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Characterization of Waters in the Construction Zone of the Channel of Fishing Port of Grand-Lahou, Cote D'ivoire

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ABSTRACT: In the estuary of the river Bandama, a channel will be construct to facilitate navigation. This channel will connect the fishing port of Grand-Lahou's vocational high school to Atlantic Ocean. Thus it is essential to have an environmental impact assessment study to understand the impacts arising due to construction activity. This study was performed to determine present physico-chemical characteristics of the waters in Grand-Lahou estuary in order to assess their possible alteration due to construction activity. Remote sensing and water samples collected in situ are both methods used to achieve this study. The measured physico-chemical parameters showed that waters in Grand-Lahou estuary are highly mineralized (electric conductivity ranging between 152 $\mu\text{S}/\text{cm}$ and 52380 $\mu\text{S}/\text{cm}$), anoxics (negative values of the oxydo reduction potential). This may explain a gradual depletion of its fauna. Multivariate statistical techniques (Agglomerative Hierarchical Clustering) used in this study allowed to determine various parts of water which could be grouped into three zones for monitoring water quality. Moreover, this study allowed to realize the physico-chemical parameters maps.

KEYWORDS: AHC, Remote sensing, River Bandama estuary, Physico-chemical parameters, Grand-Lahou, Côte d'Ivoire.

I. INTRODUCTION

In recent years, coastal erosion at Bandama river estuary, has received considerable attention due its catastrophic impacts in terms of loss of living space, damage to properties and infrastructural facilities. This leads riverine population whose fishing is the main economic activity to leave their native land and become gradually farmers. Halieutics resources got scarce because of the pollution of this aquatic environment. Moreover, the estuary of Bandama presents shallows disrupting navigation. As a result, the population is pauperized due to the drastic downturn of the fishing activities. The government, faced with these socioeconomics problems, plans to dredge shallows waterways and construct a channel connecting the fishing port of Grand-Lahou's vocational high school to Atlantic Ocean. This to give a boost to the fishing activity. Even if this project will solve the economic problem, one expect that dredging and construction activities can alter waters quality in the estuary. Hence, it is important to characterize present state of the waters in Grand-Lahou estuary.

II. METHODOLOGY

2.1 Study area

Bandama river estuary in Grand-Lahou (Côte d'Ivoire) is the only one outlet of Bandama river into the Atlantic Ocean. It is located in the eastern side of Grand-Lahou lagoon, between 4°26 N and 5°20 N latitudes and 4° 20 W and 5°20 W longitudes. Three main channels are on this area (Fig. 1). These are the Nyouzoumou channel (channel through which waters of the Nyouzoumou lagoon flows into the estuary) in the South-West, the fluvial channel (Bandama channel) in the East and the Tagba channel (drains waters of Tagba lagoon into the estuary) in the North.

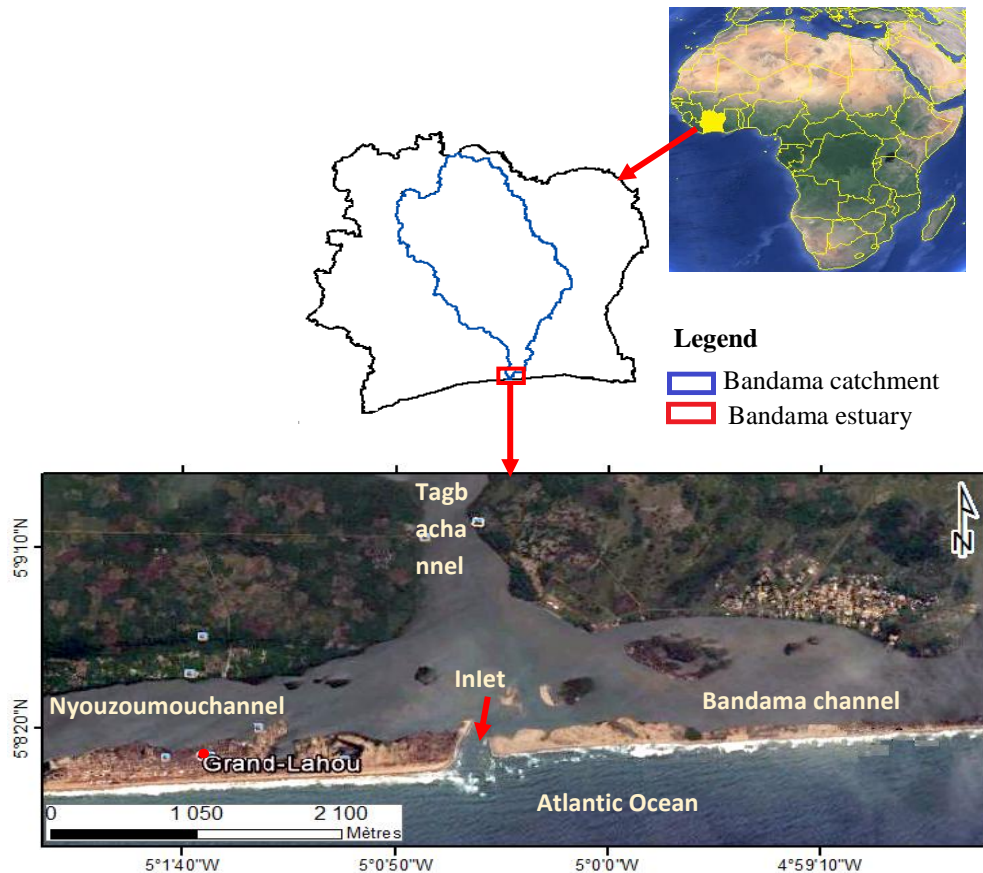


Fig. 1. Location of Bandama river estuary

2.2 Data

Physico-chemical parameters needed for characterization of Bandama river estuary are the following: pH, salinity, conductivity, temperature, Oxido Reduction Potential (ORP) and Total Dissolved Solids (TDS). These parameters were measured *in situ* in 51 stations spread throughout the estuary. As far as suspended matters mapping is concerned, we needed *in situ* measures of Total Suspended Matters (TSM) concentration (mg/l) and the scene 196-56 of the sensor ETM+ of Landsat 7. All these data were acquired within the framework of the project of channel construction.

2.3 Maps of the distribution of the physico-chemical parameters

ArcGIS 10.2 was used for generation of physico-chemical parameters distribution map. The method selected is the IDW (Inverse Distance Weighting) in order to interpolate values of each parameter measured in the sampling station.

2.4 Agglomerative Hierarchical Clustering (AHC)

Statistical analysis is accomplished by Agglomerative Hierarchical Clustering (ACH) in XLSTAT software. From field data set (stations coordinates in row and physico-chemical parameters values in column) one compute proximity matrix between sampling stations by using euclidian distance in order to cluster them together. These stations are aggregate in homogeneous cluster according to Ward method.

2.5 TSM concentration map generation using LANDSAT ETM+ image

First step in image processing is radiometric correction to convert the raw image (band 2 of Landsat ETM+) to surface reflectance. Secondly, a mask map is made for separating water from land. The corrected image resulting will be used to retrieve the TSM concentration map. For mapping TSM from the corrected image, the statistical approach has been

used by correlate (linear regression) the pixel's values of this image with TSM field data. Finally, density slicing classified raster image was done. ENVI 5.1 software has been used for all above-described processes.

III. RESULTS AND DISCUSSION

3.1 Spatial distribution of physico-chemical parameters in Bandama river estuary

pH and Temperature

The pH varies slightly in the estuary ($7.07 < \text{pH} < 8.23$). On the whole, the pH is high near the sea, in Tagba and Nyouzoumou channels. Lows values of pH are observed in fluvial channel (Fig. 2). This distribution implies that the pH of waters, under marine influence are alkalines, unlike those that are in contact with fresh waters which are rather acids (N'guessan et al.[1]). As regards the temperature, it also varies slightly in the estuary ($26.24 \text{ }^\circ\text{C} < \text{Temperature} < 31.87 \text{ }^\circ\text{C}$). The low values of temperature are noticed in outlet of Bandama river into the Atlantic and in the areas under marine influence (Nyouzoumou and Tagba channels). The highest temperatures are recorded in the stations located in fluvial channel (Fig. 3). Hence, waters from the Atlantic Ocean are fresher than waters of Bandama river flowing in the sea. Bandama estuary is shallow (the estuary having water depths less than 7 m), what makes the mixing of waters of the bottom and surface easier. Because of this reason, the pH and the temperature are homogeneous in the estuary. This seems to be a characteristic of the tropical countries' estuaries (Varlet [2]; Durfour [3]).

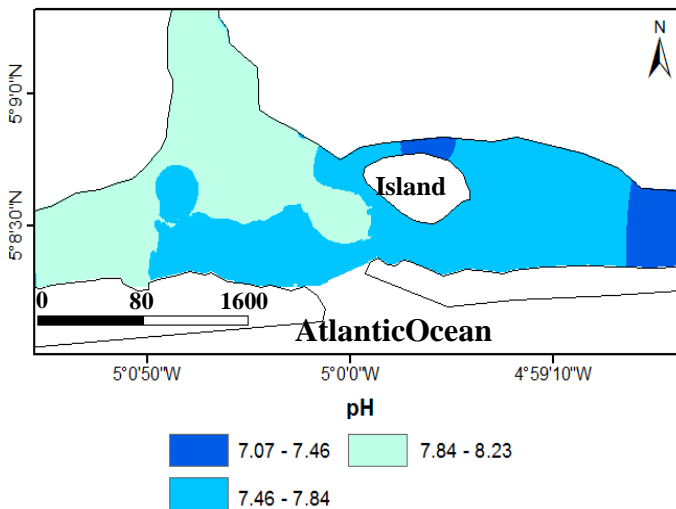


Fig.2.Surface distribution of the pH to Bandama river estuary

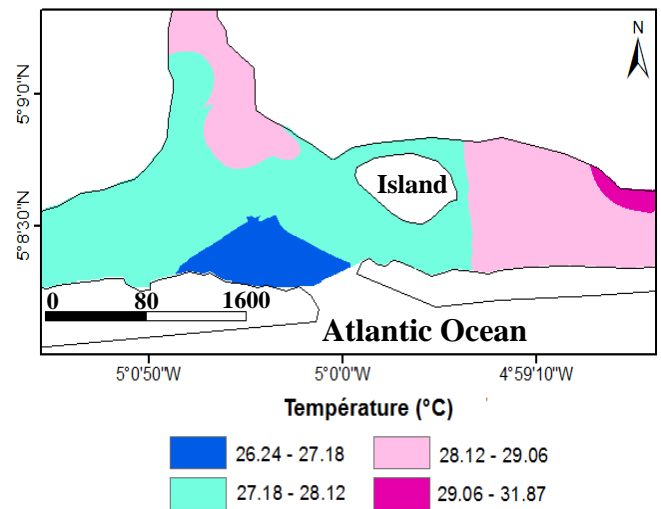


Fig.3.Surface distribution of the température to Bandama river estuary

ORP

In the study area, only negatives values of ORP are recorded (Fig. 4). A negative value of ORP characterizes a reducing medium (septic water, putrid fermentations, presence of anaerobic bacteria) and anoxic waters. This particular living condition could affect negatively wildlife in the estuary. Villanueva's [4] works corroborate this point of view, indeed, these ones show the depletion of fish stocks in the estuary. Reduction phenomenon can lead to the transformation of nitrates into nitrites and into ammoniacal compound. Konan et al. [5] record high content of nutrients (phosphates, nitrates et nitrites) in the same study area due to the lixiviation of fertilizers during the wet season.

Salinity

In Bandama river estuary, the salinity has a heterogeneous distribution due to the presence both of sea waters and continental waters. On the whole, the high values of the salinity are recorded in the Nyouzoumou channel ($4.71 \text{ } \text{‰} < \text{salinity} < 17.81 \text{ } \text{‰}$) (Fig. 5) due to the proximity of the sea. The salinity is almost null ($0.07 \text{ } \text{‰} < \text{salinity} < 0.98 \text{ } \text{‰}$) in Bandama channel due to the fresh water of Bandama river flowing in this channel.

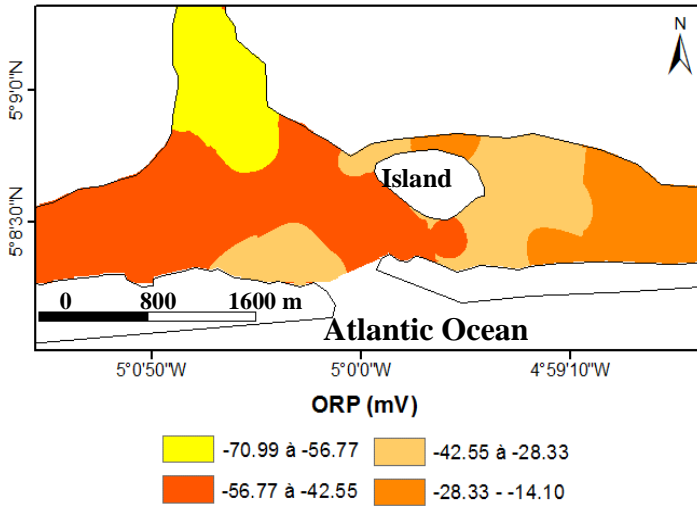


Fig.4. Surface distribution of the ORP to Bandama river estuary

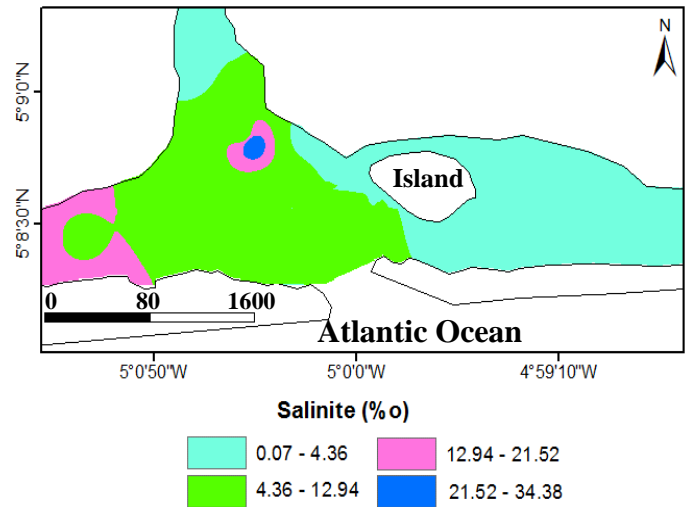


Fig.5. Surface distribution of the salinity to Bandama river estuary

Conductivity and TDS

With regards to the conductivity and TDS (TDS principal constituents are usually, calcium, magnesium, sodium, and potassium cations and carbonate, hydrogencarbonate, chloride, sulfate, and nitrate anions.) the high values of these parameters are noticed throughout the study area. What let suppose that Bandama river estuary is significantly influenced by the Atlantic Ocean. The highest values are recorded in the stations located near ocean and lowest ones are located in fluvial channel. Water conductivity in the Bandama river estuary can be partly due to the mineralization of the blocks of rocks which characterize ivorian western littoral. This water is charged in dissolved solids, what shows its significant mineralization. The distributions of these two parameters are shown in Figs. 6 and 7.

3.2 TSM concentration map derived LANDSAT ETM+ image

TSM map retrieved from Landsat ETM+ after application of the statistical algorithm show detailed information on water turbidity. It appears that Bandama river discharges have caused high TSM concentrations in the estuary. But the higher TSM concentrations are recorded in the Nyouzoumou and Tagba channels (Fig. 8). In this zones the currents velocities are very low to push away suspended sediments what explains the high concentration of TSM. Going from

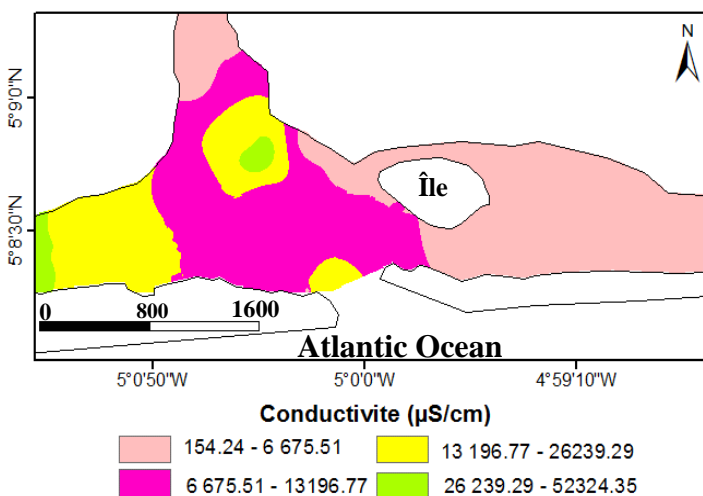


Fig.6. Surface distribution of the conductivity to Bandama river estuary

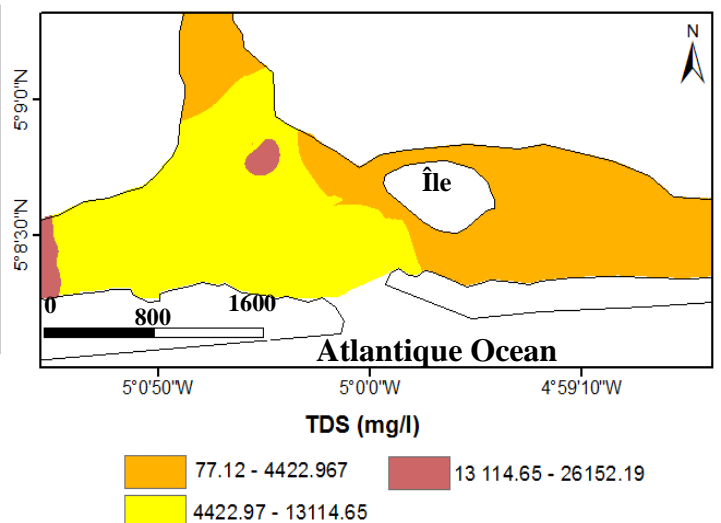


Fig.7. Surface distribution of the TDS to Bandama river estuary

the middle part of estuary to the inlet zone, TSM decreases. As Wognin et al.[6] have mentioned TSM distribution in Bandama estuary depends on the current flows in the estuary (tide, waves, Bandama river discharge, Nyouzoumou and Tagba lagoon current flows). This study includes the mapping of TSM by using empirical approach (statistical model). This method has been applied by many previous studies (Ritchie and Cooper [7], Boban [8]). Linear regression was proved useful for the study of the suspended sediment.

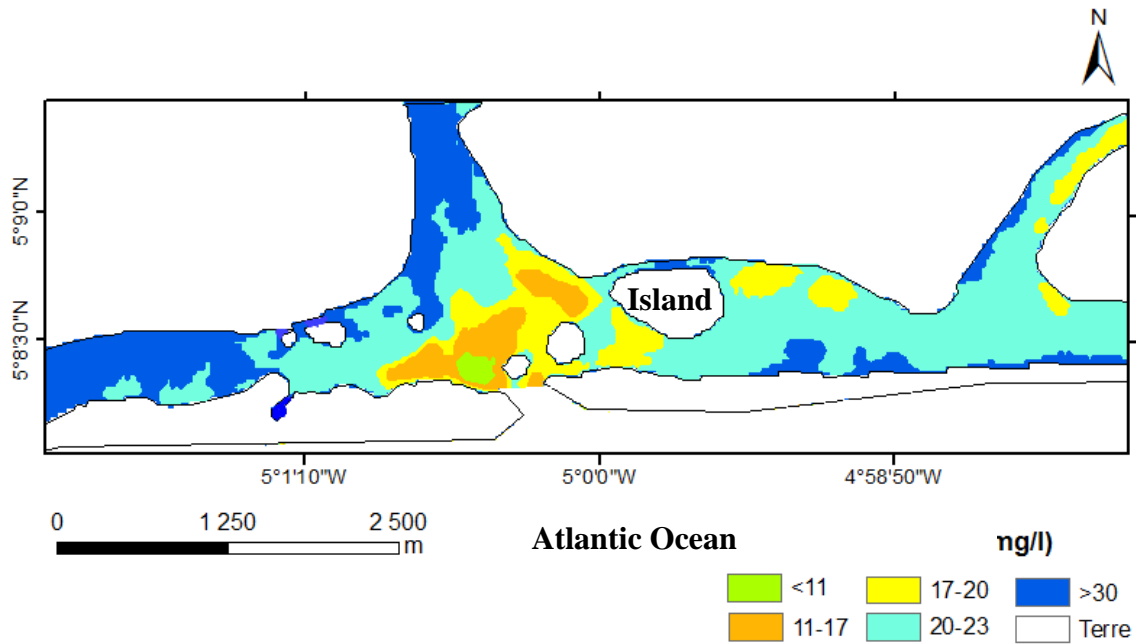


Fig. 8.Surface TSM concentration map to Bandama river estuary

3.3 Classification of sampling stations on the basis of the physico-chemical parameters

AHC method proves to be necessary to divide the estuary into homogeneous zones in order to make easier the monitoring of water quality. On the basis of the intra-stations variabilities, AHC allowed to group together sampling stations into three clusters corresponding roughly to three sampling zones in the estuary (Fig. 9). The zone I (clusters I) where fresh water of Bandama river is flowing into the sea. This zone is slightly affected by the sea (salinity is nearly null, water is weakly mineralized and warmer than sea water). The zone II (cluster II) group together sampling stations located in the inlet and Tagba channel. This zone is directly under the influence of the sea. The zone III (cluster III) drain water of Nyouzoumou lagoon into the estuary. In this zone, water is highly mineralized and current flows are nearly null, this contribute to the penetration of marine water. As showed in figure 9, the classification doesn't permit to get three zones totally homogeneous. Indeed, Bandama river estuary is an area where water from Nyouzoumou lagoon, Tagba lagoon and Bandama river are mixed together

VI. CONCLUSION

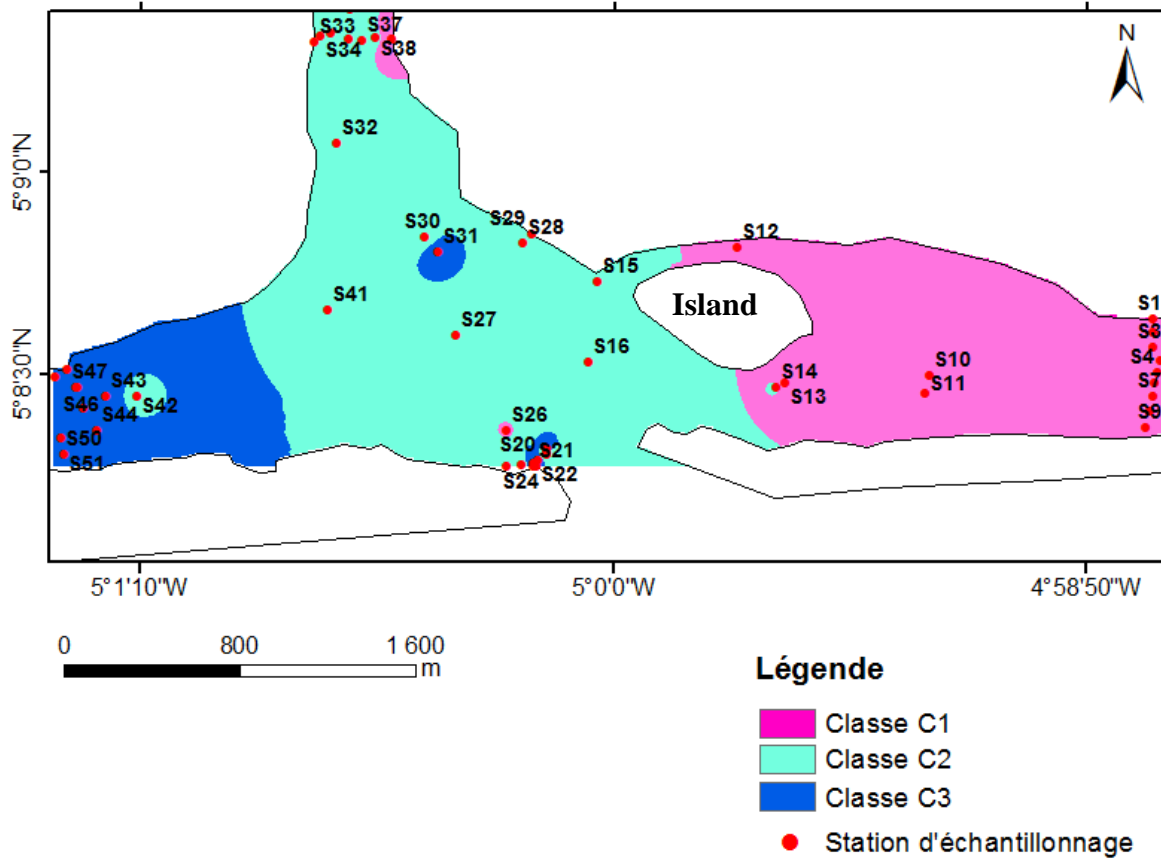


Fig.9. Cartographical approach of AHC method of physico-chemical parameters

The distribution of the physico-chemical parameters at estuary varies according to continental waters flows (Bandama river, Nyouzoumou and Tagba lagoon) and the penetration of marine water (during the low water level of the river and with spring tide). Waters of the estuary are highly mineralized (high values of conductivity and the TDS). These waters are anoxic and septic (negative values of ORP) what leads to an impoverishment of its fauna. The AHC revealed three zones of sampling stations at Bandama river estuary. Thus a later monitoring of water quality at estuary could be done with a reduced number of sampling stations by taking account of this classification. The concentration of the TSM related to the color of the estuary waters was monitored by remote sensing. Dredging activity in the estuary will increase without a doubt TSM concentration.

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