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Impact of Agricultural Activities on Micro-Algal Communities in Two Tropical Rivers of Côte d'Ivoire

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Abstract

Context: The high population density and the increase in agro-industrial activities, which characterize the south of Côte d'Ivoire, are increasingly contributing to the degradation of aquatic ecosystems. This unfortunately leads to the destruction of natural habitats of aquatic species, especially through the action of an agriculture that constantly uses agricultural inputs (fertilizers, pesticides, etc.).

Objective: This study aims to analyze the impact of human activities on surface water pollution, with a view to possibly alerting public opinion and decision-makers.

Methodology: The methodology adopted is that of using micro-algae as bio-indicators of harmful actions due to man on surface waters. Water samples were taken from two rivers in the south of Côte d'Ivoire, one with low activity (la Mé) and the other with high activity (le Boubo). After the identification and enumeration of microscopic algae, the floristic richness and density of microalgae were analyzed.

Results: The results obtained showed that in terms of floristic richness, the Boubo River provided 65.70% of the total tax collected, compared to 34.30% for the Mé River. Similarly, the spatial-seasonal analysis of phytoplankton density indicates that the Boubo is denser (89.76%) than the Mé (10.24%).

Conclusion: This study, which is the first of its kind to be carried out on the Boubo and Mé rivers, will therefore serve as a basis for comparison for further research, but above all as a means of alerting to the harmful actions of man on aquatic ecosystems.

***Keywords**: Ecosystem, Agriculture, Microalgae, Bio-indicator, River*

INTRODUCTION

The catchment areas of watercourses are generally privileged places for the installation of economic activities (agriculture, urbanisation, industries, etc.) and consequently subject to the various activities of Man. These activities are certainly an essential link in the development of the country because of the advantages they offer to the population, but they do not always take place without inconvenience to the aquatic environment. In Côte d'Ivoire, the demands of development have led to activities that are increasingly threatening aquatic ecosystems (Gourène *et al*., 1999).

Indeed, the residues of the various inputs (pesticides, fertilisers) used in agriculture in the catchment areas end up in the aquatic ecosystems and harm the quality of the water (Yapo et al., 2008; Goné et al., 2009; Koné et al., 2009). These inputs lead to a profound change in the composition and structure of the animal and plant communities living there (Ouattara *et al*., 2001; Koné *et al*., 2003; Niamien-Ébrottié *et al*., 2008).

Among the aquatic organisms, whose distribution and abundance are influenced by mineral and organic elements from the leaching of cultivated soils, algae are prominent. Algae are known to play an important role in aquatic environments, through carbon fixation, oxygenation of water bodies, and as an important food source for fish, zooplankton, etc. (Pinel-Alloul *et al*., 1998 ; Schlumberger & Bouretz, 2002).

Work on the study of phytoplankton in the rivers of the South was conducted by Ouattara (2000) on planktonic algae in the Agnéby and Bia rivers, Da (2007) in the Bia river and Niamien-Ébrottié (2010) in the Éhania, Éholié, Noé and Soumié rivers. These works, especially those of Niamien-Ébrottié *et al*. (2008) and Groga *et al*. (2017), have highlighted the impact of anthropogenic activities, especially agriculture, on the proliferation of micro-algae in rivers in Côte d'Ivoire. The Boubo and Mé rivers are not exception to this reality. Indeed, their watersheds contain large areas of human occupation as well as large village plantations (Mé) and industrial cash crops (Boubo). Contrary to the work of Niamien-Ébrottié, the present study is based on two zones that differ in the intensity of related activities (old and new cocoa loops) in order to better perceive the impact of anthropic activities on the modifications of the floristic composition of the algae of the Boubo and Mé rivers.

The aim of this study is to analyse the impact of agricultural activities on the microalgal population of the Boubo and Mé rivers. Specifically, it aims to :

- ✓ measure the nutrients in the Boubo and Mé rivers ;
- ✓ analyse the seasonal floristic composition of microalgal communities ;
- ✓ determine the seasonal dynamics of microalgal densities.

MATERIALS AND METHODS

Presentation of the study area

The sampling rivers are located between 5° and 6°50' N and between 3° and 5°50' W. They are 130 km long for the Boubo and 147 km for the Mé. They are located in the south of Côte d'Ivoire (Figure 1). Sampling was carried out on the Boubo and Mé rivers during four sampling campaigns and during the four climatic seasons that characterise the south of the country. The first campaign took place between May and June for the long rainy season, the second in August for the short dry season, the third between October and November for the short rainy season and the fourth in February for the long dry season.

Nutrient dosing

The analysis of nutrient salts (nitrates and orthophosphates) was carried out using a UV-JASCO 530 spectrophotometer. Also, the determination of nitrates (NO3-) was carried out using the molecular absorption spectrometric method with molybdate after reduction with cadmium (NF T90-045) according to AFNOR (2005a). As for orthophosphates (PO43-), the aluminium molecular absorption spectrometric method (NF T90-023), according to AFNOR (2005b), was used for their determination.

Phytoplankton sampling

Qualitative study

For each sampling campaign, a certain amount of water was transferred to the 25 µm mesh plankton net with a bucket. After filtration, the contents of the net collector were collected in a 40 ml pillbox and immediately fixed with commercial formaldehyde at a concentration of 5%. These collections will subsequently be used for the observation and identification of microalgae.

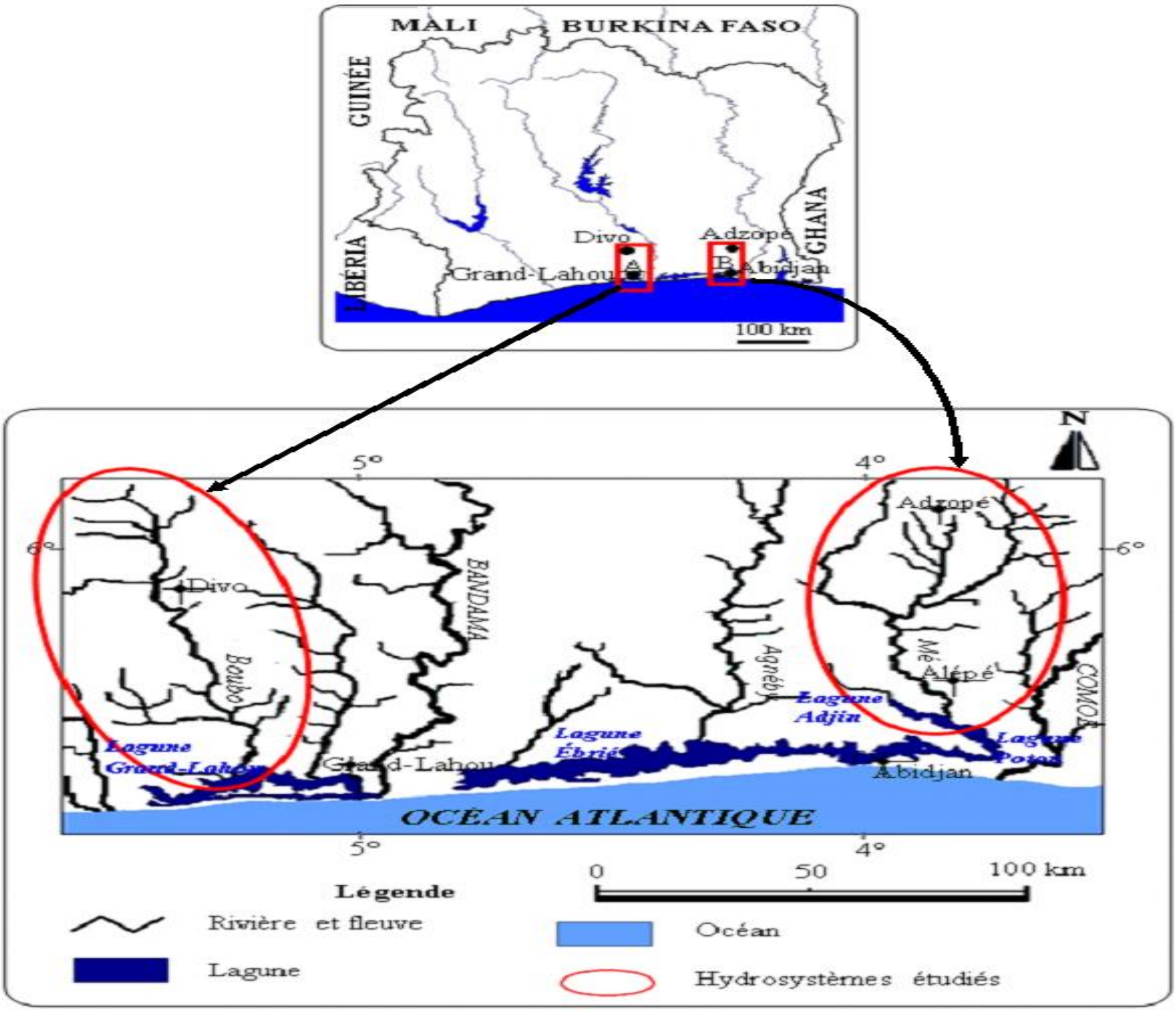

Figure 1 : Location of the sampling study site (Anonymous, 2009; modified by Salla).

Quantitative study
Taxon counts

The quantitative study was carried out using samples taken from the surface with 1 litre bottles. The contents of the bottles were fixed with formaldehyde. The counting was carried out under an inverted ZEISS microscope. The quantitative study method adopted is that of Utermöhl (1958).

Analysis of phytoplankton community structure
Jaccard similarity index

The similarity between two communities (habitats) was estimated by the Jaccard similarity index. According to Schaeffer et al (2005), this index varies from 0 (no similarity) to 1 (identical environments). It is obtained using the formula :

$$S_j = \frac{c}{a+b+c} \quad \text{(Equation 1)}$$

where: a = number of taxa specific to station 1; b = number of taxa specific to station 2; c = number of taxa common to both stations; Sj = Jaccard similarity index.

Specific wealth

Specific wealth consists of quantifying the number of different taxa in a given area. This index is therefore very sensitive to the sampling effort, to the estimation of the real number of species, to the identification bias and assumes equivalence between taxa.

Measuring the diversity of the phytoplankton community

Shannon-Weaver diversity index

To describe a community, ecologists use several indices that express diversity or evenness. The indices provide information on the structure of the stand from which the sample is taken and how individuals are distributed among different species. Any variation in diversity indices for samples taken from the same stand over time therefore reflects changes in the structure of the stand and makes it possible to monitor its overall evolution over a certain period or cycle of time (Daget, 1976).

The Shannon-Weaver diversity index (H), which is the most commonly used, was chosen for this study. Its value represents the average amount of information provided by the attribution of an individual to a species, the percentages of importance of the species (Pi) being known (Frontier, 1983), i.e. :

$$H' = -\sum_{i=1}^{S}(p_i) \times \mathrm{Log}_2(p_i) \qquad \text{(Equation 2)}$$

where :

N = total number of individuals of all species in the sample; ni = number of individuals of one species in the sample; pi = proportional abundance or percentage importance of the species: pi = ni/N; S = total number of species.

Thus, as H' increases, diversity increases. When it decreases, diversity is minimal. Its value is maximum when H' tends to infinity.

Equitability index

Equitability was defined in order to compare the diversity of two stands with different numbers of species (Dajoz, 1982). This index makes it possible to study the regularity of species distribution (Pielou, 1969). It varies between 0 and 1 and reflects the quality of organisation of a stand (Dajoz, 2000). A low equitability indicates that the stand is dominated by few species. It tends towards 1 when all species have the same abundance. Its formula is :

$$E = \frac{H'}{\mathrm{Log}_2 R_s} \qquad \text{(Equation 3)}$$

H' = Shannon-Wiener diversity index; Rs = total number of species.

RESULTS AND DISCUSSIONS

Results

Nitrates and orthophosphates

Fluctuations in nitrate levels are observed in the Boubo and Mé rivers. In general, high concentrations are noted during the main rainy season, while low concentrations are encountered during the main dry season. In the Boubo River, the range of nitrate concentration variations is 0.44 to 2.2 $mg.L^{-1}$.

In the Mé River, nitrate levels oscillate between 0.64 and 2.04 $mg.L^{-1}$, with a maximum value recorded during the main rainy season and a minimum value during the main dry season. Nitrate levels do not show significant variation (Mann-Whitney test, $p > 0.05$) at seasonal level. However, there is a significant difference observed from upstream to downstream ($p < 0.05$; Kruskall-Wallis test).

As for orthophosphates, the values are between 0.01 $mg.L^{-1}$ and 0.5 $mg.L^{-1}$ in the Boubo River. The highest concentration is obtained in this river during the long dry season. On the Mé River, the highest concentration (0.4 $mg.L^{-1}$) is noted during the short dry season and the long dry season. The low values are measured during all seasons in the Mé River. The Kruskall-Wallis test shows significant differences ($p < 0.05$) in orthophosphate levels at seasonal level.

Taxonomic composition of the phytoplankton community

The phytoplanktonic flora of the Boubo and Mé rivers comprises a total of 272 taxa. The Boubo River is the environment where the greatest number of taxa is collected with 203 taxa against 106 in the Mé River; almost double in qualitative terms.

In the Boubo River (Figure 2), all phyla are represented. These are Chlorophyta (43.83%), Heterokontophyta (24.14%), Euglenophyta (16.75%), Cyanoprokaryota (13.31%), Dinophyta (1.48%) and Rhodophyta (0.49%). The first two phyla contain more than half of the taxa. In the Mé River (Figure 3), the largest group is the Heterokontophyta representing 36.79% of all taxa, followed by the Chlorophyta (31.13%) and the Euglenophyta (29.25%). On this river, Dinophyta and Rhodophyta were not observed.

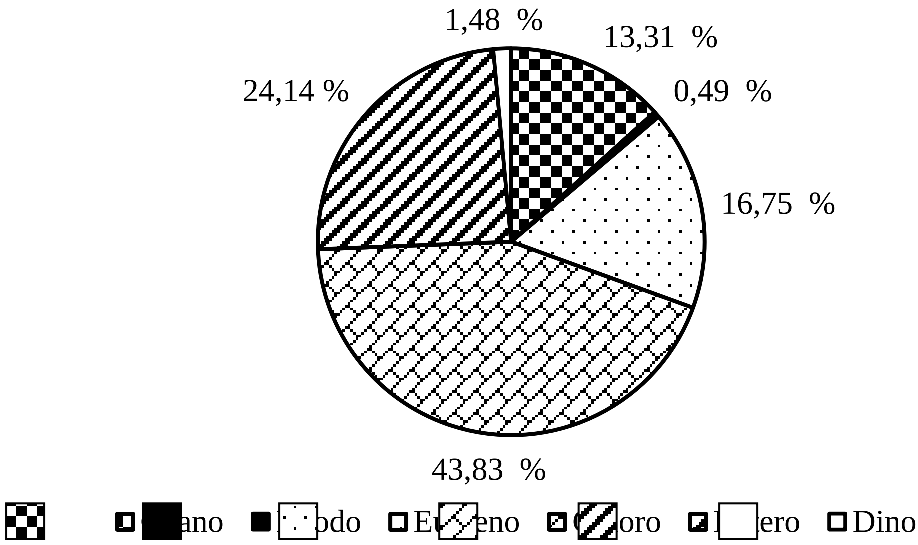

Figure 2 : Proportions of different taxonomic groups observed in the Boubo River

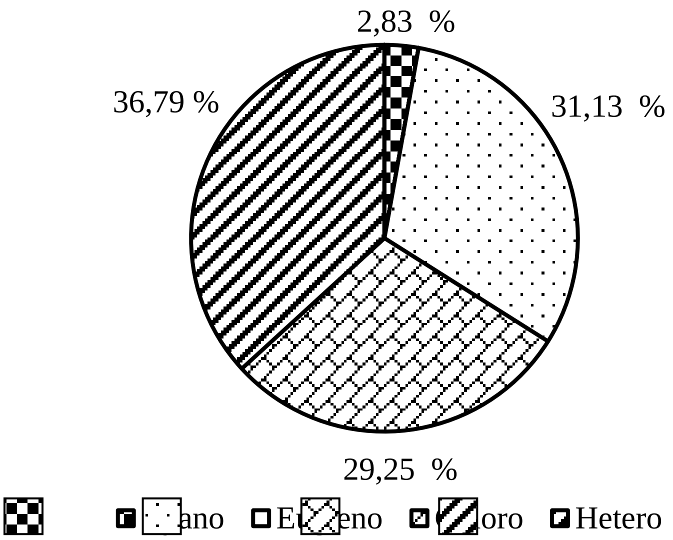

Figure 3 : Proportions of different taxonomic groups observed in the Mé River

Similarity between the stands of the different stations

Jaccard's similarity index (Sj) indicates that the floristic composition of the Boubo River (Sj = 0.51) has little affinity with that of the Mé River (Sj = 0.33). The similarity index values obtained indicate that each habitat has its own characteristic.

Quantitative study of the phytoplankton population

Spatial and seasonal variations in phytoplankton density

The spatial-seasonal analysis of phytoplankton density indicates that the Boubo River has a denser population (89.76%) compared to the Mé River (10.24%). The abundance of the respective phytoplankton groups indicates a clear predominance of Chlorophyta (49.68% of the total population), followed by Heterokontophyta (33.45%). The other remaining groups (Cyanoprokaryota, Euglenophyta, Dinophyta and Rhodophyta) represent only 16.87% of the total densities of the two rivers surveyed. The Boubo River is characterised by an abundance of Chlorophyta (11,414,103 ind.L^{-1}) and Heterokontophyta (11,245,103 ind.L^{-1}) during the short dry season. Cyanoprokaryota (2,132,103 ind.L^{-1}) and Euglenophyta (1,341,103 ind.L^{-1}) have lower densities. As for the Mé River, it presents relatively lower abundances, with a predominance of the Heterokontophyta (2,073,103 ind.L^{-1}), followed by the Chlorophyta (752,103 ind.L^{-1}) and the Euglenophyta (667,103 ind.L^{-1}). All these phyla show a high abundance during the short dry season.

Shannon-Weaver and equitability indices

The diversity index values oscillate between 0.78 and 4.92 bits.$cells^{-1}$, respectively during the long dry season and the short rainy season in the waters of the Boubo River. As for the water of the Mé River, the lowest diversity index (0.11 bits.$cells^{-1}$) is obtained during the long rainy season and the highest index (2.7 bits.$cells^{-1}$) is recorded during the short dry season. The diversity index does not differ significantly between the sampling seasons (Kruskal-Wallis test, $p > 0.05$).

Concerning the equitability relative to the Boubo and Mé rivers, the index does not show significant intra-river variation (Kruskal-Wallis test, $p > 0.05$). The extreme values of equitability obtained vary in the same proportions as the diversity index. A fluctuation of 0.13 to 0.77 is observed respectively during the long dry season and the short rainy season (Boubo River). In the Mé River, the range of variation of equitability evolves from 0.02 to 0.48, respectively during the long rainy season and the short dry season.

Discussion

Nutrients

Nutrient salts are abundant during the rainy seasons. Their presence allows the production of phytoplankton in the Boubo and Mé rivers. Thus, the high levels of nitrates and orthophosphates, which are more pronounced in the Boubo River, are responsible for the high densities of Chlorophyta and Heterokontophyta in the Boubo River on the one hand, and of Heterokpntophyta and Chlorophyta in the Mé River on the other. These results are consistent with the observations of Angelier (2000).

Qualitative aspect

The qualitative analysis of phytoplankton populations shows that the Boubo and Mé rivers can be considered rich in taxa. Indeed, 272 taxa were inventoried in the two hydrosystems. The taxonomic richness would be linked to the strong disturbance of the ecosystems due to the excessive input of nutrients. These results are similar to those obtained by Ouattara (2000) on the Bia and Agnéby rivers. The Boubo River is richer (203 taxa) than the Mé River (106 taxa). This situation could be explained by the way the watersheds are occupied. Indeed, the discharges generated by the presence of large industrial plantations, factories, manganese washing stations and urban wastewater in the Boubo River favour the development of microalgae compared to the Mé River, where these activities are less pronounced.

The seasonal study showed that river waters are richer in taxa in the rainy season than in the dry season. The increase in water level and certainly the force of flow would favour this predominance observed during the flood period. In addition, the periphytic algae are often found drifting after being pulled up by the current. This phenomenon is very frequent in running water (Coste, 1996, Lavoie *et al*., 2003). According to these authors, the stronger the current, the more the algae are detached from the substrate. Niamien-Ébrottié, (2010) obtained similar results in four rivers in the South-East of Ivory Coast.

The similarity indices are low on all rivers. This would indicate a difference between the rivers. This lack of similarity would be due to the lotic nature of the environments studied. Indeed, according to Statzner

& Higler (1985) and Lavoie *et al*. (2003), given their current state, rivers continually change their characteristics from upstream to downstream, depending on external inputs.

Quantitative aspect

Seasonal variations in phytoplankton density

The analysis of the phytoplankton population of the Boubo and Mé rivers indicates that these rivers harbour a fairly diverse population, with a higher abundance in the Boubo River than in the Mé River. This observed abundance would be due to the more accentuated fertilization of the Boubo River. Indeed, the Boubo River is supplied with fertilizer residues and organic matter from the cleared riparian fields. The individuals responsible for this predominance belong to the Chlorophyta and Heterokontophyta, respectively in the Boubo River and the Mé River. The dominance of these phyla is justified according to Cavalla (2000) by the great plasticity of the organisms in these groups to proliferate in all aquatic ecosystems. Moreover, the taxa that make up these groups are the most numerous in the world.

Of the six phyla identified, Chlorophyta and Heterokontophyta are abundant in both rivers. The freshwater nature of the environments surveyed would be the reason for their abundance in the collections. Indeed, according to Krammer & Lange-Bertalot (1991) these two taxonomic groups predominate in freshwater environments. This proliferation is all the more important as the environments are rich in various fertilising elements from the catchment areas. These results are in line with those observed by Groga (2012). In addition, Heterokontophyta have specialised structures that allow them to colonise environments efficiently and rapidly RECORD (2010).

Diversity Index

The study of spatial and seasonal variations in the diversity index showed that the waters of the Boubo and Mé rivers show a high diversity of species, varieties and forms, with values above 2 bits/cell in some places, especially during the dry seasons, in general. Diversity sometimes reaches values of 4 bits/cell at the Boubo River during the short rainy season. This would indicate that this environment is subject to a variety of ecological requirements. Indeed, according to Frontier (1983), in exceptionally diverse environments, the Shannon diversity index does not exceed 4.5. The values obtained in the present study are close to those obtained by Niamien-Ébrottié et al. During the rainy season, the enrichment of the river in nutrients would favour the proliferation of taxa that are less resistant and/or less tolerant of environmental conditions (Dauta, 1978).

CONCLUSION

The importance of anthropic pressures, depending on the catchment area, significantly influences the quality and dynamics of the microalgal communities of the rivers studied. This is more marked at the river level where human activity is important; notably for the Boubo River than in the Mé River. This difference is explained by the relatively high levels of nutrient salts noted in the Boubo River. The high presence of nutrient salts favours the proliferation of aquatic plants, in this case microalgae.

The compositional analysis showed that the phytoplanktonic flora recorded gave 203 taxa identified in the Boubo River against 106 taxa for the Mé River. The microalgal abundance of Chlorophyta and Heterokontophyta in the Boubo and Mé rivers reflects the high nutrient content of these water bodies, especially in the Boubo River watershed, due to the large industrial plantations in this area. The effects of activities are more accentuated during rainy periods. The preponderance of Chlorophyta, Heterokontophyta and Euglenophyta density, known for their development in eutrophic environments, should call the public authorities to account for the threats to the quality of the water of the rivers studied in particular, but above all to the water of the South of the country in general, taking into account the demographic explosion and anthropic activities (domestic, agricultural and industrial) which are growing more and more to the detriment of sustainable development.

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