meet a criterion of refined and targeted research at local level, and that they add value to the growing debate on improving water management.

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