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The Salient Issues of Coastal Hazards and Disasters in Nigeria

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Abstract

The Nigerian coastline which stretches about 853 km has four distinct morphological zones namely, Barrier Lagoon, Mahin Mud coast, Niger Delta and Strand coast. Nigeria's coastal zone is richly blessed with various natural resources like oil, gas, fish, sand etc., which are presently being exploited for economic development. Coastal populations have increased erratically from about 20% of the National population in 1993 to approximately 51,037,122 m (30% of the national population) in 2011. Development of coastal areas in Nigeria is accelerating and user conflicts are increasing. Both natural and anthropogenic activities in the coastal zone are leading to coastal hazards and eventual rapid degradation of the area. Significant coastal hazards include coastal erosion, storm surges, floods, land subsidence, pollution, especially oil spills and possibly seismicity, which could lead to earthquakes and tsunamis. These hazards are leading to disasters and effecting the socio-economic sustainability of the coastal area.

Keywords

Erosion, Floods, Pollution, Degradation, Hazards, Disasters

1. Introduction

The Nigerian coastal and marine area consists of a narrow coastal strip of land bordered by the Gulf of Guinea of the Central Eastern Atlantic. The total area of Nigeria is 923,768 sq·km, of which 13,000 sq·km constitute water. The coastal areas stretch inland for about 15 km in Lagos to about 150 km in the Niger Delta and about 25 km east of the Niger Delta. The coastline stretches for about 853 km and is prone to hazards such as coastal erosion, flooding due to storm surge and rainfall, land subsidence and pollution especially from oil spills. Reports have it that serious flood disaster has occurred in large cities such as Lagos, Port

Harcourt and Warri [1]. Other such floods have occurred in smaller coastal communities like Ilaje, Ijebu coast and Eket. These hazards, resulting from meteorologic and oceanographic events led to disasters for coastal dwellers. As noted, [2] [3] there is a broad consensus from a number of different scientific disciplines that the world is warming at a rate faster than at any other time in the last one thousand years due to a rapid rise in greenhouse gases. Sea level has also been steadily rising since the early 1800s. According to the 4th IPCC assessment [4] global warming will continue even if all the greenhouse gases were kept at the 2000 levels. The implication is that, storm surge events will intensify and multiply causing greater havoc. The Nigerian coastal area also experiences a tropical climate consisting of rainy season from May to October and dry season from November to April. During the peak of the rainy season in June/July rainfall amounts could exceed 200 mm/day in Lagos, Warri, Port Harcourt and Calabar causing extensive floods. Rainstorms along the coast, are accompanied by very strong winds, intense rainfall, accompanied by flooding and lots of runoff. The rainy season sometimes coincides with extreme oceanographic conditions which are characterized by storm surges.

According to the World Fact Book [5], the estimated population of Nigeria is 203,452,505 people of which over 20% live along the coastal area. Several mega cities have evolved consequently. Lagos for example is a mega city with a population of about 20 million people. Other near-mega cities along the coast are Calabar, Warri and Port Harcourt having between 8, 10 and 15 million people respectively. The increase in human population and associated pressure on the environment will lead to uncontrolled exploitation of the coastal resources. According to [1], a crisis situation is building up along the Nigerian coast due to the vulnerable nature of the coastline and other factors.

2. Coastal Morphology

The morphology of the Nigerian coastal area has been well documented by several authors including [6] [7], and others. The major morphological zones along the coast are (**Figure 1**) namely:

- Barrier lagoon coast, lying between Badagry and Ajumo east of Lekki town.
- Mahin mud coast east of the barrier lagoon coast, lying between Ajumo and the Benin river-estuary in the north-western flank of the Niger delta;
- Niger Delta, lying between Benin river in the west and Imo River in the east and;
- Strand coast, lying between Imo River and the Nigerian/Cameroon border in the east with the Cross River inclusive.

2.1. Barrier—Lagoon Coast

The Barrier-lagoon coastal complex (**Figure 1**) stretches from Badagry in the east to around Agerige village where the coastline starts a southward inflection. The barrier bar consists of beach ridges fronted by a very narrow beach with

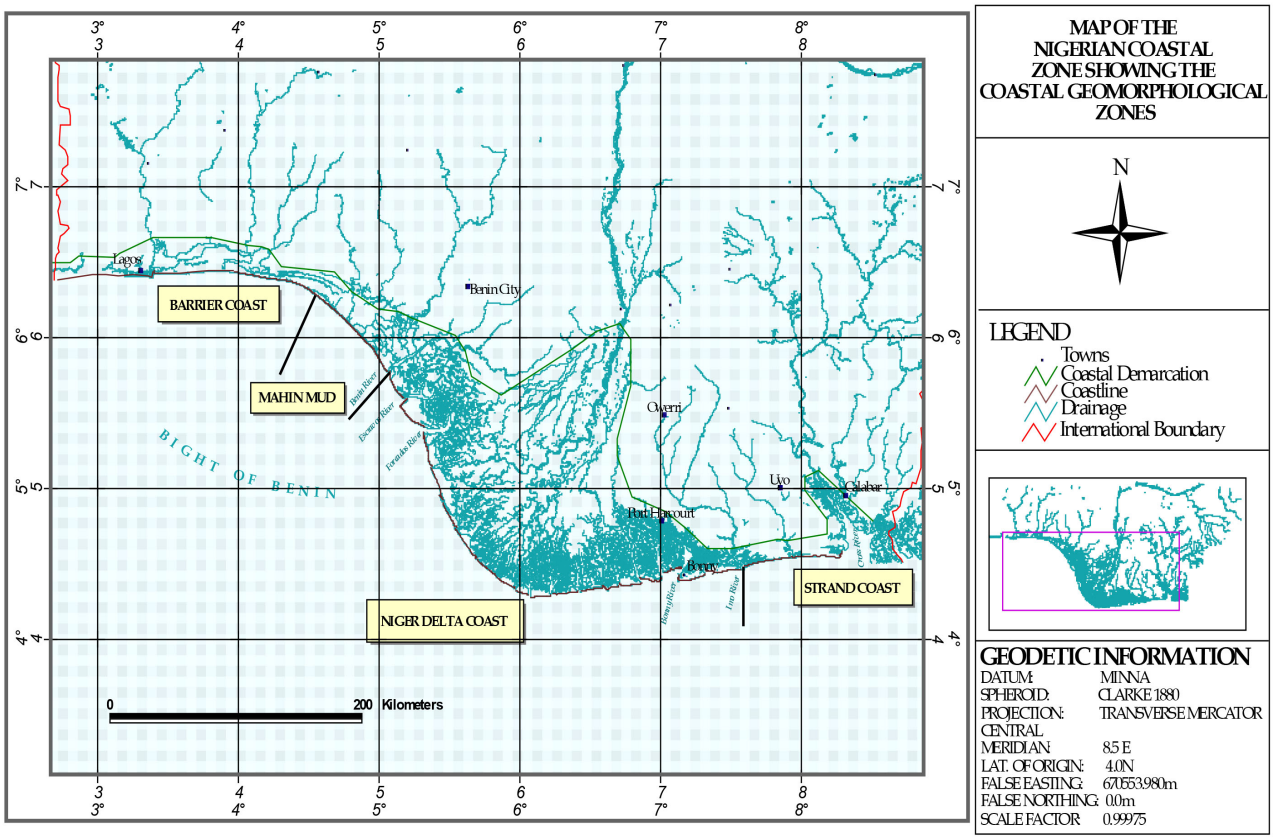

Figure 1. Map showing the different geomorphological zones along the Nigerian coast (Awosika *et al.* 2000).

foreshore gradient of about 1:50. Beach crest elevation is between 3 - 4 m above mean low-low water. The foreshore is backed by narrow and sandy beach ridges, which are, aligned parallel with the coast.

2.2. Mahin Mud Coast

The Mahin mud coast is a muddy coastal complex which lies east of the barrier lagoon coast and stretches to the Benin River in the northwestern flank of the Niger Delta (**Figure 1**). The Mahin mud coastline runs from NW to SE between latitudes 5˚52'00"N and 6˚25'00"N. Relief ranges from sea level along the coast backed by a wide expanse of tidal flat **Figure 1**. Additionally, the morphological zone also has a wide expanse of coastal plain with relief rising gently from 2 m to about 50 m above mean sea level.

2.3. The Niger Delta

The Niger Delta extends over an area of about 75,000 sq·km and accounts for 7.5% of Nigeria's land mass covering a coastline of 560 km, about two-thirds of the entire coastline of Nigeria. The Niger delta is rimmed by a chain of sandy barrier islands approximately twenty in number [6]. The Niger delta spreads over a number of ecological zones; sandy coastal ridge barriers, brackish or saline mangroves, freshwater permanent and seasonal swamp and lowland forests.

The mangroves and wetlands along the major estuaries between Benin river in the west and Cross River in the east have a total brackish area of 2520.79 sq·km.

2.4. Strand Coast

The Strand coast stretches from Imo River eastwards to the Cross River estuary along the Nigerian Cameroon boundary (Figure 1). Within the Strand coast is composed of the mangrove swamps with species composition like those of the arcuate Niger Delta zone. Some parts of the estuaries in this zone are populated by the palm: Nypa fructicans which is particularly dominant in the Qua Iboe River area. The mangrove species Rhizophora racemosa are found along the Cross River estuary and in isolated pockets along the coast. The Calabar Port is the only Ports along this coast.

3. Coastal Hazards in Nigeria

Significant coastal hazards include coastal erosion, storm surge, floods, land subsidence, pollution especially oil spill and possibly seismicity which could lead to earthquake and tsunami.

3.1. Coastal Erosion

Coastal erosion is a hazard, affecting the entire Nigerian coastline. Established rates of erosion in some areas along the Nigeria coastline are in Table 1. Several studies [3] [8] [9] have revealed that the natural causes of erosion include low lying coastal topography, intense wave and tidal regime, vulnerable soil characteristics, nature of shelf width, topography, and the occurrence of offshore canyons.

Anthropogenic factors responsible for erosion especially in Lagos include the construction of harbor protecting structure in the form of moles (to prevent the silting of the Commodore channel to the ports) and several other jetties as landing sites for vessels. The hotspots of erosion along the Nigerian coastline are discussed below.

Table 1. Established rates of Erosion along the Nigerian Coastline.

COASTAL MORPHOLOGY	MAJOR AREAS	EROSION RATE PER YEAR (METERS)
Barrier Lagoon	Badagry, Victoria Island in Lagos and Lekki	25 - 30 in Lagos. 10 - 15 m in Badagry
Mahin Mud	Awoye, Molume,	20 - 22
Niger Delta	Escravos, Forcados, Brass and Bonny	18 - 20
Strand Coast	Ibeno–Eket	16 - 20

3.1.1. Lagos Bar Beach

The problem of erosion at the Victoria Beach in Lagos is traceable to the construction of moles between 1908 and 1912. These moles were to protect the dredged deep (Commodore Channel) entrance into the Lagos harbor from intense wave action and the silting up of the channel. The construction of breakwaters interrupted the long-shore transport of sand from west of the west mole to the east along the shoreline, resulting in the trapping of about 0.5 and 0.75 million cubic meters of sand per year behind the west mole leading to an accreting Lighthouse beach on the western side of the harbor entrance [8]. In Lagos for example, over 14×10^6 m^3 of sand were dredged from offshore borrow pits between 1960 and 1990 to nourish the fast-eroding Victoria Beach. About 13×10^6 m^3 of sand were dredged from the Lagos Lagoon between 1990 and 1991 to nourish the Lekki phase 1 housing scheme development project area, [10].

In recent times high-energy waves have intensified the rate of erosion resulting in the undermining of the foundation of homes, businesses, and public infrastructures. For example, in Lagos, the Alpha, Goshen and Mayegun beach environments were completely eroded within a short time as a the "Great Wall" protecting a multi-million Dollar housing project in Victoria Island, Lagos resulting in the intensification of approaching wave on the beach. Incessant shipwrecks along the fragile Victoria and Lekki beaches have further worsened the existing high rate of erosion along the coast. The entire Barrier Lagoon coast in the Lekki peninsular is fast eroding due to the low topography, wave energy and especially human intervention. The net erosion (in reference to berm crest movement) recorded at all the ten stations along Okun Ajah shoreline (east of Lagos Bar beach) from October 2010 to March 2011 (dry season) range from 0.04 m to 1.26 shown in **Table 1** and **Figure 2** with some ephemeral accretion [3].

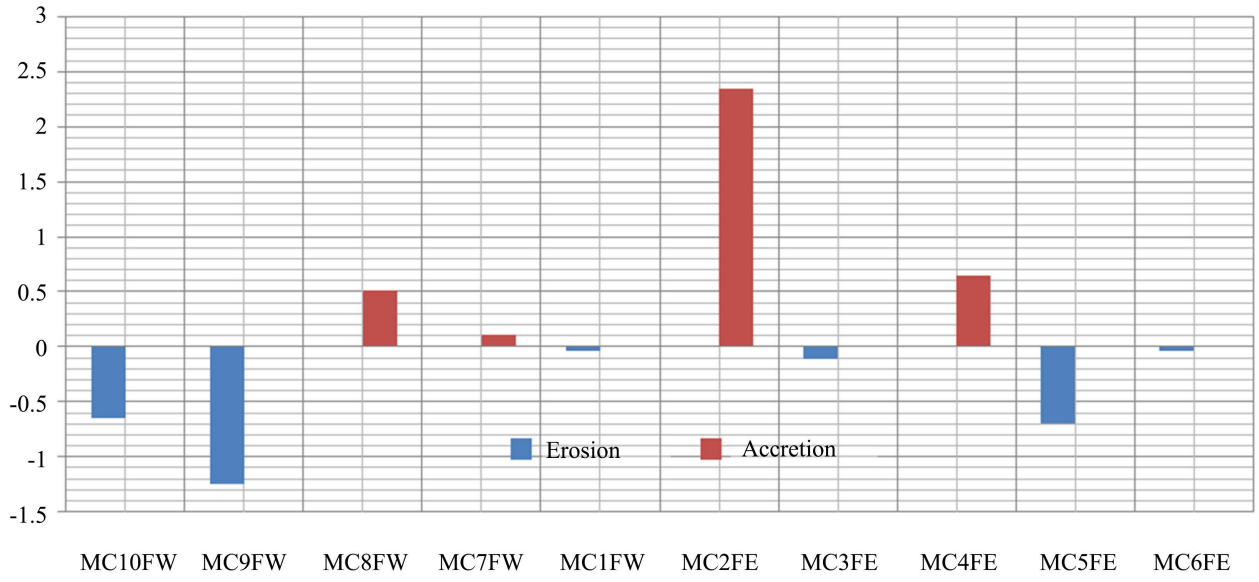

Figure 2. Plots of net erosion/accretion at each monitoring station during the entire study period.

3.1.2. The Mahin Mud Coast

The Mahin mud coast has a low-lying coastal beach plan with an active beach of 50 to 80 m wide. Average wave height is about 0.5 m with wave angel of 5.7. Beach sediment size are predominantly mud and fine sand which is well sorted. The muddy sediments are easily thrown into suspension when they come in contact with water, making the area highly vulnerable to erosion. The beach is fast eroding at a rate of 20 to 22 m annually, **Table 1**.

3.1.3. Forcados and Bonny (Niger Delta Coast)

The Niger Delta coast is generally low lying, well-endowed with natural inlets and rimmed by 20 islands, [8]. The beaches are sandy with a gentle gradient of about 1:40. Beach sediment is predominantly fine sand and well sorted. In Forcados, erosion rates of 18 - 25 m annually were reported by [8]. In Bonny, beach erosion/accretion trends between 2011 and 2015 were about 15 - 20 m annually.

3.2. Flooding

The beaches along the Nigerian coastline are susceptible to flooding and inundation due to their very low topography. Some areas along the beaches are almost at sea level. Such low-lying beaches like the Victoria/Lekki Bar beach and Mahin Mud beach are easily flooded during high tides. Whenever storm surges coincide with spring tides most beaches at a maximum elevation of 3 m above sea level are usually topped by high waves resulting in flooding.

Flooding of the Victoria Island and other low-lying areas of Nigeria are common especially during the rainy months of May to July. These floods are more pronounced during the peak of the oceanographic season in the months of April and August when ocean swells which develop far out in the Atlantic pound the coast with devastating effects. The coincidence of spring and high tide conditions in addition to blocked drains lead to flooding of streets and houses. Analysis of drainage channel levelling data [11] revealed that many channels have reversal flows as a result of land subsidence and are also blocked by refuse (solid waste), sediment and obstructions by buildings. All the drainage channels studied showed that solid waste obstructed channels from the head to the outfall. The dumping of domesticated refuse directly into the drainage channels exacerbate the problem of seasonal flooding on the streets of Lagos. Flooding of the Victoria Island environment by storm surge is observed every year however, on the 29th May 2009, **Figure 3** shows that the height of the swell reaching the coast average about 2 m above normal high tide levels. Recently in August 2011, swells reaching over 4 meters above normal high tide levels devastated the Lagos coastline pulling down buildings.

The Bar Beach erosion problem has over the years been aggravated by periodic ocean storm surges. From observation by the Nigerian Institute for Oceanography and Marine Research, the months of April to June and August to October are known as the peak periods when ocean storm surges occur along the shoreline. Between three to four major storm surges are experienced annually

Figure 3. Flooding of the bar beach and the surrounding areas adioining beach in Victoria Island Lagos on 29 the May 2009.

during these months. During such periods, there is a sudden rise in sea level that result in high plunging waves which top the beach and spill ocean water on to the streets of Ahmadu Bello Way, Alpha coastal community and beyond, [2]. When this happens, large amount of beach sediment is eroded and washed away leading to flooding of large parts of the Victoria Island and other coastal communities.

In a recent study of the causes of flooding in Victoria and Ikoyi Islands of Lagos, [11] found that the annual flooding on the islands is caused by drainage channels which lack enough drainage heads to discharge runoffs into the lagoon.

The coastal area especially the Niger delta and the adjourning Mahin Mud coast also experience very high rainfall and storm surges. The poor drainage allows storm waters to collect in the hollows and eventually flood large areas within the Delta. Many settlements have had to move upland many times to escape being washed away by floodwaters.

3.3. Salinisation of Ground Water

In the Benin and Niger Delta basin, salt-water intrusion into the recent sediment aquifer occurs beneath a fresh water lens in the belt stretching from the coastline to a distance of about 5 km in some places. In the eastern part of the Benin basin repressed by Akodo, the fresh water aquifers in the Coastal Plains Sands are sandwiched between salt water-bearing sands, [12]. The saltwater wedge is penetrating deeply into the delta particularly during the dry seasons. This has reportedly caused drinking water wells to become saline. Saltwater intrusion has also been found to occur in the unconfirmed aquifers of the Coastal Plains Sands in a zone stretching from Apapa to Lekki within Lagos metropolis. The intrusion of saline water into groundwater supplies is on the increase and would adversely affect both ground and surface water quality leading to death of flora and fauna

that cannot tolerate high salinity.

The Nigerian coastal zone is composed of young sedimentary sediments which are still compacting. Compaction of Holocene deposits is considered [13] to be the primary cause of widespread subsidence in the Mississippi deltaic plain. Such processes result in subsidence and ultimate lowering of the already low-lying coastal topography. This phenomenon has though not been quantified in a particular area, [8] recorded rates of subsidence of more than 2.5 cm/year after correcting for loading effects by the oil tanks at the site of a tank farm along the Niger delta coast. This could be understandable as due to the weight exerted by the oil in the tank farm on the area. However, this is a localized effect, there is no quantitative data to substantiate the rates of subsidence solely on oil and gas withdrawal. More studies and monitoring of this geological hazard will be necessary.

Another localized, and perhaps better documented human-induced factor in subsidence is that associated with groundwater withdrawals [14]. Withdrawal of oil, gas and ground water can impact surrounding wetland and coastal areas resulting in subsidence as a result of loss of pore spaces in the young and compacting sediment.

3.4. Pollution

In Nigeria, the development of the petroleum industry is particularly important as it is the main backbone of the economy. Activities of this sector produce pollutants which are usually accompanied by environmental hazards and degradation. These pollutants include Petroleum hydrocarbons from the oil industry, Solid wastes (especially from domestic activities) and Sewage. The impacts are varied and depend among others on the chemical nature of the waste in question, physical and chemical characteristics of the recipient environment as well as the biological traits of exposed organisms. Due to unavailability of sewage treatment plants in coastal mega cities, raw sewage is generally disposed off in coast waters, and offshore. This practice is very prevalent in Lagos, Warri and Port Harcourt where coastal population is very high. This introduces pathogens which generally affect human health in the environment. The ocean and beaches are used as dumping grounds for a variety of wastes from ships and even industries. Results of some previous assessment of beach debris along Victoria Beach in Lagos, [15] revealed that plastics and foamed plastics constituted the most abundant debris category amounting to 31.86% of total pieces of debris collected. This was followed by paper and metal categories constituting 16.67% and 10.45% respectively. Rubber and glass categories constituted 7.36% and 6.88% respectively while cloth category amounted to only 4.06% of the total.

3.5. Sea Level Rise Impacts

Probably the main coastal consequence of an increase in global temperature is an accelerated rise in sea level. This could be due to thermal expansion of the oceanic waters and less probably melting of Alpine and polar glaciers. The rate

of sea level rise along the Nigerian coastline in the past has not been quantified due to paucity of data. The average mean sea level obtained from tide gauge records (Lagos) spanning 1960 to 1970 was found to be 0.462 m above the zero of the tide gauge [16].

Major results of Intergovernmental Panel on Climate Change (IPCC) assessments in 1990, 1992, 2007 show that most low-lying coastal states of the world will be adversely affected by sea level rise. The Nigerian coastal zone is no exception as shown in the past assessment of impacts of sea level rise on the Nigerian coastal zone [9]. Two major case studies have since been carried out by NIOMR. These are: 1) impacts of sea level rise on the coastline of Nigeria using Ariel videotape assisted Vulnerability Analysis [9] technique coupled with ground truth data, [9] and 2) implications of climatic change and sea level rise on the Niger Delta using historical and recent records and information. Results of these study reveals that several areas of the Nigerian coastal zone are highly vulnerable to climate change and sea level rise.

The barrier lagoon coastline in the western extremity with the high real estate at Victoria Island and Lekki could lose well over 584 and 602 square kilometers of land from erosion while inundation could completely submerge the entire Lekki barrier system. Such adverse impacts will affect the residential, commercial and tourist facilities on the Victoria, Ikoyi and Lagos Island at well over U.S $12 billion. The Niger Delta could lose well over 15,000 square kilometers of land by the year 2100 with a one-meter sea level rise [9]. With as much as U.S $13 billion already invested in oil mining facilities and fishing settlements in the Niger Delta, the cities, villages and fishing settlements in the Niger Delta, the potential loss to Nigeria will be very great. The strand coast on the eastern extremity of the country shares many of the characteristics of the Niger Delta but with a much narrower strip of mangrove behind the narrow Atlantic barrier islands. This region could lose over 400 square kilometers of its land by the year 2100. Much of the land loss from sea level rise will be due to inundation.

3.6. Seismicity-Eartquake and Tsunami

The Nigerian continental margin is generally regarded as passive or aseismic. However, recent seismicity reported along the coastal areas of Ghana, Cote d' Ivoire, Nigeria and Cameroon may indicate possible crustal movement in the oceans adjoining these coastal states. The deep-seated faults like Romanche, Chain, Charcot and Cameroon fracture zones, **Figure 4** which originates from the mid-Atlantic ridge, could induce seismicity in the mid-Atlantic ridge. Also, the rebirth of seismicity in the Cameroun volcanic region could generate kinematic crustal movements in the adjoining continental margin.

Withdrawal of fluids in the form of oil and gas especially from offshore Nigeria, Cameroon and Gabon could also induce some instability and lead to some crustal movement. Such spontaneous tectonic event like earthquake could generate tsunamis which could be very destructive especially due to the low-lying nature of the Nigerian coastal zone.

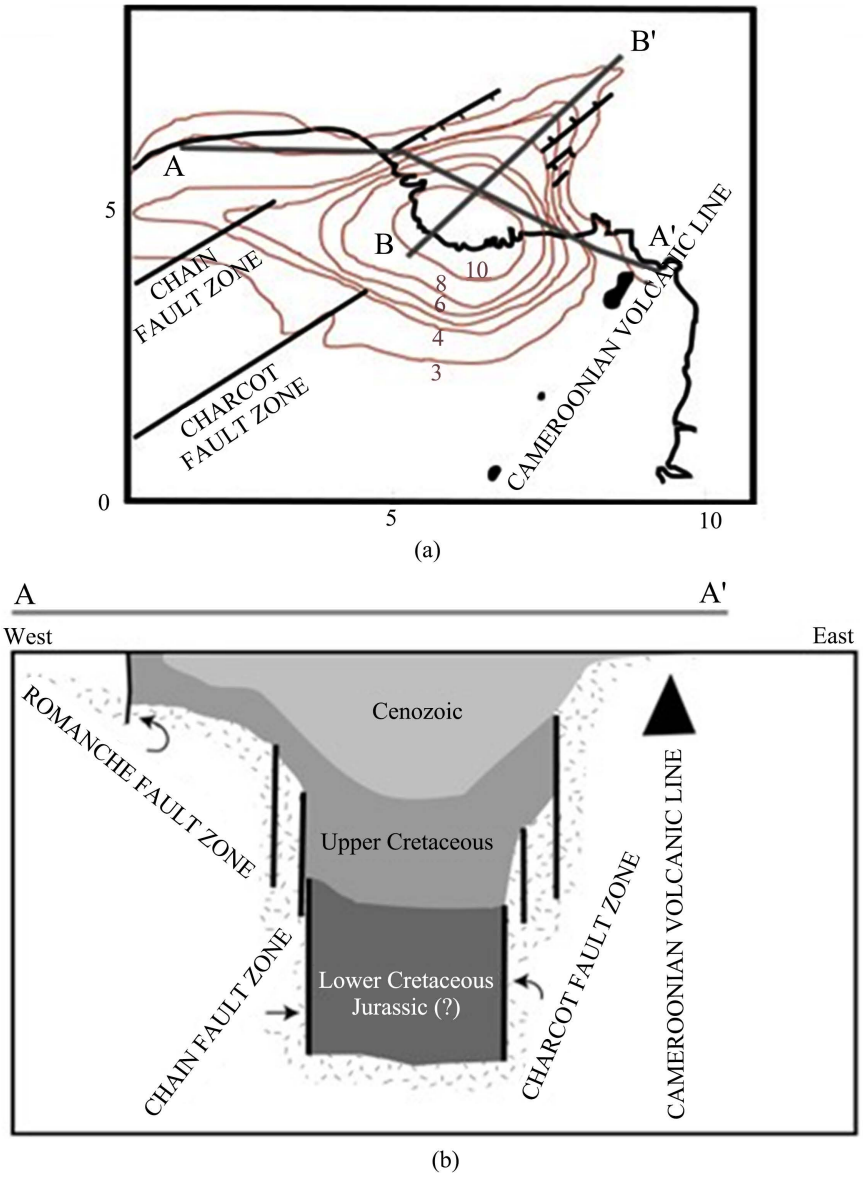

Figure 4. (a) Isopach map of total sediment thickness of the Niger delta; (b) Diagrammatic west-east (A-A') cross section through the Niger Delta Region showing fracture zones [17].

4. Conclusions

The economic loss due to degradation of the coastal areas will have serious consequences on the development of the Nigeria coastal area. Disaster along the coast due to erosion, flooding, pollution and salinization constitutes major environment challenges for Nigeria. The economic loss due to such disasters is unquantifiable and would have dire consequences for the economy of Nigeria. In many places like Lagos Bar beach, Forcados, Bonny and Brass, hard structures like groins have been constructed to control coastal erosion and avoid disaster, however many of these structures have failed to solve the problem. Rather, they have resulted in the transfer of the problem down drift. Understanding the

oceanographic processes is necessary for an integrated and sustainable management of coastal hazards and implementation of any adaptation or mitigation options. A holistic approach to all these environmental problems calls for an Integrated Coastal Management (ICM) that will have a national approach. These management plans are, however, ineffective because of the following reasons:

- Lack of co-ordination and interactions between agencies with coastal zone mandates.
- Lack of trained personnel and infrastructure for implementing ICM.
- Inadequate data and information on coastal zone processes and activities; and
- Lack of adequate communication facilities for exchange of data and information.

Disaster reduction principles and practices depend on solid information base, best-practice information management, robust methodologies and tools for analyzing hazard and risk. The need for adequate data and information on erosion and other coastal hazards like flooding, subsidence and possible earthquake and tsunami is paramount for decision making. This level of understanding is possible only when accurate, appropriate and timely information is available and presented in a format that can be easily utilized by decision makers.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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