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Influence of the Water Content of Foreshore Sediments in the Tidal Morphological Construction Process: Coarse Sand and Fine Sand Facies in Port-bouët and Assouinde Coastal Sectors Case, Cote-d'ivoire

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The erosion of sandy coasts has become a major concern for coastal populations, private investors and governments. In Côte d'Ivoire, several studies have been carried out to better understand the mechanisms of this hazard on coastal morphologies. So our knowledge of tidal shoreline morphologies on microtidal coasts such as those of Côte d'Ivoire reveals two trends: erosion of the foreshore near high tide, and a deepening near low tide, or a deepening near high tide and an erosion near low tide, depending on the part of the foreshore. The contribution of hydrodynamic parameters, in particular significant swell height and theoretical tide, explains these trends, although not exhaustively. Water content in sediment was analyzed to understand its impact on shoreline morphologies resulting from the action of hydrodynamic forcing. To this end, two altimetric surveys synchronized with sedimentological monitoring of the submerged foreshore in coarse and fine sand facies were carried out at Port Bouët and Assouindé on the Ivorian coast. These studies showed that erosion occurs at times of high water content, when saturation in the sediment is reached. This observation was clearly evident on coarse sand facies, but less so on fine sand facies. The fine sand facies has a greater capacity to absorb water and therefore remains less vulnerable to foreshore erosion. Granulometry is therefore a parameter that influences the morphological response of beaches.

Keywords: Erosion; water content in sediment; coastal morphology.

1. INTRODUCTION

Côte d'Ivoire's 566 km coastline [1] backs onto the Atlantic Ocean. This shapes the coastline under unusual storm swell conditions, with those recorded since 1984 having significant heights of between 2.10 and 2.7 m [2]. These swells shape the coastline in spectacular retreats, usually within one or two tides. For example, an exceptional swell in 2007 caused the entire coastline to recede by 1 to 18 m [3]. In August 2011 and June 2014, storm swells pushed the coast back between 6 to 12 m [4]. In July 2018, a storm swell set back the coast by 2.9 m at the Port Bouët lighthouse [5]. Although rare, these events leave an extremely negative mark, particularly in terms of the destruction of infrastructure, often unfortunately installed right on the coastline. As a result, the scientific community is stepping up studies in the coastal field, with a view to gaining a better understanding of the processes involved in the construction of coastal morphologies. Apart from stormy events, the tidal construction of the littoral morphology, concentrated in the foreshore, presents itself in an alternation of fattening and erosion respectively at ebb and flood [6]. However, the work of [7] situates the alternation between fattening and erosion respectively at ebb and flood in the tidal morphological construction process of the foreshore. Several hypotheses could explain the tidal morphological construction of the foreshore during ebb and flood. The aim of this study is to understand the influence of subsurface sediment water content on foreshore morphology.

2. MATERIALS AND METHODS

2.1 Description of Experimental Protocol

The study of the influence of subsurface water saturation rate on aerial morphology was carried out on the coarse-grained (784.46µm) Port-Bouët and fine-grained (231.96µm) Assouindé shorelines [5]. On each of these shoreline segments (Figs. 1 and 2), two cross-shore profiles (A and B) 20 m apart were created. Morphologies during the tidal cycle are monitored by placing iron rods (stakes) every two meters in the submerged foreshore. These stakes are numbered from the high foreshore A1, A2, ..., An on profile A and B1, B2, ..., Bn on profile B according to the width of the uncovered foreshore (Fig. 3). Monitoring consisted in manually measuring the heights of the stakes every 5 min after the passage of the waves, using a tape measure attached to a support which serves as a ruler. Sedimentological sampling is carried out at the foot of the posts at 4 m intervals every hour of the tidal cycle.

2.2 Determination of Morphological Trends in the Tidal Cycle

Morphological trends such as accretion, erosion and stability are known by means of variations in stake heights (HP). The difference in stake height between time (t) and time (t+1) gives the resulting reworking (Rr).

Rr=HPt - HP(t+1) [8].
Rr > 0 means fattening;
Rr= 0 means stability;
Rr < 0 means erosion.

The accumulation over time of the various Rr's gives the cumulative resultant reworking (RrC).

RrC(t+1)=Rrt + Rr(t+1) [6].
RrC > 0 means the point is getting fatter;
RrC= 0 means point stability;
Rr < 0 means point erosion.

Fig. 1. Location of altimetric and sedimentological monitoring profiles on the Port-Bouët coastline

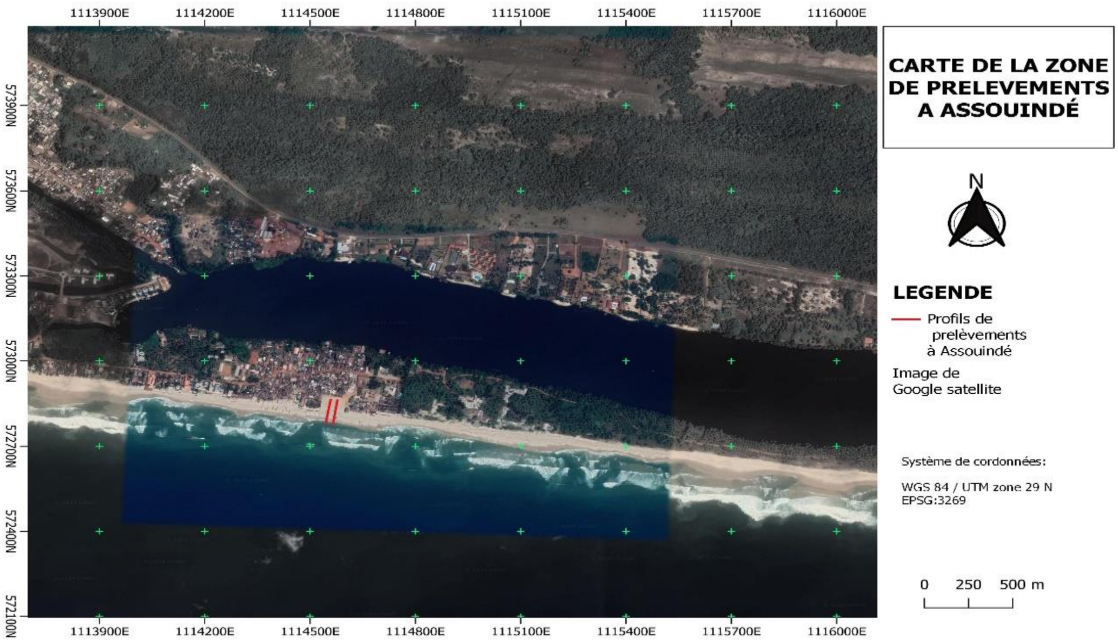

Fig. 2. Location of altimetric and sedimentological monitoring profiles on the Assouindé shoreline

Fig. 3. Presentation of an altimetric and sedimentological monitoring profile at Assouindé

2.3 Determination of Incorporated Water Stocks in Sediment

Sediments collected in situ are weighed using a Scout pro SPU402 electronic balance with 0,01 accuracy and a maximum load of 400 g. The wet mass is obtained. The sediments are then dried in an oven at 100°C for 24 hours. The dry mass is taken again. The mass of water incorporated is obtained by dividing the wet mass by the dry mass.

Water mass = Wet mass - Dry mass.

3. RESULTS AND DISCUSSION

3.1 Relationship between Water Mass Incorporated in Sediment and Morphology

3.1.1 Fine-grained assouindé shoreline

The results concern points A1 and A3 on the high foreshore and A5 at the high-mid foreshore limit. Point A1 is 11.6 m from the daily swash boundary (Fig. 4 a, a' and a''). These points, once in the swash zone, have undergone 100% sedimentological and morphological monitoring, and are therefore the most suitable for interpretation. The mass of water in the sediment ranged from 10.375 g to 120.263 g at point A1, from 50.537 g to 163.825 g at point A3 and from 67.4 g to 138.716 g at point A5. The curves showing the evolution of water in the sediment do not show any particular pattern. They appear as a succession of ascending and descending phases of varying duration. These different phases reflect the great variability of water content in the sediment during the tidal cycle.

Two morphological trends emerge: The first, marked by points A1 and A3, is morphological stability due to small sedimentary movements or the absence of sedimentary movement when the swash zone retreats. This stability occurs around low tide in the ebb phase. This is followed by a phase of erosion, peaking around high tide in the ebb phase. The second trend, marked by point A3, is also marked by a phase of stability due to small sedimentary movements around low water in the ebb phase. This is followed by a phase of accretion, mainly in the flood phase.

3.1.2 Port-Bouët coarse-grained coastline

The results are from points B9, B11 and B13, with point B9 located 14.1 m from the limit of the daily swash zone. These points on the low foreshore have the advantage of being 100% within the swash zone during the monitoring period. Water mass in the sediment ranged from 5.44 to 24.06 g at point B9, from 6.27 to 27.63 g at point B11 and from 4.35 to 27.78 g at point B13. The curves showing the evolution of water levels in the sediment during the monitoring period generally show two phases: a descending

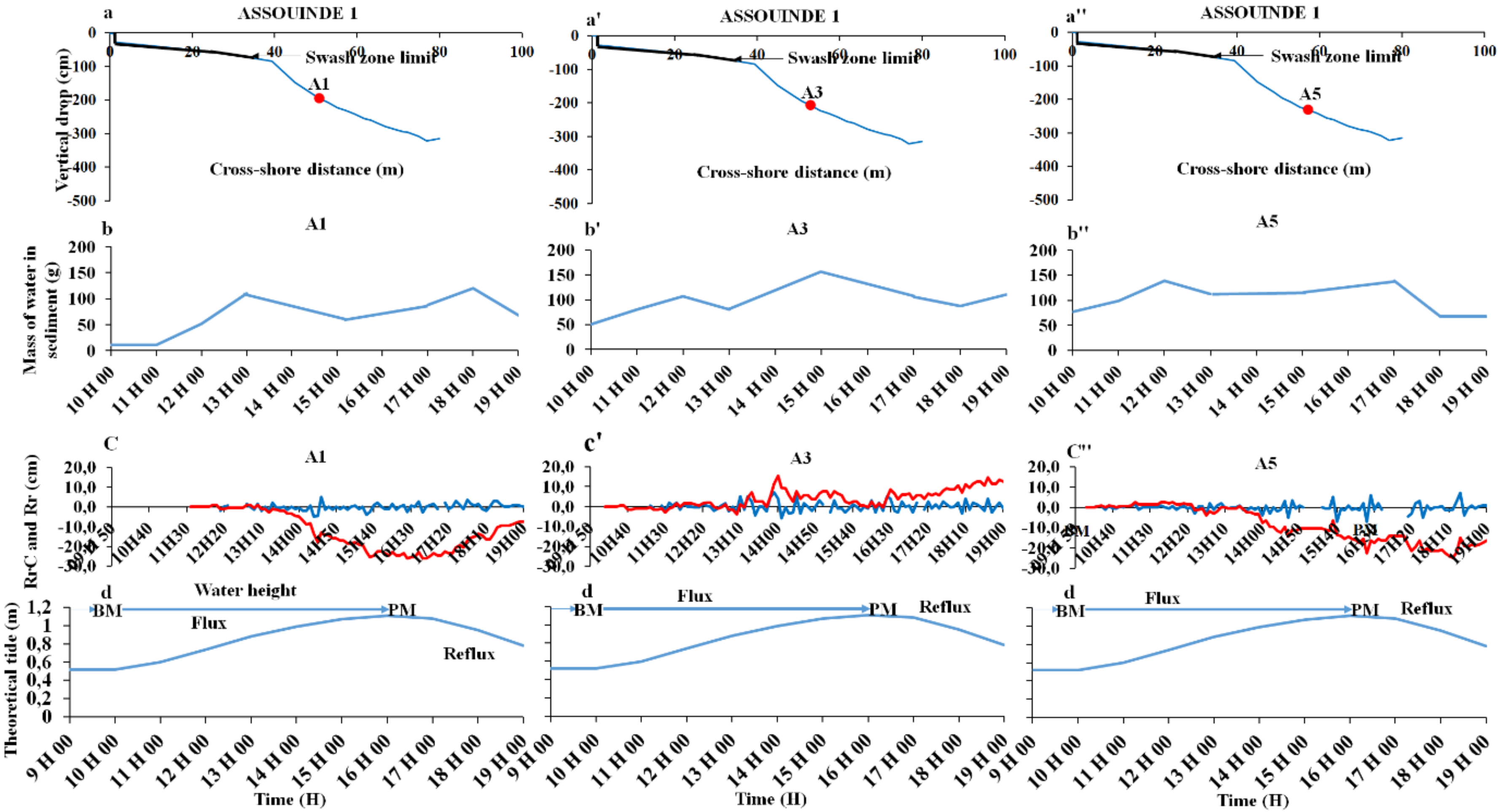

Fig. 4. Relationship between sediment water content and morphology of a foreshore point in a tidal cycle on a fine sand facies

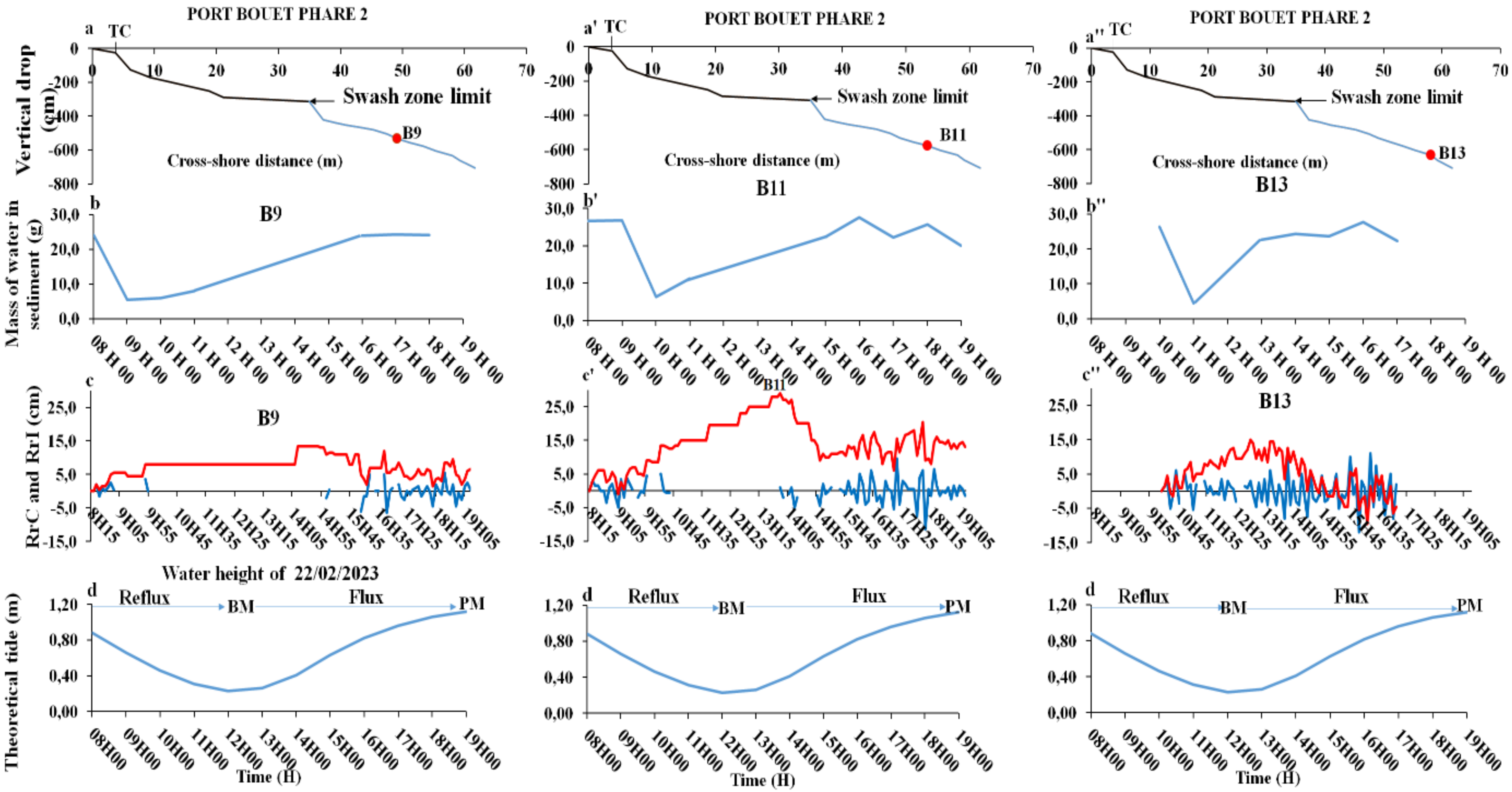

Fig. 5. Relationship between sediment water content and morphology of a point on the foreshore during a tidal cycle in a coarse sand facies

phase linked to a decrease in water levels, and an ascending phase linked to an increase in water levels.

The falling phase occurs at ebb tide, when the water table gradually recedes (Fig. 5 b, b' and b''). The rising phase occurs on the flood as the water level rises. The general shape of the water level curve in the sediment thus follows the tidal curve. Small variations in sediment water content are also observed in a general phase (Fig. 5 b', b'').

The morphologies observed on these three points, which reflect the general morphological evolution of the whole area, are characterized by an accretion phase and an erosion phase (Fig. 5 c, c' and c''). The accretion phase occurs at ebb tide, when the water table gradually retreats offshore, reaching its maximum in the immediate vicinity of low tide (Fig. 5 c', c''). The erosion phase occurs on the flood, when the water table gradually rises towards the mainland, reaching its minimum in the immediate vicinity of high tide (Fig. 5 c, c' and c''). Synoptic analysis of the sediment water content curve, the morphological evolution curve and the tidal curve reveals that erosion occurs at the same time as the water level in the sediment rises. Accretion, on the other hand, occurs when the water content in the sediment decreases. In the action of the up rush, the water column of the surf is mixed with sediment, which is deposited with infiltration if the water content of the substrate in place is unsaturated. However, if the water content of the substrate is saturated, no infiltration is possible. All the sediment mixed with the water column in the breaker turns over, ripping out the previously deposited sediment as it goes. This could explain why accretion occurs at times of low water content and erosion at times of high water content.

3.2 Water Mass Content in Coarse and Fine Sediment

In the coarse sediment, the saturation water masses in 10 samples of 100 g vary between 17.48 g and 23.49 g. This gives a difference of 6.01 g.

In the fine sediment, the saturated water mass in 10 samples of 100 g varies between 21.63 g and 22.71 g. This gives a difference of 1.08 g. The water mass distribution curve in the fine sediment is almost a constant straight line (Fig. 6). The small difference in the mass of water at saturation in the fine sediment indicates good homogeneity in the distribution of the grains. This homogeneity favours fewer voids between the grains.

Out of 10 fine samples, 5 have a greater mass of water at saturation in the sediment than in the coarse sediment. This corresponds to 50% of the samples studied. Only 2 samples, i.e. 20% of the samples studied, had a smaller mass of water in the sediment than in the coarse sediment. And 3 samples, or 30%, had the same water mass in both fine and coarse sediment.

3.3 Vulnerability to Erosion According to Particle Size Facies

The Port-Bouët coarse sediment has the lowest water saturation values. In fact, 50% of samples show lower water saturation values in the coarse sediment (Fig. 6). The maximum difference in water mass at saturation in the coarse sediment is 5g. This difference is 0.14g in 20% of samples when it's the fine sediment that has the lowest water content values. This means that coarse sediment reaches saturation faster than fine sediment. If erosion occurred at the time of the highest water masses in the coarse sediment, this means that the coarse sediment is more vulnerable to erosion than the fine sediment.

The work of [9] describes a proportional relationship between the tensile force required to erode the bottom of a non-cohesive sediment such as pebble, gravel or sand, and the diameter of the particle. This description indirectly relates to the water content in the sediment, since particle size determines water content. This study clearly shows that the mass of water required to saturate 100 g of fine sand is almost entirely different from that for coarse sand.

The work of [10] also concluded that for a given sediment and shear stress, the erosion rate is a unique function of bulk density (water content) and can be expressed as a product of the powers of shear stress and bulk density.

Synthesis work by [11] reveals soil resistance to erosion as water content in the sediment increases up to a certain threshold. Once this threshold is reached, soil resistance decreases with increasing water content, and soils become more susceptible to erosion. This last conclusion is in line with that of this work, where erosion is observed at times of high water content in the sediment.

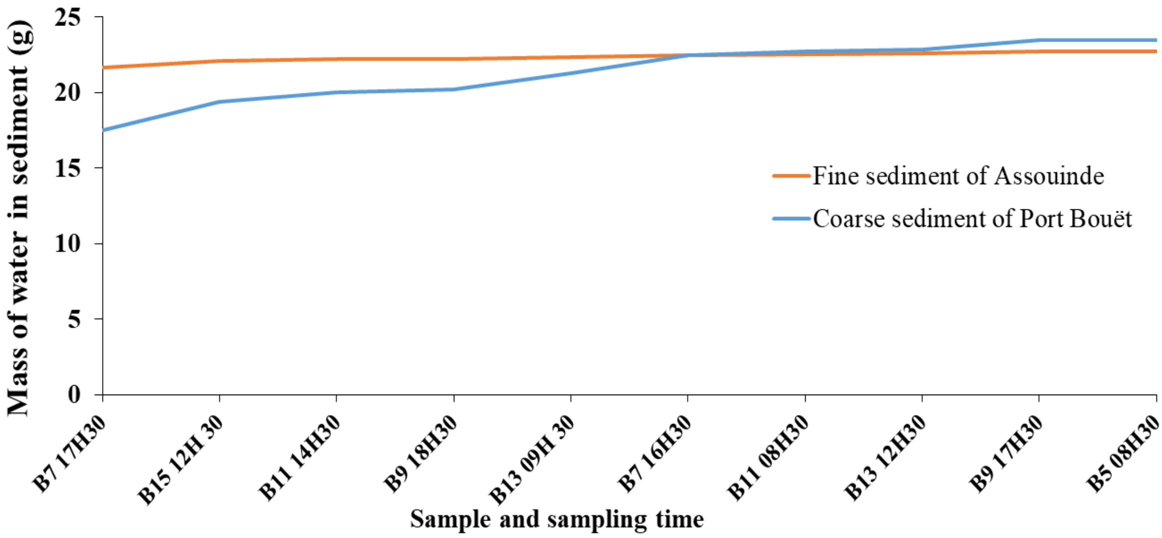

Fig. 6. Water mass for saturation of 10 samples of 100 g of fine sediment from Assouindé taken on 22/02/2023 and coarse sediment from Port Bouët taken on 04/05/2023

Romanus et al. [12] addressing soil erosion conditions, concluded that high or low water content leads to high erosion rates. Moisture content also has a positive impact on the erosion resistance of finer soils and a negative effect on the erosion resistance of coarse-grained soils. In this study, in which two facies were examined, fine and coarse sands, clear-cut erosion was observed for water-saturated coarse sands, and less clear-cut erosion for saturated fine sands. Similar results were obtained in the present study.

The results of this work have also been described by Gerard et al. [13] on cohesive soils, where runoff erosion decreases with decreasing water content. In this study, the soils studied, although not cohesive and not subject to runoff but to the action of up rush and back swash, show significant erosion at times of high water content. Conversely, erosion is low during low water levels.

4. CONCLUSION

Due to its dynamic nature and exposure to wave swash and backswash, foreshore morphology on coarse and fine sand coasts such as Abidjan Port-Bouët and Assouindé is constantly under construction. This tidal construction mechanism is characterized by ebb tide accretion, mainly around low tide, and flood tide erosion, mainly around high tide. Erosion occurs at times of high water content in the in situ sediment. Coarse sand facies generally require less water for saturation than fine sediment. It is therefore more vulnerable to erosion than fine sand. The water masses required to saturate 100g of fine sand are almost identical, reflecting virtually identical resistance to erosion. This could explain the almost similar morphologies observed on the Assouindé coastline, with little variation in the cross-shore and long-shore directions. On the contrary, on the Port-Bouët coast, where the water masses for saturation of 100 g of coarse sand vary greatly, the resistance capacity varies and the morphology is quite diversified in both cross-shore and long-shore directions.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Abe J. Contribution to knowledge of the morphology and sediment dynamics of the Ivorian coast (case of the Abidjan coast). Modeling tests for rational management.

Thesis for the Doctorat d'Etat Es-Sc. Nat,Univ. Abidjan. 2005;309.
2. Gbegbe M, Yao KS, Akobe AC, Monde S, Abe J. Return period estimation of storms on the ivorian coastline. Journal of Environmental Hydrology. 2019;27:9.
3. Konan KE, Bamba SB, Abe J, Aka K. Impact of recurrent storms on the Vridi Port Bouet coastal perimeter model in European Journal of Scientific Research, ISSN 1450-216X. 2009;28(2):186-192.
4. Bamba Y. Study of coastline dynamics between Jacqueville and Port Bouët using satellite images and field observations. PhD thesis. Houphouët Boigny Univ. 2016;277.
5. Saimon AM, Yao KS, Konan KE. Shoreline retreat by blow: the case of the Port-Bouët Phare coastal perimeter. F. Tech & Doc. Vulg. 2019;9-13.
6. Saimon A. Contribution of sediment reworking in the characterization of the mobile layer at the scale of the tidal cycle of the Abidjan littoral sector. Doctoral thesis in oceanology. Félix Houphouët Boigny University. 2017;345.
7. N'ganza KPA. Morphodynamic evolution of the coast from Port Bouet to Mondoukou: Remodelling in the swash zone. Doctoral thesis. UFHB. 2020;255.
8. Koffi KP. Contribution à l'étude des processus sédimentaires dans la zone littorale Aquitaine (France) remaniements et transport en suspension. Thèse 3éme Cycle. Univ. Bordeaux I. N°1718. 1981;135.
9. Migniot C. Study of the physical properties of various very fine sediments and their behavior under hydrodynamic actions. Paper presented to the Technical Committee of the Société Hydrotechnique de France on March. 1968;1968.
10. Jepsen R, Roberts J, Lick W. Effects of bulk density on sediment erosion rates. Water Air Soil Pollut. 1997;99:21-31. Available:https://doi.org/10.1007/BF02406841
11. Moragoda N, Kumar M, Cohen S. Representing the role of soil moisture on erosion resistance in sediment models: Challenges and opportunities. Journal of Earth Science Reviews (Elsevier). 2022; 229:104032.
12. Romanus UA, Dominic CN, Chinemelu CN, Arinze TM, Philip OPE, ACO. Geospatial analysis of soil erosion susceptibility and causative factors in Anambra state, south east, Nigeria. Scientific review. 2022;8(1):5-32.
13. Gerard G, Loch R. J. Effects of initial water content and soil mechanical strength on the runoff erosion resistance of clay soils. Australian journal of Soil Research. 1993;31(5):549-566.

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