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Sedimentary Dynamics in the Estuarine Bay of Abouabou from 1975 to 2015 (Ebrie Lagoon, Côte d'Ivoire)

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Abstract

The Ebrie lagoon in Côte d'Ivoire is dotted with numerous estuarine bays, including Abouabou Bay located on the south shore, east of Abidjan in the peri-urban area. This bay is particularly confined with an arrow entrance channel, which would constitute an element of protection against forcing. But due to strong natural and anthropogenic pressures, we wonder about the state of the environmental profile (morphology, lifespan) of the estuarine bay of Abouabou. It is in this context that this study, which integrates recent hydrodynamic approaches (digital echo sounding, GPS positioning, etc.), analyzes the evolution of sediment dynamics over the past four(4) decades (1975-2015) of the Abouabou Bay. The evolution of the bay shows a surface variation from 3.90(1975) to 3.81 km² (2015) or a reduction of 0.09 km². The depths of the bay go from 12.2(1975) to 7.8 m (2015) or an increase of 4.4 m. The slopes of the banks become steep, changing from 11.5°(1975) to 8°(2015), a drop of 3.5°. Sedimentary inputs are estimated at 5,279,518.33 m³ and eroded sediments at 2,859,485.20 m³, i.e. a positive sediment budget of +2,420,033.50 m³. The sedimentation rate is that of the order of 1.6 cm/year.

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Introduction

Estuarine bays, due to their position at the edge of continental and marine domains, are subject to a wide range of natural and/or human activities that can disrupt their natural balance. In Côte d'Ivoire, nearly one-fifth of the Ebrie Lagoon's area consists of bays, including the Abouabou Bay. This bay, once considered free from external influences (Tastet, 1975; Varlet, 1978; Affian, 2003), is no longer so today (Touré *et al.*, 2010; Ekponon *et al.*, 2024), due to the expansion of Abidjan and the development of agricultural and pastoral activities. This report analyzes the impact of natural and human-induced forces on sedimentation evolution over the past forty

(40) years (1975 - 2015) in Abouabou Bay. The study integrates morphological characteristics and estimates the sediment budget over this time period.

Physical Setting of Abouabou Bay

Abouabou Bay is located near the Felix Houphouët-Boigny International Airport, between latitudes 5°15' and 5°18' N and longitudes 3°52' and 3°56' W, on the southern shore of the Ebrie Lagoon to the east of Abidjan. It covers an area of 3.90 km² and lies in a peri-urban zone, bordered by the villages of Abouabou (to the north) and Benegosso (to the south), with mangroves along parts of its shores. The bay has a single narrow

entry channel on its western side, giving it the unique characteristic of a confined environment.

Materials and Methods

The MNRF (2011) bathymetric survey standardization guide served as the basis for field measurements. The survey of Abouabou Bay was conducted in July 2015 (rainy season) using an echo sounder coupled with a GPS with a precision of 2 meters. Data was collected along N-S and E-W radials spaced approximately 150 m apart with sampling intervals of about 20 m (Figure 2), resulting in 2,557 bathymetric soundings. The data are referenced to sea level zero and validated according to IHO standards (2008). Slopes were calculated to determine the water flow direction using the following equation (Diangone *et al.*, 2019):

$$\text{Tg}\alpha = h/d \text{ therefore } \alpha = \text{Arctg } h/d \text{ (1)}$$

Where:

(h) is the elevation difference between two isobaths (in meters),

(d) is the horizontal distance between isobaths, measured on the bathymetric map (in meters),

(α) is the slope (in degrees or percentage).

The monitoring of sediment dynamics in the bay was conducted by comparing Tastet's (1975) bathymetric map with the 2015 map.

MapInfo software was used for digitizing and georeferencing the bathymetric maps, while Surfer software was utilized to create the bathymetric maps.

Estimation of the sediment budget involves calculating depth differences for identical points on the maps (Castaings, 2008). This can be represented cartographically (Figure 3) and through the volume report generated by Surfer software (Figure 4).

Results and Discussion

Geomorphological Aspects of Abouabou Bay

The 3D map in Figure 5 shows that Abouabou Bay is an elongated body of water oriented east-west and southeast, covering an area of 3.9 km². Its depths range from 0.8 to 26 m, with an average depth of 7.8 m. The

bay is characterized by shallow areas at 8.8 m and depressions reaching up to 26 m.

Comparison of Morphological Characteristics of the Bay from 1975 to 2015

The metric parameters of Abouabou Bay's morphology, shown in Table I, indicate that the bay's surface area decreased from 3.90 km² (1975) to 3.81 km² (2015), a reduction of 0.09 km². The average depth declined from 12.2 m (1975) to 7.8 m (2015), and the slope of the shores decreased from 11.5° (1975) to 8° (2015), corresponding to an elevation drop from 4.4 m to 3.5°. This reduction in surface parameters indicates sediment deposition in the bay.

Wango *et al.*, (2015) also confirmed the filling of this bay for the period 1979–2000 based on a decrease in maximum depth. According to these authors, the maximum depth of 26 m in 1979 decreased to 23 m in 2000, representing a reduction of 3 m.

Sediment Budget Estimation by Overlaying the 1975 and 2015 Maps

The residual map, resulting from the overlay of the 1975 and 2015 bathymetric maps, shows a heterogeneous distribution of sediments in the bay (Figure 6). It highlights areas of infill and erosion in the morphological evolution of the bay's channels. This uneven sediment distribution reveals that the thickness of sediment deposits (11 m) is greater than that of eroded sediments (4.5 m), a net increase of 6.5 m, indicating an infilling process occurring in the bay.

Sediment Budget in Abouabou Bay

Table II shows that the volume of sediment accretion (5,279,518.33 m³) is greater than the volume of eroded sediments (2,859,485.20 m³), resulting in a positive sediment budget (+2,420,033.50 m³). This indicates sediment accumulation in the bay, with a sedimentation rate of approximately 1.6 cm/year. This sediment influx may be attributed to soil runoff following vegetation cover loss in the city of Abidjan and sand quarrying in the bay's surroundings. Wango *et al.*, (2015) also confirmed sedimentation in Abouabou Bay based on the observed bed rise, noting that sediments responsible for this rise come from the remobilization of sands along the bay's shores. According to Togba *et al.*, (2024), morpho-bathymetric changes in water bodies are due to sediments from their surroundings.

Table.1 Evolution of the surface parameters of the bay from 1975 to 2015

Settings	1975	2015	Variables
Area(km ²)	3.90	3.81	-0.09
Maximum depth(m)	26	26	0
Average depth(m)	12.2	7.8	-4,4
Slope(°)	1to11.5	1to8	-3.5

Table.2 Sediment budget of Abouabou bay from 1975-2015

Parameters	Sediment budget 1975 to 2015
Accumulated sediment volume (m ³)	5279518,33
Eroded sediment volume (m ³)	2859485,20
Sediment balance (m ³)	+2420033,50
Sedimentation rate (m/year)	0,016

Figure.1 Location of Abouabou bay (Kando, 2019)

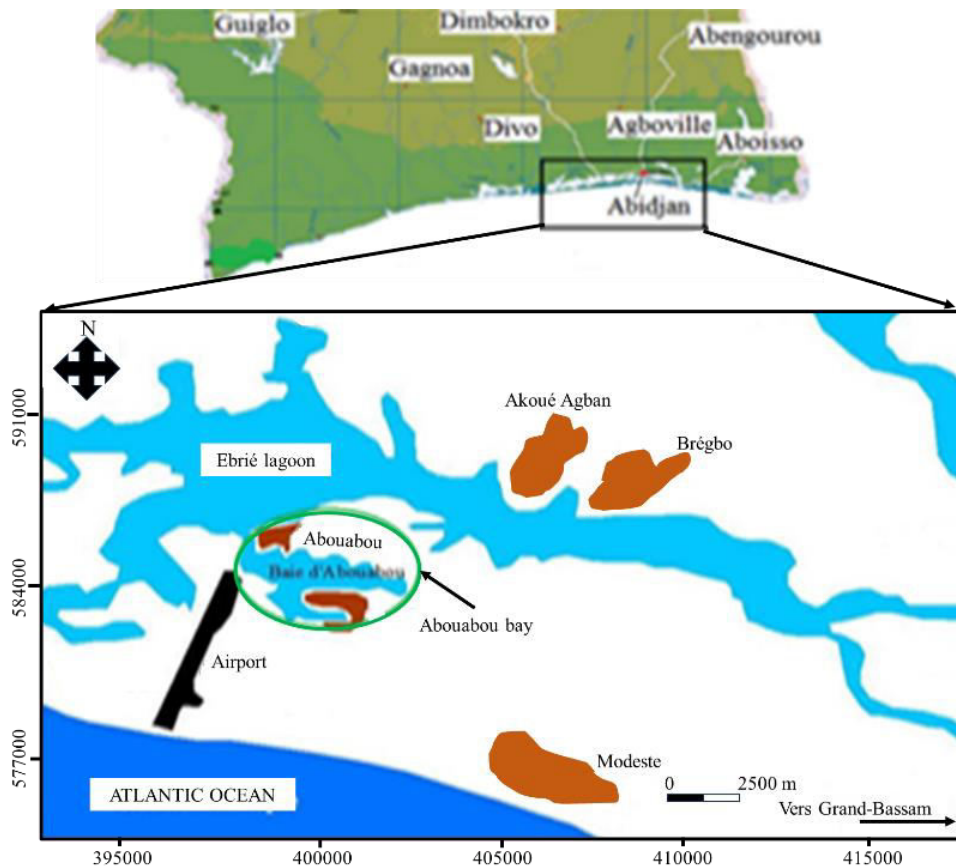


Figure.2 Positioning map of probes in Abouabou Bay

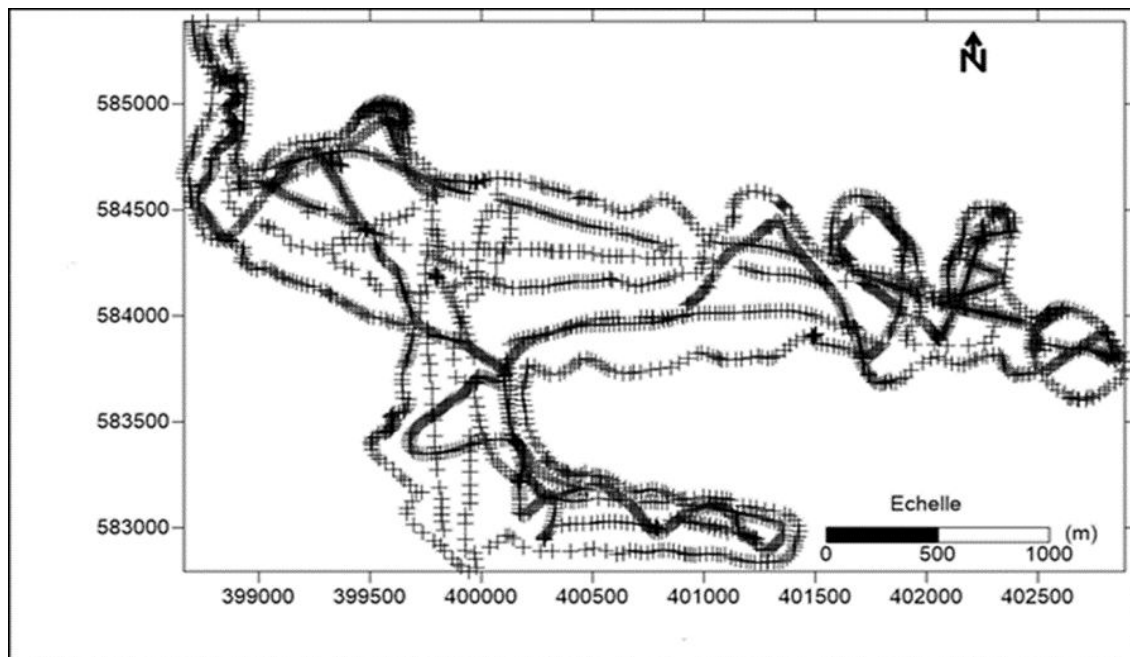


Figure.3 Principle of bathymetric evolution analysis (Castaings, 2008)

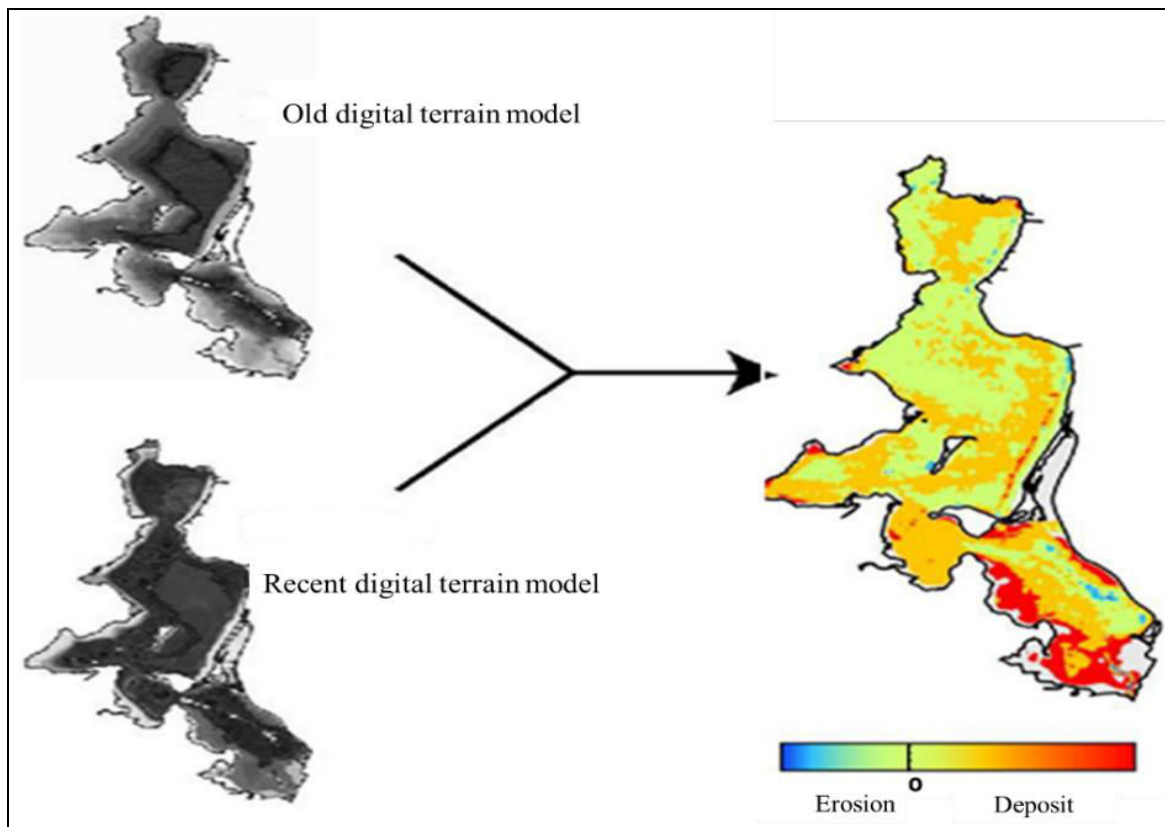


Figure.4 Determination of the “Grid volume” ratio

Grid Volume Computations	
Sun Aug 20 21:23:24 2017	
Upper Surface	
Grid File Name:	C:\Users\pc\Desktop\volume bathy 1.grd
Grid Size:	62 rows x 100 columns
X Minimum:	398664.135
X Maximum:	402890.185
X Spacing:	42.687373737374
Y Minimum:	582793.089
Y Maximum:	585390
Y Spacing:	42.572311475409
Z Minimum:	-25.696297758981
Z Maximum:	10.1041467496
Lower Surface	
Level Surface defined by	Z = 0
Volumes	
Z Scale Factor:	1
Total Volumes by:	
Trapezoidal Rule:	-15081539.548166
Simpson's Rule:	-15164434.669054
Simpson's 3/8 Rule:	-15103156.176506
Cut & Fill Volumes	
Positive Volume [Cut]:	16488867.766521
Negative Volume [Fill]:	31570783.673284
Net Volume [Cut-Fill]:	-15081915.906763
Areas	
Planar Areas	
Positive Planar Area [Cut]:	6842529.6717776
Negative Planar Area [Fill]:	4132146.0597722
Blanked Planar Area:	0
Total Planar Area:	10974675.73155
Surface Areas	
Positive Surface Area [Cut]:	6844705.5625307
Negative Surface Area [Fill]:	4145684.6027044

Figure.5 Digital Depth Model of Abouabou bay from 2015

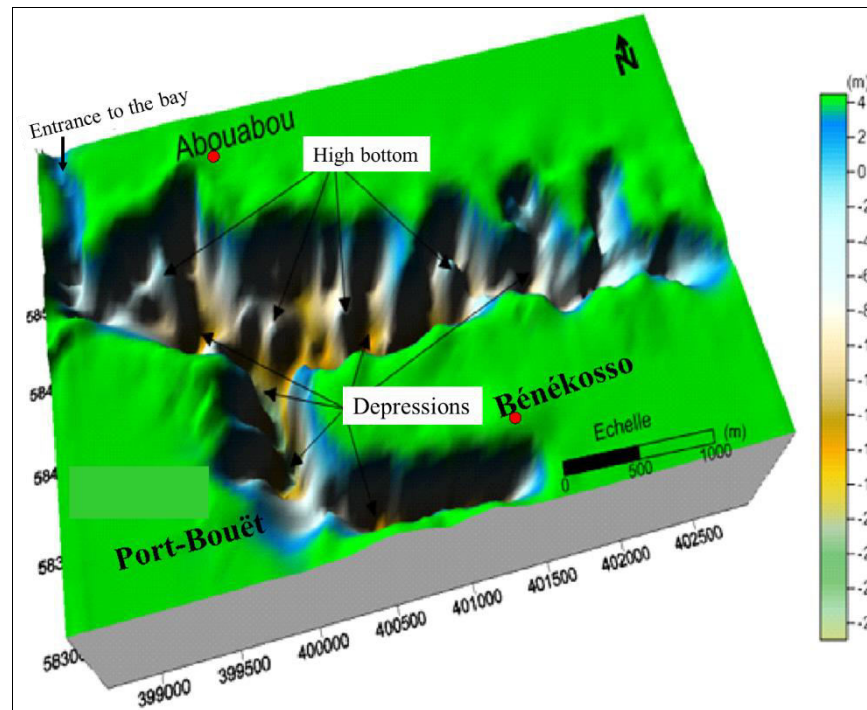
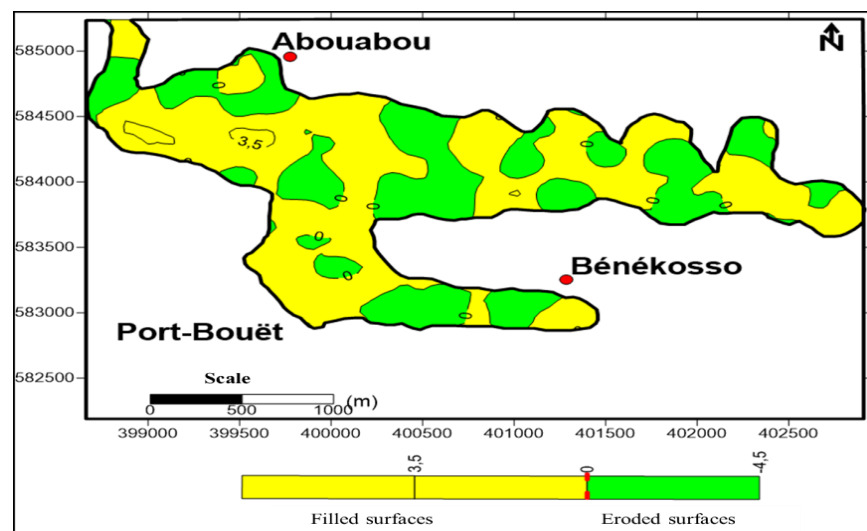


Figure.6 Residual map of Abouabou Bay from 1975 to 2015



Additionally, the Comoé River, which feeds the eastern part of the Ebrié Lagoon, could be another source of sediment influx into the bay, carrying organic and mineral materials during flooding. Kouamé (2017) observed this sedimentation phenomenon in some bays of the Ebrié Lagoon, with varying sedimentation rates. Sedimentation rates increase with anthropogenic pressure, as seen in lower rates in the rural bays of Bingerville (1.3 cm/year) and M'Badon (1.6 cm/year)

compared to urban bays like Koumassi (2.3 cm/year) and Cocody (3.2 cm/year).

Conclusion

Abouabou Bay has retained almost the same area over forty years (1975–2015), though other surface parameters have declined, indicating sediment deposition in the bay. The positive sediment budget (+2,420,033.50

m³) over this period and the pre-dominances of deposits (11 m) over erosion (4.5 m) suggest sediment accumulation in the bay, with a rate of 1.6 cm/year. Recent data from this study will serve as a basis for the sustainable management of this fragile ecosystem.

Author Contributions

Kando, Kouame and Irie participated in the field work, data processing and writing of the article. The study was supervised by monde.

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