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Dynamics of the Ebrié Lagoon from 1986 to 2017 (Southern of Ivory Coast): contribution of Remote sensing and GIS

[*]Jean-Baptiste KASSI[1], Cyprien Koffi YOBOUE[2], Gnangui Christian ADON[3]

[1] Université Félix Houphouët-Boigny, Centre Universitaire de Recherche et d'Application en Télédétection (CURAT),
Département des Géosciences Marines, 22 BP 801 Abidjan22, Côte d'Ivoire,
[2] Université Félix Houphouët-Boigny, Centre Universitaire de Recherche et d'Application en Télédétection (CURAT),
[3] Université Félix Houphouët-Boigny, Centre Universitaire de Recherche et d'Application en Télédétection (CURAT),

Abstract :
Situated in the South of Ivory Coast. Lagoon Ebrié presents an interest for tourist and socioeconomic. However, it has been subjected to strong anthropogenic pressure, in the case of the work of development and the construction of habitats on its borders causing silting and filling the lagoon Bays. The objective of this study is to evaluate the dynamics of the bays of the water of the city of Abidjan from 1986 to 2017 in order to contribute to a better management of these environments. The study was realized thanks to the use of satellite data and thanks to the observations of ground. She based on the diachronic analysis of the years Landsat satellite images 1986, 2000, 2015 and 2017. The results showed a negative evolution of whole of the surface of the water of the Ébrié Lagoon which went from 8742 hectares in 1986 to 8393 hectares in 2017 is a regression of 4% of the surface of the water. Besides, the study revealed that the determining factor of the loss of the surfaces of the lagoon water is the anthropogenic pressure.

Keywords : Remote sensing, GIS, lagoon bay, Ebrié lagoon, Cote d'Ivoire

1. Introduction

Around the world, lagoons and more generally the paralic environments, are original ecosystems that participate in both marine and continental domains [6]. Space or bio-space, the lagoon is a confined environment [16]. As a result, lagoonal littoral ecosystems constitute areas of dual interest: a scientific interest because they are fast-changing and complex systems, because of their situation at the Terre-Mer interface, and a socio-economic interest (aquaculture, tourism etc.).

In Ivory Coast, the big zones lagunaires as that of Ebrié also undergo a strong demographic pressure bound to their situation of particularly productive ecosystem and the contributions of nutriments connected to multiple activities caused very often the eutrophication [2]. Placed in the extreme the South of Ivory Coast, the lagoon Ebrié, following the example of all other lagoons of the world, suffers from the blocking with sand and from the filling of these plans of water.

Numerous works led on the lagoon Ebrié generally concerned the hydrology, the bathymetry, the sedimentology, the geochemistry, the pollution … [4]-[5]-[9]-[14]. But those dedicated to the use of the satellite imaging for the follow-up of the evolution of the surfaces of the stretch of water lagunaire are a few [2]-[12]-[13]. Nevertheless, seen the scale of the anthropogenic pressure which practices everywhere from the point of view of water lagunaire, it is imperative that we have a synoptic view on the evolution of the bays of the stretch of water of the lagoon Ebrié. It is from this perspective that this study was introduced. So, the main objective of this study is to estimate the dynamics of the bays of the stretch of water of the lagoon Ebrié of the city of Abidjan from 1986 till 2017. She joins, indeed, in A sustainable management policy of the environment lagunaire.

2. Study area

The lagoon Ebrié is a part of the system lagunaire coastal Ivory Coast the lagoons of Grand-Lahou, Potou, Aghien, Tendo and Ehy. The system lagunaire Ebrié extends over a 566 km^2 surface shared in 523 km ² for the lagoon Ebrié and 43 km ² for the system Aghien-Potou. He is lengthened on a distance of 130 km and reaches a maximum width of 7 km with an average depth of 4,8 m being able to reach 15 - 20 m by places [1]. The Ebrié system possesses numerous bays (Banco, Cocody, Biétri etc.) who represent near the fifth of the surface of the stretch of water (99 km ² on 523 km ²). The lagoon Ebrié is situated between the longitudes 3°40 ' and 4°50 ' the West and the latitudes 5°15 ' and 5°20 ' the North and makes border with ten municipalities of Abidjan except the municipality Abobo (Figure 1). He has an overturning pond covering a 93 600 km^2 surface among which 78 000 km ² are drained by the river Comoé and the rest by rivers Agnéby and Mé [9].

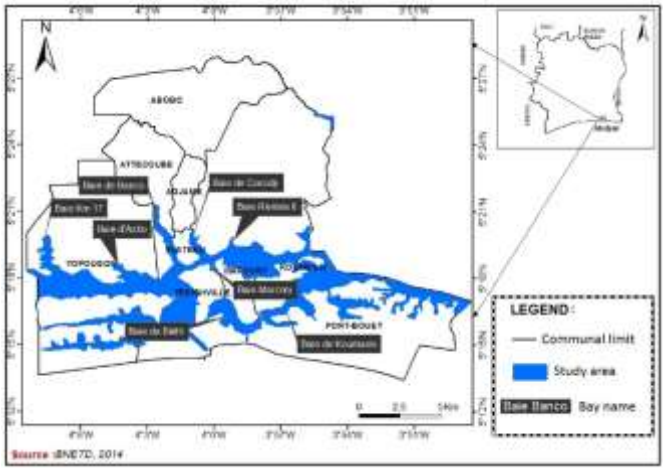

Figure 1: Localization of the zone of study

3. Material and Methods

3.1. Data

The used data are essentially constituted:

- **Of satellite images**

The database of satellite images includes four images Landsat stemming from sensors TM (Thematic Mapper), ETM + (Enhanced Thematic Mapper Plus) and Landsat 8 Oli (Operational Land Imager) and an image DEM (12,5 m) of the sensor PALSAR downloaded thanks to the data of archive of Satellite Alaska Facility (ASF) covering the period 1986 in 2017.

- **Of cartographic data**

A georeferenced vectorial digital layer of the district of Abidjan and its municipalities and another vectorial layer relative to the limits of the lagoon Ebrié were used.

- **Of demographic data**

The data of volume of population of the district of Abidjan stemming from the last census of 2014 served to show the evolution of the population Abidjanaise.

3.2. Method

- **Overseen Classification of the images**

Before the classification of the images, a calculation of the indication of the séparabilité of the classes is made to estimate the reliability of the sites of training (for the mission of ground) which are going to be of use to classifications. The method of the chosen séparabilité of the classes is the one of the distance of Jefferies-Matusita. She highlights the probability of a pixel to belong to a class. The distance of Jefferies-Matusita is between 0 and 2. The more the value gets closer to 2, the more there is of séparabilité spectral assuring a good precision of classification. A value superior to 1,8 or 1,7 is generally used to agree that two classes are different [3].

For the overseen classifications, the method of maximum of credibility based on the classifier of Bayes was applied to the images. The principle of this Bayesian classification is to partitionner an image by a calculation of probability of membership in a region given by every pixel of the image. Indeed, she calculates the probability of a pixel to belong to a given class. The algorithm classifies the image by basing itself on the spectral stemming information zones of training [4].

A mission of ground, was made on all the images from 1986 till 2017 to validate this type of classification.

- **Extraction of the surface of the stretch of water lagunaire**

The data obtained from the classification of every image Landsat TM (1986 ETM) + (2000), OLI (2015) and OLI (2017) were of use to us as support. Indeed, every map of land use from 1986 till 2017 was taken as database for the extraction of the surface of the stretch of water lagunaire. For the extraction, the outlines of the stretch of water lagunaire Ebrié stemming classifications are digitized what gives a layer of the surface of every year.

- **Surface evaluation of the stretch of water lagunaire**

The calculation of the loss of surface of the stretch of water between 1986s, 2000, 2015 and 2017 is estimated by making the difference of surfaces (surface of the class in the date t2 - surface of the class in the date t1) in the software QGis. This value

gives a precise idea of the loss of environment entrainée by the filling according to the relation: $S_c = S_1 - S_2$

With S1: surface of the class in the date t1, S2: surface of the class in the date t2 (t2 > t1) and filled Sc surface.

This relation allows a general estimation of the volumes filled according to the average depth of the stretch of water according to the following equation: $V_c \approx S_c \times P_{moyenne}$

With $P_{moyenne}$: depth averages of the stretch of water and V_c the filled volume.

We calculate then the annual average rate of expansion (Tc) according to FAO [10] from the following equation:

$Tc = [(S_2 / S_1)^{1/t} - 1] \times 100$

Where Tc: rate of change (%), S_1: surface of the class in the date t1, S2: surface of the class in the date t2 (t2 > t1) and t: number of year between two dates.

If Tc is positive, he translates an extension of the stretch of water of bays

If Tc on the other hand is negative it, translated a backward movement thus a loss of surface of the stretch of water.

4. Results and Discussion

4.1. Results

Evolution of the stretch of water lagunaire from 1986 to 2017

Figures 2, 3 and 4 show the evolution of the stretch of water lagunaire Ebrié between 1986 and 2017. The color sky blue represents the surface of the stretch of water lagunaire and the dark blue color the surface of the filled zone. Lagunaires zones which appear dark blue represent the on-surface losses at the level of the lagoon from one year to an other one. From 1986 till 2000, the filled surface is little marked and localized in the Plateau and in Yopougon. From 2000, we note an increase of the filled surfaces who notice strongly in the bays of Port-Bouët and Koumassi (Figure 4).

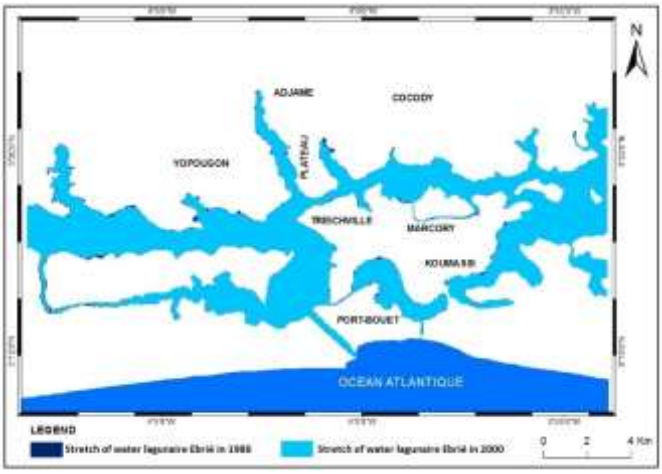

Figure 2: Map of evolution of the stretch of water lagunaire from 1986 to 2000

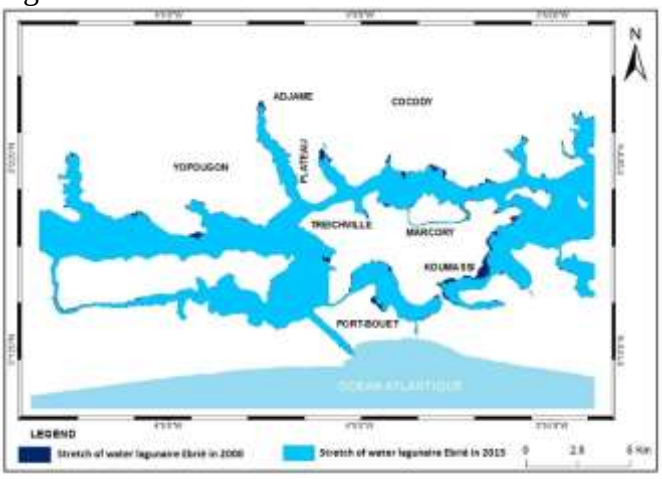

Figure 3: Map of evolution of the stretch of water lagunaire from 2000 to 2015

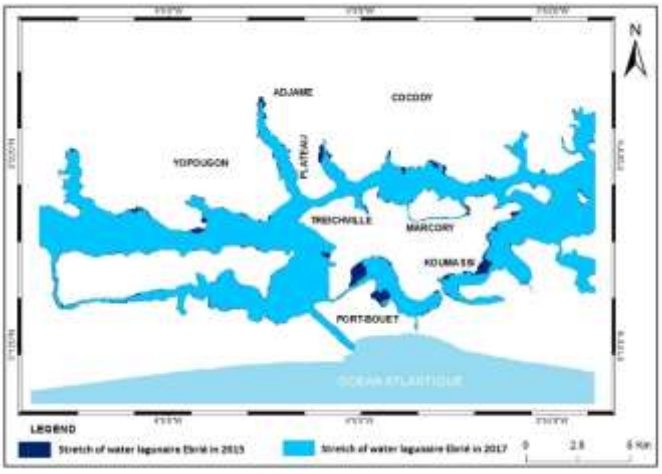

Figure 4: Map of evolution of the stretch of water lagunaire from 2015 to 2017

The graph of the (Figure 5) reveals that from 1986 to 2000, the surface of the lagoon passed of 8742 ha in 8611 ha or 131 ha of loss. From 2000 to 2015, she passed of 8611 ha in 8567 ha or 44 ha. Of 8567 ha in 2015, the surface of the stretch of water lagunaire passed in 8393 ha in 2017 (that is 174 ha of loss). We notice a regression of the surface of the stretch of water lagunaire essentially located on the banks of the lagoon.

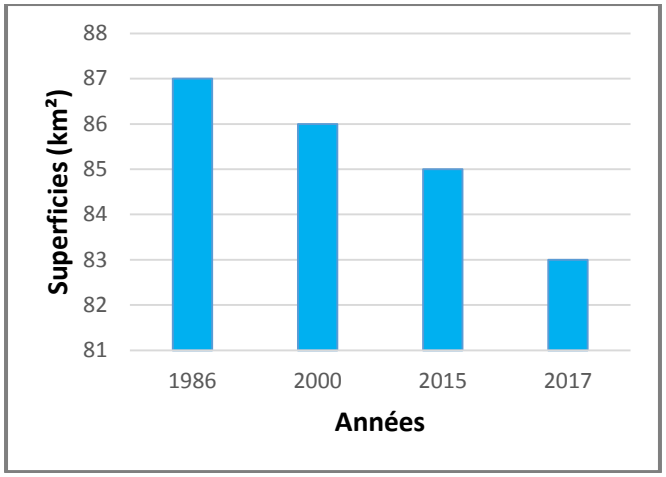

Figure 5: global Evolution of the stretch of water lagunaire between 1986 and 2017

Table I shows the annual rate of change of the lagoon water body between 1986 and 2017. It shows that the average annual average change in the surface of the body of water is negative overall. Between 1986 and 2000, the lagoon lost annually an area of -0.11%. From 2000 to 2015, the annual loss is estimated at -0.03% and between 2015 and 2017 it is -1.02%. It should be noted that the lower the average annual rate of change in the evolution of the water body, the greater the loss in the surface of the water.

Table I: Rate of variation of the lagoon Ebrié between 1986 and 2017

Années	Tg (%)	Tc (%)
1986 – 2000	-1,5	-0,11
2000 – 2015	-0,51	-0,03
2015 – 2017	-2,03	-1,02

Tg: global rate of change
Tc: annual average change rate

4.1.1. The lagoon areas filled between 1986 and 2017

Figure 6 shows the limit of the lagoon water body in blue and the spaces lost in red from 1986 to 2017. An evaluation of the area of Baies du Banco and Cocody, gives us 280 ha in 2017 against 332 hectares in 1986 for Banco and 109 hectares in 2017 against 149 hectares in 1986 for Cocody. The bay of the Banco lost 52 hectares between 1986 and 2017 and that of Cocody 40 hectares. As for the distance of the stretch of water lagunaire separating Koumassi to Port-Bouet, she was 726 m in 1986 against 134 m in 2017. It shows that in a few years, the stretch of water separating both municipalities will be filled. If we consider the rhythm of current filling, in eighty-three (83) the years, that is in 2100, the lagoon Ebrié will have lost about 14,68 % of its surface is 1 283,58 hectares.

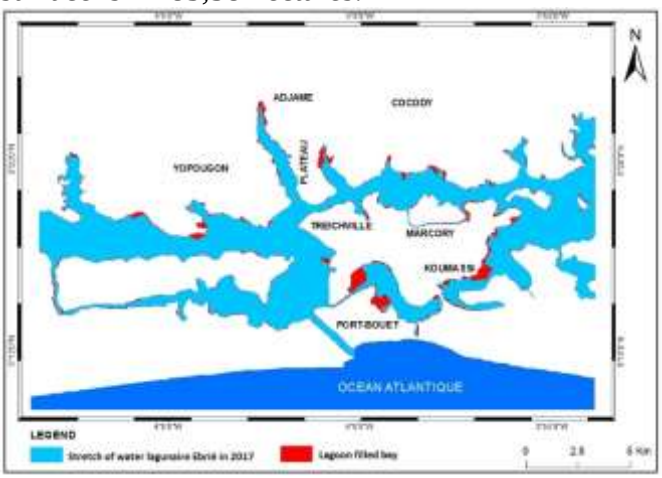

Figure 6: General map of the filled areas of the lagoon water body between 1986 and 2017

4.1.2. Factors behind the dynamics of the Ebrié lagoon in the city of Abidjan.

4.1.2.1. Natural factors of the dynamics of the banks of the lake lagoon

- **Fluvial sedimentary inputs**

The silting up of the Ebrié lagoon bays is due in part to the sand coming directly from the surrounding sandy formations (Continental Terminal highlands, low Holocene trays or Holocene sand bars), either by shoreline alteration or by contribution rivers.

- **The hydrodynamics**

The low internal circulation of the lagoon in the bays favors sedimentation. In fact, the estuarine bays of Abidjan undergo a strong anthropic pressure which modifies the circulation of the masses of water. In the narrow channels, the currents are exclusively alternative while in the deep coats, the currents are gyrating and waters are badly renewed [13]. As a consequence, the energy of the tidal stream falls and does not manage to penetrate inside bays. There is a bad exchange with the main channel, what allows to think that pollutants which are forwarded in these bays by means of sewers, of envoys and of systems of rejection of industrial waste stay, for the main part, inside without being able to be evacuated.

4.1.2.2. Anthropogenic factors of the dynamics of the berries of the lagoon Ebrié

- **Demographic pressure**

Since the 1950s, the urban area of Abidjan does not stop increasing in a spectacular way. The demographic development of the city which was 350 000 inhabitants in 1965, exceeded the million to reach in 1998 a number of 3 120 417 inhabitants is a

tenfold increase of the population of 1965 according to the National Institute of the Statistics (INS). Of 1998 in today, according to the last General Census(Inventory) of the Population and the Housing environment (RGPH) of 2014, the population Abidjanaise is estimated to 4 395 243 inhabitants against a little more than three millions in 1998 (Figure 7). This demographic development does not go without consequence on the urban space. He had for corolaire a need growing in accommodation which became a social problem in the urban area of Abidjan. This reality is made to the detriment of the banks which undergo an unprecedented degrading pressure.

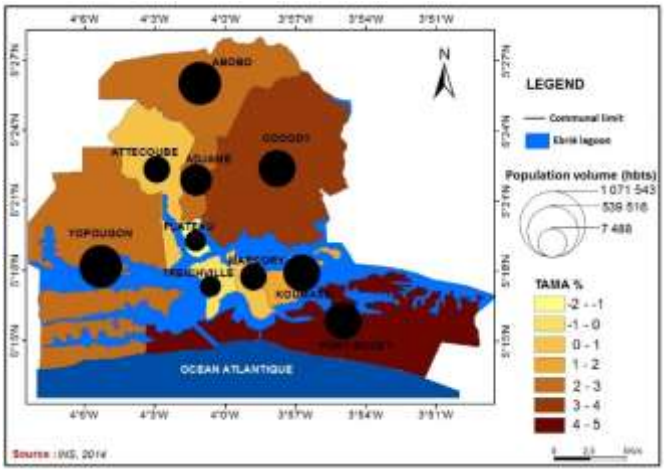

Figure 7: Map of the population volume of the city of Abidjan

- **An uncontrolled galloping urbanization**

The bays of the Ebrié lagoon are more and more affected by the development and artificialisation works (construction of commercial or fishing port, establishment of companies on the lagoon edges, etc.). This disturbs the water exchanges and favors sedimentation. It is the case for example of the project of the extension of the autonomous port of Abidjan (Photo 1), of the project of protection and valuation of the bay of Cocody (Photo 2). So, there are industrial installations around the lagoon (companies of cement works at the level of the bay of the banco to Attécoubé (Photo 3) and of the construction project of a fishing port to Attécoubé). In other sector, as to Koumassi and Marcory, the banks of the lagoon are spaces often suited in secret. In these places, it is the precarious housing environment which develops in an environment there where the waste of household waste is masters troubles. The inhabitants of these municipalities (Marcory and Koumassi) bank up the water of the lagoon to build houses. . Backfilling is done with household garbage dumped by the population [15]. Also, when the current of the water increases, there is enormous damage (recurring floods, the obscuration of the ways and an uncontrolled occupation of the grounds).

Photo 1: Storage of sand for backfilling the Abidjan port extension project

Photo 2: Cocody Bay embankment (corniche) for the project to save Cocody Bay

Photo 3: Installation of cement company and backfilling of Banco Bay in Attécoubé

- **The failure of the sewerage system**

The sealing of the bays of the lagoon is often the fact of the failure of the sewer system. These stuffy environments establish the principal points of outcome of the sewerage system of the city of Abidjan. The phenomenon of clogging bays is mainly due to the inflow of runoff that drain to the bays, significant amounts of sands and sludge from the conurbation of Abidjan. The bays of the Ebrié lagoon are most often considered as the "natural" outlet for effluents. It is generally spaces of rejections of sewers and envoys of run off water that are the cause of filling of these bays by waste and sands from the city. It is the case at the level of the ledge (bay of Cocody) that is considered as the release of the pond of the Guru by receiving all the garbage and the sandy sediments since Abobo (Photo 4). And even on these spaces filled, some local residents practice the market gardening culture (Photo 4). Also, the western end of the bay of banco, in the municipality of Attecoubé, is the field of finishing runoff and sandy sediments from the municipality making these environments unhealthy and favoring their filling (Photo 5).

Photo 4: Exit of emissaries on the Cocody bay, land advance and anthropogenic activities

Photo 5: Exit of emissaries on the lagoon bays in Attécoubé

4.2. Discussion

Mapping the dynamics of lagoon water levels is both interesting and delicate. Remote sensing is an effective tool in monitoring the evolution of lagoon systems. The methods for estimating the evolution of lagoons are numerous [5]. The method of estimation which was used within the framework of this study is the follow-up by surface evolution by the use of the satellite data. The limits of this technique can be in their spatial resolution. The high-resolution satellite images will supply certainly results more decisive than those of the average spatial resolutions who can not see all the details of the borders of the stretch of water. In these conditions, we have to watch that the images is taken in similar weather conditions where the water level is the same [5]. However, in term of diachronic study the image Landsat is the most requested because of their seniority. So, in our case, we used the images Landsat TM, ETM + and Oli to follow the surface evolution of the lagoon Ebrié. This method is in adequacy with that used by Louaya [12] to study the geomorphology of the complex lagunaire of Nador (Morocco) by using the images Landsat MSS, TM, ETM + and Oli 8. In the same order, El-Asmar [9] used six Landsat imagery between 1973 and 2011 to map the change in the Burullus lagoon surface (Egypt). The results of our work showed that the Ebrié lagoon decreased by 349 ha between 1986 and 2017. This loss in surface of the lagoon water plan of the lagoon Ebrié is the fact of the advance of the frame on the water reflecting the embankments operated during this period. These results corroborate those of Pottier [15] in a study conducted between 1955 and 2004 on the Banco, Cocody and Marcory bays, which showed that the surface loss of more than 90 ha for the bay Banco and almost 60 ha for Cocody Bay is due to backfilling. As for Wilke [19], they showed that the most important cause of filling was the remblaiement which caused the loss about 40 % of the surface of the stretch of water between the XIXth and the environment of the XXth century during a study led on the lagoon of the palm in Aude (France).

Conclusion

The different treatments from Landsat satellite images allowed us to follow the spatio-temporal evolution of the lagoon Ebrié water. A diachronic analysis done on the evolution of the lagoon bays showed that the berries of the Ebrié lagoon lost about 349 hectares of their surface between 1986 and 2017. This situation is on one hand the fact of the impacts of the natural phenomena from the point of view of lagunaire water but on the other hand the man contributed to it by means of the elevations of the surroundings of waters lagunaires or for arrangements(developments), installations of factories or for the construction of housing environments for the populations.

References

[1] Affian K., Djagoua E. V., Kouamé K. F., Gioan P. et Biémi J. (2002). Etude par télédétection aéroportée d'un environnement lagunaire en zone tropicale: Cas de la lagune Ebrié en Côte d'Ivoire. Revue Télédétection, vol. 2, n°4, pp. 233-242.

[2] Anoh P. (2001). La lagune Ebrié de 1955 à 1998 : Pollutions des eaux et encombrements des baies urbaines de l'agglomération d'Abidjan. Revue Géotrope, n°1 pp. 62-78.

[3] Bindel M., Hese S., Berger C. et Schmullius, C. (2011). Evaluation of red-edge spectral information for biotope mapping using RapidEye. Revue Remote Sensing for Agriculture, Ecosystems, and Hydrology, vol. 817, pp. 1-9.

[4] Caloz R. et Collet C. (2001). Précis de télédétection. Traitement numérique d'image de télédétection. Presse de l'Université du Québec, Canada, pp 1-400.

[5] Casting J. (2008). État de l'art des connaissances du phénomène de comblement des milieux lagunaires. Mémoire de Master 2, Réseau de suivi lagunaire, Cépralmar, 100 p.

[6] Dufour P. et Slepoukha M. (1975). L'oxygène dissous en lagune Ebrié: influence de l'hydroclimat et des pollutions. Document Centre Recherche Océanographie Abidjan, vol. 6, pp. 75-118.

[7] Durand P. et Skubich M. (1979). Recherches sur les lagunes ivoiriennes. Document Centre. Recherche Océanographie Abidjan, 55 p.

[8] Durand J.R., Philippe D., Daniel G. et Zabi F.G.S. (1994). Environnement et ressources aquatiques de Côte-d'Ivoire. Les milieux lagunaires, institut français de recherche scientifique pour le développementen coopération, 556 p.

[9] El-Asmar H., Maysa M.N.T. et Abdelbaset S.E.-S. (2016). Morphodynamic changes as an impact of human intervention at the Ras El-BarDamietta Harbor coast, NW Damietta Promontory. 18 p.

[10] FAO (1996). Forest resources assessment 1990 - Survey tropical forest cover studies of change processes. FAO Forestry, Rome (Italie), 130 p.

[11] Girard., Sircoulon J. et Toucheboeuf P. (1971). Aperçu sur les régions hydrologiques. in : le milieu naturel de Côte d'Ivoire. ORSTOM, n°50 pp. 109-156.Grillo S. (2004). L'équilibre de la lagune vénitienne au XVIIème siècle : naissance de l'approche moderne. *in*. Eau et développement dans l'Europe moderne sous la direction de S. Ciriacono, pp. 169-182.

[12] Louaya A. et Hamoumi N. (2016). Apport de la télédétection dans l'étude de l'évolution morphodynamique du complexe lagunaire de Nador (Maroc) au cours des 40 dernières années. XIVème Journées Nationales Génie Côtier-Génie Civil, Toulon, pp. 381-388.

[13] Monde S., Coulibaly A.S., Wango T.E. et Aka K. (2011). Hydrodynamique de l'estuaire de la lagune Ebrié (Côte d'Ivoire). Revue Paralia, vol. 4, pp. 1-14.

[14] N'doman, V.N.P.R. (2010). Étude des milieux lagunaires et péri-lagunaires : cas des baies de Cocody et du Banco de 1955-2010. Maîtrise de Géographie, Université Cocody Abidjan, 92 p.

[15] Pottier P., Affian K., M'Boua V., Anoh P., Kra Y., Kangah A. et Marc R. (2008). La lagune Ébrié à l'épreuve de la pression anthropique. Revue de géographie du littoral, pp. 165-184.

[16] Tastet J.P. (1979). Environements sédimentaires et structuraux du littoral du golfe. Thèse de Doctorat, Université Bordeaux, 181 p.

[17] Tastet J.P. (1994). Géologie et sédimentologie. *in* Durand J. P., Dufour P., Guiral D. et Zabi S. G. F. Environnement et ressources aquatiques de Côte d'Ivoire. Les milieux lagunaires, Paris, ORSTOM, vol. 2, pp. 35-57.

[18] Thiam M.D. (2006). Environnement et évolution des bordures lacustres et lagunaires du fleuve Sénégal. Thèse de Doctorat, Université Cheikh Anta Diop de Dakar, 513 p.

[19] Wilke M., Bouttière H. et Muller M. (2001). Étude de faisabilité d'interventions légères susceptibles d'améliorer la circulation des eaux à l'intérieur de la lagune de La Palme (Aude) et de freiner la sédimentation naturelle. Deuxième partie : Bilan sédimentaire et mécanismes de comblement. CEH, 58 p.