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Assessment of Coastal Modification and Surf Zone Induced Erosion in Itak Abasi Beach, Eastern Niger Delta, Nigeria

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ABSTRACT

Research aimed at evaluating coastal vulnerability to erosion and shoreline encroachment due to flooding-ebbing cycles of waves. Daily cross sectional topographic profiles were measured from the backshore to the lower foreshore in five study stations at 1km interval and surf zone hydrodynamic parameters were monitored. The beach a modern, high energy, mesotidal and dissipative environment with average slope of ≤2° and a width of 90-180 m and sediments were characteristically fine to very fine grained, poorly to very well sorted sands. Volumetric change depicts all the morphozones but the lower foreshore was dominated by net accretion, the upper foreshore recording the highest volume (+ 7.92 m^3/m). The lower foreshore had a sediment volume of - 15.0 m^3/m. Time-averaged beach stability index varies from 140 – 260, 40 – 60, 15 – 30, 10 – 36, and 4 – 120 in stations 1, 2, 3, 4, and 5 respectively and intensity of mobilization decreased with distance from the estuary. Accretion increased with infiltration during tidal flooding indexing a dry beach and low groundwater table. Oversaturation, high groundwater table and exfiltration accounted for erosion at the lower foreshore. Findings are useful for foreshore protection design and prediction of saltwater migration into groundwater aquifers. Beach development for tourism is recommended.

1. INTRODUCTION

The coastal zone in the Niger delta is inundated by diurnal tides, surf zone induced waves and longshore current subjecting the environment to erosion. Coastal erosion in the region is a major environmental hazard visible in several coastal communities as retreating coastlines and beach hazards have been identified in terms of the vulnerability of coastal areas to damage with regard to loss of property or infrastructure. Coastal infrastructures such as jetties which were accessible without walkways as at the time of design and construction have to be improvised with walkways or totally inaccessible from the shoreline. The beach which is the immediate coastal environment extending from the surf zone to the backshore of the dune region is a highly dynamic environment implying that the sedimentary geologic characteristics of a modern beach may vary markedly in time and space. Sedimentary processes include wind, waves, tides and currents; and organisms and man may also play major roles in determining sedimentary characteristics of beaches. Coastal sediment transport processes result from external processes mainly in the form of tide and wave-driven currents, wind generated waves and currents, or directly by inducing aeolian sediment transport and dune development. The tidal regime and wave climate may exhibit a large spatial variability and play an important role in explaining the diversity in coastal landforms. Swash run-up and beach groundwater processes control the sediment sorting and transport, erosion or accretion on the beach face.

Sediment aggradation and degradation cycles commonly observed on beaches result from complex factors such as sediment mobilization in the breaker and surf zones, longshore current transport, and availability of sediments [1-2] making a generalization of sedimentary processes in beaches impossible. Grant has linked beach ground water behavior and swash zone sediment transport proposing that a "dry" beach (one with a low water table, which he equated with unsaturated conditions below the beach surface) allows swash to infiltrate [3-4]. The reduction in swash depth due to infiltration reduces swash velocity allowing sediment deposition. Therefore, a dry beach promotes accretion. Conversely, on a "wet" beach (one in which the water table is at or near the beach surface) the swash and backwash retain their depth because infiltration is limited. Backwash flows may be augmented by ground water outflow from the beach. It has been generally adduced that infiltration losses during swash run-up favours sediment accretion above the stillwater line.

Coastal engineering require data on swash run-up for design of coastal infrastructures such as breakwaters and USGS report on SWASH [5-6], a new method of monitoring coastal erosion has stressed the importance of data on the shoreline position which depends on swash zone processes for monitoring coastal change**.** A major limitation on acquisition of this data is the dynamics of the beach environment and the sedimentary processes. Factors which affect sediment mobilization in the breaker and surf zone, longshore current transport, and availability of sediments equally determine beach aggradation and degradation thus making generalization of sedimentary geologic processes of beaches impossible [1-2, 7].

In spite of detailed documentation of tide and wave-induced variability in the hydrodynamic and morphodynamic characteristics of beaches, there is a paucity of data on the studied beach. However, some insight into the latter is contained in the works of Antia, and Antia and Nyong [8-12]. The above studies documented beach cusps and geomorphology and proposed morphodynamic models of beach susceptibility to tar pollution as well as implication of beach dynamics to coastal engineering.

In other locations, Heathershaw et al. [13] studied tidal variations in compaction of beach sediments while Engstrom [14] examined beach foreshore sedimentology and morphology in the Apostle Islands, North Winconsin. Greenwood and Hale [2] focused on depth of activity, sediment flux and morphological changes barred nearshore environment, whereas Chaudri et al. [15] examined the sedimentary of beach sediment of the west coast of India. Wadell [16] evaluated swash groundwater – beach profile interactions while temporal and spatial variability in intertidal sedimentation rates has been investigated by Carling [17].

The beach west of Qua Iboe River estuary, called Itak Abasi Beach, is the study location of the present investigation and types and patterns of sedimentary processes, sediment characteristics and net accretion and or erosion in the study area have been evaluated. Section 1 of the research presents introduction and brief review of the concept, section two and three describe the study location and methodology respectively while the results and discussions are presented in section 4. Section 5 Concludes and makes recommendations for future studies and preservation of the study environment.

2. STUDY LOCATION

2.1 Location and geomorphology

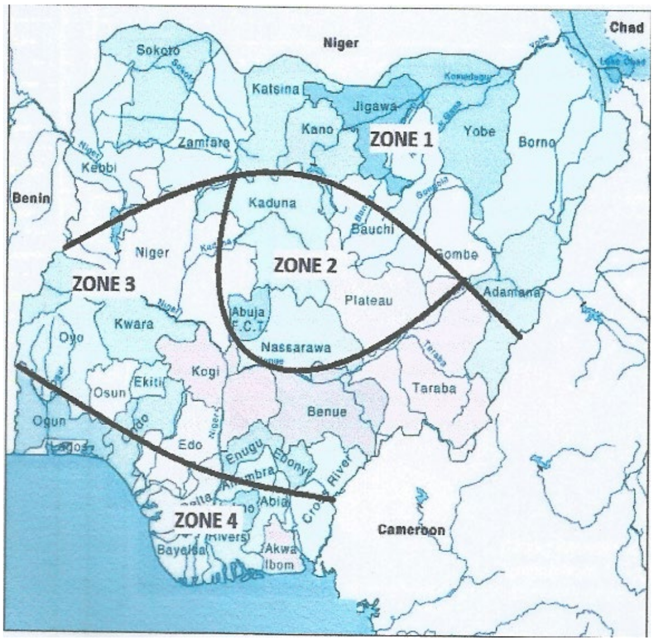


Figure 1. Climatological map of Nigeria showing the study location

Itak Abasi beach is located on the southeastern coast of Nigeria, Eastern Niger Delta (Figure 1). It is part of a modern mesotidal (tidal amplitude 2-4 m) beach stretching between the Qua Iboe River and Imo River estuaries. The studied area is five km long and is adjacent to the Qua Iboe River estuary. Its geographical coordinates are defined by latitude 7°50' and 8°00' North and longitude 4°30' and 4°33' East. The physiography of the study area is coastal plain (< 3 m above mean sea level). It is undeveloped with fine to very fine sand as dominant constituents. Muddy sediments occur occasionally. The beach is wide, extending between 90 and 180 m from backshore to mean low tide water line. The beach generally shows backshore, berm, and upper, mid and lower four shore zones (Figure 2). However, some segments of the beach lack in berm region. The foreshore slope averages about 2°, although markedly steeper in the vicinity of the estuary. The backshore to upper foreshore transition region generally depicts beach cusps. Some segments of the beach also show scarps ranging between 10-60 cm in height but typically lack dunes in the backshore (Figures 2 and 3).

Figure 2. Alongshore view of the mid-foreshore

Figure 3. Alongshore view of backshore - berm region showing erosional edge

2.2 Climate and hydrodynamic condition

According to Adefolalu [11], the climate of Nigeria coast is tropical equatorial with sunshine being high throughout the year and maximum between January and May while minimum occurs in July and September. Temperatures range, on average, between 26 and 27 °C during the dry months of February to

March and about 24 °C during wet months of June and September.

Daily temperatures oscillate between 31. 7 °C and 23 °C in dry season highest average values of humidity reach 90 in August as against an average minimum of 74 % in February. Rainfall is most intense (>3500 mm) between April and October, the values being 5 - 7 times higher than in November to March (500 mm).

Tides in the study area are semi diurnal, with a mean range of 1.8 - 2.4 m the average value of the tidal range places Itak Abasi at beach in mesotidal regime based on the classification Davies (1964) cf Antia [12]. Wind and wave conditions along the Nigerian coast can be distinguished into three by Antia [10] namely calm (November - January), transition (February - April) and storm (May - October). Prevailing onshore (mostly southwesterly) winds have a modal velocity of 6 - 9 m/s with a marked increase in frequency during the storm season.

2.3 Geologic setting

Itak Abasi beach is the active ridge of a series of Holocene abandoned beach ridges backing it. The inter ridge spaces are prominently dominated by mangroves forming brackish water swamps. The beach is composed primarily of moderately to very well sorted, fine to very fine quartz and feldspathic grains. Biogenic activities in the soft-bottom sediments in the form of bioturbation structures Richter [19] by the macrozoobenthic groups are quite conspicuous in the beach. They move both surficial and internal sediments up to a depth of 1m by burrowing, crawling, grazing and tunneling in the sediments [20-21].

3. METHOD OF STUDIES

Field investigations were conducted during the period spanning 30th September and 20 October 1995. After reconnaissance, the 5km long study location was divided into 5 sectors and stations (1-5) established at 1km intervals with station closest to the estuary. Data collected include morphologic, hydrodynamic and sedimentary characteristics.

3.1 Morphologic features

Principal amongst the morphologic features was the geomorphology of the beach which was evaluated through continuous beach profiling at each of the five study stations. Profiling was done with the aid of graduated staff s and tape using the horizon as reference. The profile data were used to prepare geomorphological map of the study area (Figure 4a and Figure 4b).

A typical cross section distinguishes the beach into the backshore, berm, upper, middle and lower foreshore morphozones with the latter extending into the surf zone. The upper foreshore is taken to extend 20 m seaward from the berm edge succeeded by the mid foreshore which is 20 m long. The lower limit of the mid foreshore to the low tide water line defines the lower foreshore.

Beach profiles were conducted daily at the study stations from which estimates of day to day net volumetric changes at the beach morphozones over two time intervals (10 September - October 20 1995) was calculated.

3.2 Hydrodynamic features

Hydrodynamic parameters influencing the characteristics of the beach were monitored. These include longshore current velocity and direction, wave height, swash excursion length, and wave and swash periods. The longshore current velocity was estimated by tracking the movement of a floating object over known distances and corresponding drift time; drift direction was ascertained with the aid of a compass. The wave height at breaking was estimated with the aid of a graduated staff held just above the water level close to the breaker line. Wave periods and swash periods were obtained with use of stop watch. This involved observing a series of successive waves and swashes over known time intervals.

3.3 Beach stability index

The variations in the surf-scaling parameter as an index of beach mobility and or stability were evaluated using Guza and Inman [22] equation. It is given as

$$\epsilon = H\,(2\pi)^{-2}T^{-1}g\ \ (\tan\beta)^{-2}, \tag{1}$$

where H is wave height, β is beach slope, and T is wave period.

4. RESULTS AND DISCUSSION

Typical daily beach profile measurements are presented in Figures 4a and 4b along with tidal elevation curve during the neap tide of the study period (Figure 5) while the sediment volumetric change on the studied beach over time (10 September - 20 October 1995) calculation from the beach profiles are presented in Figure 6 showing the backshore - berm, upper foreshore and mid foreshore morphozones to be characterized by net accretion with the highest volume recorded in the mid foreshore of station 2 (+ 8.20 m^3/m) and upper foreshore of station 1 (+7.92 m^3/m). By contrast, the lower foreshore was dominated by erosional activities, with highest erosion (-15 m^3/m) occurring close to the estuary.

Runup on a beach is a common attribute of a shoreline environment as the waves are constantly breaking and expending their energies. This process to a high degree affects the sediments water content, beach saturation and ground water table evaluation causing variable permeability characteristic on the in-situ beach sediments [13].

Moreover, sediments characteristics, especially mean grain size and sorting (Table 1) are known to exert a marked influence on permeability of beach sediments [22-23] which affect beach saturation, infiltration and sediment deposition and or exfiltration and erosion.

Higher mean grain size at low groundwater elevation in the mid-foreshore, upper foreshore and backshore – berm beach sun-environments are responsible for the accretion while a low water table at the still water line characterizes the erosion in the morphozone. Time-averaged beach mobility and or stability index varies from 140–260, 40–60, 15–30, 10–36, and 4–120 in stations 1, 2, 3, 4, and 5 respectively. Very high values (>> 33) of the parameter such as at the stations 1, 2 and 5 of the study area (Figure 7) suggests highly dissipative beach condition or low mobility tendency [24]. Some segments of the beach (station 3) depicts temporary low surf-scaling parameter values, hence a high mobility tendency.

An increase in wave height (Figure 8) is usually accompanied by a large swash runup and excursion length with bedload and deposition. This is because with increase with swash period and runup length beach saturation and water content increase, thus raising the ground water table elevation and causing exfiltration and erosion.

It was noted that low values of swash (t) to wave periods (T) was typically found close to high water when plunging breakers increase in frequency; the opposite is the case at low tides when splitting breakers dominate the surf zone with decrease in t/T ratio, increase infiltration is implied.

Table 1. Beach morphodynamic parameters

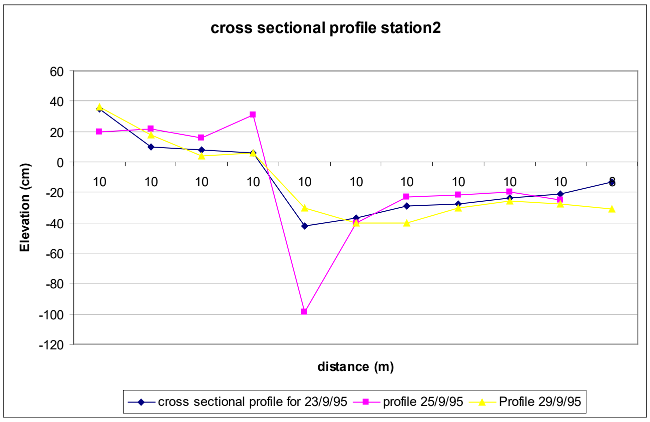
Gradient	2°	
MEAN GRAIN SIZE (phi)		
Backshore – Berm	2.03 - 2.27	Fine sand
Upper foreshore	2.32 - 2.93	Fine sand
Mid-foreshore	2.32 - 3.33	Fine sand to very fine sand
Lower foreshore	2.17 - 2.88	Fine sand
SORTING (phi)		
Backshore – Berm	0.28 - 0.40	Very well sorted - moderately sorted
Upper foreshore	0.29 - 0.80	Very well sorted to moderately sorted
Mid-foreshore	0.55 - 0.76	Moderately well sorted to moderately sorted
Lower foreshore	0.47 - 1.06	Well sorted to poorly sorted
Profile	Dissipative beach	
Upper beach face sedimentary structures	Swash marks, rill marks, rhomboidal marks, wave ripples, cuspate ripples	
Lower beach face sedimentary structures	No structures	
Internal sedimentary structures	Parallel and even lamination	
Dominant sediment mobilization		
Backshore – Berm	Net accretion	
Upper foreshore	Net accretion	
Mid-foreshore	Net accretion	
Lower foreshore	Dominantly erosion	

Sediments properties range from fine to very fine sands and are moderately to very well sorted and positively to negatively skewed. Kurtosis also varies from mesokurtic to leptokurtic.

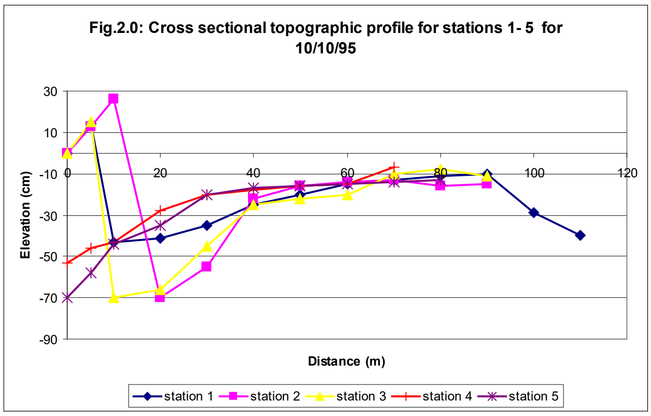
Morphodynamic parameters (Table 1) depict typically fine to very fine sand. The Backshore - berm and upper foreshore regions are characterized by very well sorted - moderately sorted fine sand, while the mid foreshore is dominantly moderately well sorted to moderately sorted fine to very sand classes. The lower foreshore sediments were characteristically well sorted to poorly sorted fine sands (Table 1).

Daily averages of wave height during the study period (Figure 8) ranged between 20 cm – 55 cm; wave period between 3 – 18 sec, 6-12 sec the modal range while breaker pattern is dominantly spilling and plunging.

Longshore current (Figure 9) observed mostly close the low tide at the monitoring stations were dominantly eastward attaining a maximum velocity of 80 cm/s close to the Qua Iboe river estuary. The highest frequency of westward directed longshore current was close to the estuary.



(a) Cross sectional profile of Station 2



(b) Cross sectional profile of stations on 10/10/1995

Figure 4. Cross sectional topographic profile

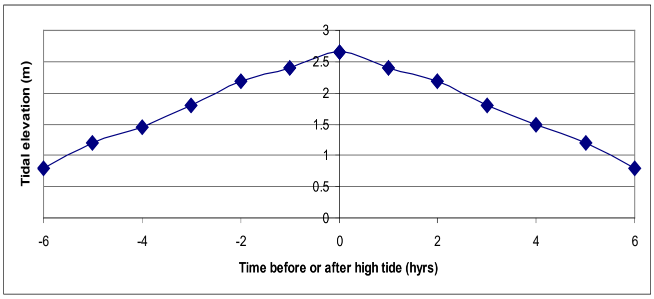


Figure 5. Typical tidal elevation curve during the study period

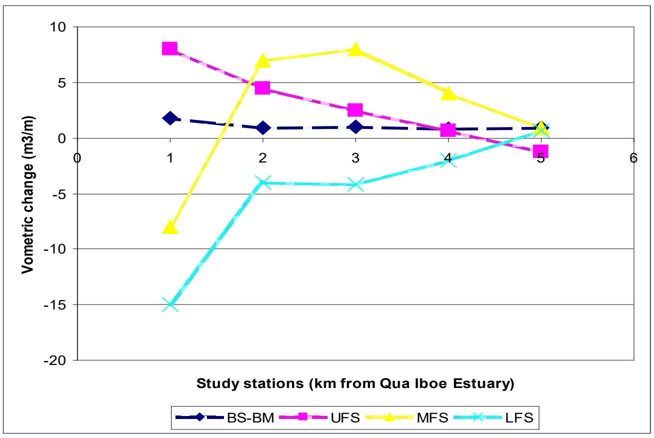


Figure 6. Sediment volumetric change

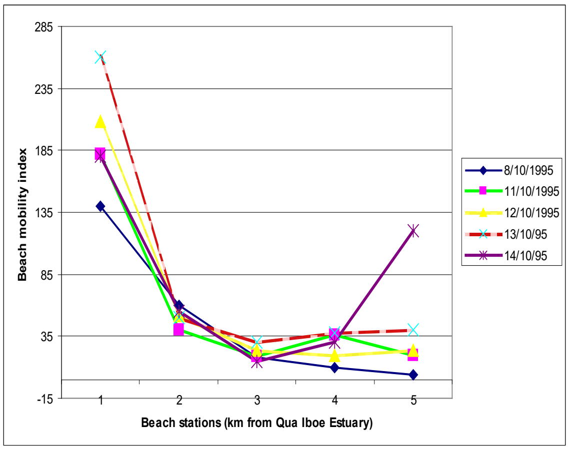


Figure 7. Beach mobility Index

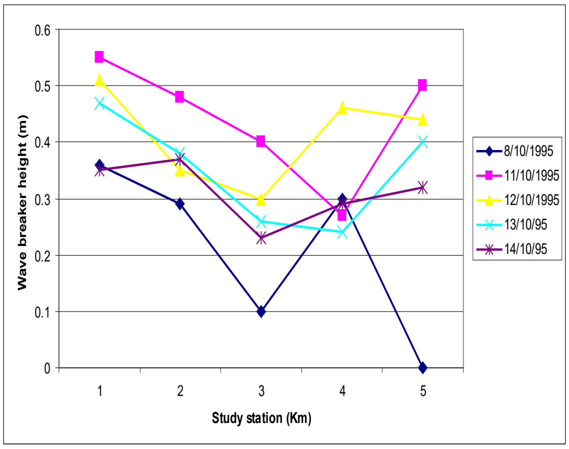


Figure 8. Wave breaker height

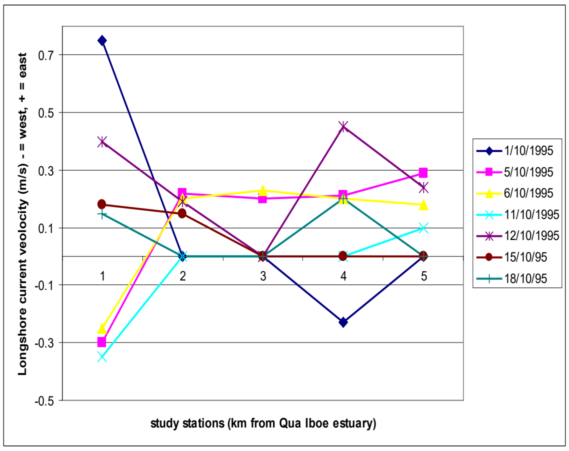


Figure 9. Longshore current velocity

5. CONCLUSIONS

The backshore – berm, upper foreshore and mid-foreshore sub-environment were characterized by deposition while the lower foreshore was dominated by erosion. Characteristic sedimentary processes were mainly winds, wave and tides. Sediment properties range from fine to very fine sands and are moderately sorted to very well sorted and positively to negatively skewed. Surf zone hydrodynamic were observed to exert a huge influence in the processes causing modification of the beach and erosion and accretion at different beach morphozones. It is recommended that the beach be developed as a tourist centre in view of its scenic beauty and periodic studies of the accretion and or erosion be carried out as pre-design tool for shore protection works and as a basis for predicting the groundwater table elevation and migration saltwater into the oceanic coastal aquifers.

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