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# Vulnerability to Sea Level Rise of Badagry Coastline, Lagos, Nigeria

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## Abstract

Climate change and its anticipated effect of sea level rise have been predicted to affect all coastal communities of the world. These impacts which will be in form of increased coastal erosion, inundation, flooding due to storm surges and salt water intrusion into freshwater resources will however be asymmetrical depending on the coping capacities and preparedness of the communities. This paper uses remote sensing and GIS techniques to determine the vulnerability Index (CVI) of the Badagry coast to sea level rise using coastal morphology; topography, shoreline erosion; tidal range and the socio-economic characteristics variables. The result revealed that in relation to the coastal morphology 65% of the shoreline covered fall within the very high vulnerability class. About 80% based on coastal slope, falls under moderate to very low vulnerability classes. The tidal range of the entire stretch of the coastline falls within a hydrographic station whose spring tide range is about 0.914 and therefore falls within very low vulnerability class, 70% of shoreline change reveal moderate to very high vulnerability classes, while socio-economic characteristics shows that about sixty percent (60%) are engaged in primary occupations (fishing and farming) which are very high vulnerable to sea level rise. The integration of the variables in the (CVI) model revealed that about 50% of the coastline belong to the high and very high risk classes, a relatively smaller part (30%) belong to the moderate risk class while a small part (about 20%) belong to the low risk class. Thus with the predicted sea level rise of 0.59 m by 2100 as noted by IPCC (2007) a large part of the Badagry coast especially areas around the Border town are at risk of being inundated and eroded. It is recommended that sensitization of the people on various coping strategies be carried out from time to time. Also, alternative skills acquisition that will ensure that the people are not totally dependent on coastal resources be acquired.

**Keywords:** Climate Change, Shoreline erosion/accretion, morphology, tide and Lagos.

## 1.0 Introduction

Casualties and damages caused by natural disasters, while fluctuating strongly have been increasing in recent decades (Ebert and Kerle, 2008). Climate change as part of these natural disasters is already modifying life on Earth, because around the globe, seasons are shifting, temperatures are climbing and sea levels are rising. The world's present situation can be seen in the review of the observed impact of climate change on the natural and human environment as presented by the working group II of the fourth assessment report (IPCC, 2007) which shows that with regard to changes in snow, ice and frozen ground (including permafrost), there is high confidence that natural systems are affected. Examples include; enlargement and increased numbers of glacial lakes as can be seen in the size of Lake Tsho Rolpca of the Nepal, which was observed to have increased from 0.23km$^2$ to 1.65 km$^2$ within 1957 and 1997 leading to threats of devastating glacial lake outburst floods (Agrawala et al., 2005). Another example is the increasing ground instability in permafrost regions, and rock avalanches in mountain regions as can be seen in the increased rock fall caused by the 2003 summer heat wave resulting in the active layer deepening of the Swiss Alps from 30% to 100% between June and October 2003 (Gruber et al., 2004).

Based on growing evidence, there is also high confidence that negative effects on the hydrological systems are occurring. This include increased runoff and earlier spring peak discharge in many glacier- and snow-fed rivers as is obvious in the arctic drainage basin of Ob, Lena and Mackenzie where

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an annual increase of 5%, winter increase of 25% to 90% and winter base flow due to increase melting and thawing permafrost was recorded for the periods within 1935 and 1999 (Serreze et al., 2002). There is also warming of lakes and rivers in many regions, with effects on thermal structure and water quality, as can be seen in the increasing temperatures of Lakes like; Victoria, Tanganyika and Malawi having warmed up from 0.2 to 0.7$^{o}$c since the early 1900s affecting the thermal stratification and internal hydrodynamics of the Lakes and altering their phytoplankton dynamics and primary productivity (Vollmer et al., 2005).

More evidences have also shown that recent climate changes and climate variations are beginning to have effects on many other natural and human systems. Examples include; increased incidence of heat waves, killing thousands of people all over the world as can be seen in August 2003 heat wave episode in Europe with reported excess mortality in the range of 35,000 (Michelozzi et al., 2004; Conti et al., 2005; Grize et al., 2005; Johnson et al., 2005).

Other indications include; receding shoreline due to coastal erosion resulting in the salinization of freshwater reservoir, loss of biodiversity and destruction of infrastructure as reported in studies carried out by Penland et al., (2005) where they discovered a shoreline retreat of 0.61 m/yr between 1855-2002 in Louisiana, USA and that of Ross et al., (2000) where it was discovered that grassy marshes are replacing mangrove due to sea-level rise and water table changes between 1940 - 1994 in South-east Florida, USA.

A clearer view of the quagmire we have found ourselves is evident on the Lagos coastline, where climate change (through sea level rise and extreme events as well as anthropogenic activities) is impacting on the biophysical and socio-economic environment. Obvious examples include, flooding as a result of storm surges as can be seen in the series of extreme events being experienced on the coastline, especially that which occurred between 16$^{th}$ and 17$^{th}$ of August, 1995, when a series of violent swells in the form of surges were unleashed on the whole of Victoria (Bar) Beach, Lagos. Another is the erosion caused by the ship wrecks on the Lekki and Alpha beach, Lagos threatening the structures and multi-million naira Jakande Estate and Chevron's Twin Lakes Estate (Plate 1).

There is also the inundation of the Lagos coastline as a result of sea level rise as is presently being experienced in some parts and is predicted to get worse putting about two million Lagos residents at risk (Adetayo, 2011). Another obvious impact is the salinisation of the coastal aquifers as reported in a study carried out by Adewuyi et al., (2010) where it was noted that groundwater aquifers surrounding the Lagos coast (especially in settlements like Adeniji Adele, CMS and Victoria Island) presently contain impermissible conductivity value of above 1000µs/cm as compared to 126µs/cm and 208µs/cm for Ikeja and Ikotun respectively. This was basically attributed to the intrusion of salt water into the aquifer from the Atlantic Ocean.

Since global sea-level rise is likely to persist due to continuing thermal expansion of sea water, melting of land-based glaciers and melting of ice-sheets in Antarctica and Greenland (IPCC, 2001), then the presently observed impacts are likely to continue and in some cases escalate with human activities serving as catalyst. While natural hazards will conti-

Plate 1: Coastal Erosion on the Alpha (2011), Lekki (2011) and Bar Beach (1995)

nue to occur, their capacity to become disasters or merely manageable events depend on many factors, among which is the magnitude of the hazard, the vulnerability of people and their communities, the built environment and political systems (Dwyer et al., 2004). In the light of increasing frequency of disasters and continuing environmental degradation, measuring vulnerability is thus a crucial task if science is to help support the transition to a more sustainable world (Kasperson et al., 2005). This study therefore provides the important information of the vulnerability of Lagos coastline to climate change using the Badagry section as a case study.

## 2.0 The Study Area

The Nigerian coastal zone covers a stretch of about 850 km from the western border with the Benin republic to the eastern border with the republic of Cameroon. It lies within latitude $4^0$ 10’ to $6^0$ 20’ N and longitude $2^0$ 45’ to $8^0$ 35’ E with an estimated human population of over 20 million. It can be broken into four broad regions based on the differences in the general morphology, vegetation and beach type which include:

- The barrier-lagoon coast complex extending for 250km from the Benin/Nigeria border eastwards to the western limit of the trans-gressive mud beach;
- The Mahin trangressive mud coast and beach extending for 75km and terminating at the Benin river mouth on the Northwest flank of the Niger delta;
- The Niger delta coast extending from the mouth of the Benin river for about 500km to the mouth of the Imo river in the East
- The strand coast extending from the Imo River to the Cross river estuary at the Nigeria/Cameroun border.

### 2.1 Barrier-Lagoon Coast Complex

The Nigeria barrier lagoon coast, which is the specific region of interest for this study, is part of a series of Barrier Lagoon coast along the West African coast starting from Cote d’Ivoire and ending in Nigeria. The coast extends eastward for about 250km from the Nigerian-Benin border to Ajuno village, consisting of narrow beach ridges aligned parallel with the coast and backed up by the Badagry, Lagos, and Lekki lagoons with beach sediments of medium to coarse grained sand that are moderately well sorted (Ibe and Awosika, 1986).

It can be classified into four broad regions based on the difference in the geomorphologic features that ranges from the west to east. They include the followings:

- The active barrier-lagoon/beaches
- The low/upland sandy plains
- The Wetlands
- The mangrove swamps and tidal flats.

Since the study area is located on the coastal plain of Nigeria, the entire area undulate around sea level. The soil is sandy around the coastal part and except in few places the entire study area is swampy. Geologically, recent sedimentary layer underlies the study area. The sedimentary rock of alluvial materials is sandy, muddy and unconsolidated. The study area is also covered with mangrove forest at the northern part and Palm and coconut trees at the southern most part. Climatically it is within the humid tropics. The specific area of interest for this study is the 32.4759 km coastal stretch from the Border town at Seme eastward. Figure 1 shows the map of the study area.

## 3.0 Methodology

The CVI derived in this study considered seven (7) parameters (coastal morphology, coastal slope, shoreline changes, tidal range, occupation, settlement type and housing characteristics) which is in variance with most earlier coastal vulnerability studies where less parameters were considered (Pendleton et al 2004; Thieler and Hammer-klose, 1999 and Diez et al., 2007). Another major difference is the inclusion of socio-economic parameter which introduces the human aspect into vulnerability studies.

Each of the identified variables/parameters were classified into five vulnerability classes and each class was ranked / assigned weight based on its susceptibly level to sea level rise. The classes and weight are: very low, low, moderate, high and very high with rank order (weight) 1, 2, 3, 4, and 5 respectively. Fig 2 shows the methodological frame work for the study while table 1 shows the characteristics of the data used.

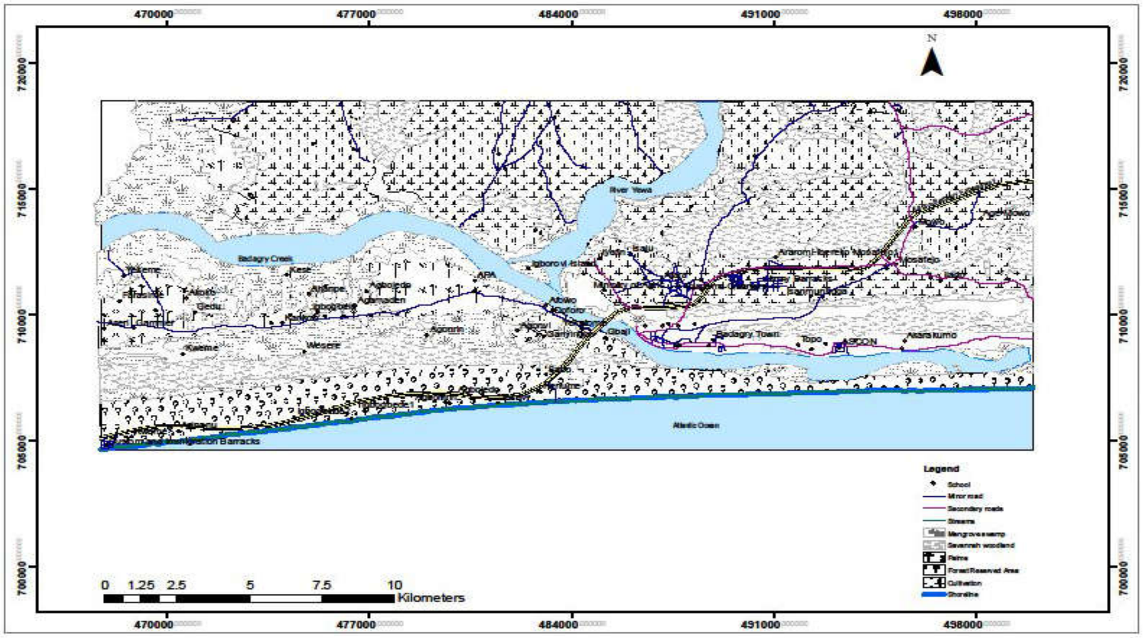


Figure 1: Map of the Study Area

### 3.1 Coastal Parameters and Their Rankings

The morphology of the study area extracted from satellite imagery and supported with field work is presented in Table 2. The contour lines and spot heights extracted from the 1:25,000 topographic sheet of Badagry and processed using Triangulated irregular network (TIN) method in 3-D Analyst module of ArcGIS was used in developing the Digital Elevation Model that gave the slope characteristics. The values derived were used to characterize the coastline using classes in Table 2 developed by Pendleton et al., (2004).

The change in the position of the shoreline shows the level of erosion or accretion that has occurred within a given time. For this study, the shift in shoreline during the 21-year period from 1985 to 2006 was analysed using Digital Shoreline Analysis System (DSAS) which revealed areas experiencing erosion and accretion. The classification is shown in table 2. Records of the tidal characteristics were accessed from the hydrographic station covering the study area (Apapa station) and this was used to calculate the mean spring tide range (the average of spring high and low tides). The character of the mean spring tide range was used to make Table 1.

With regards to the characteristic of the inhabitants of the coast, considered are; the settlement, occupation and building characteristics of the study area. These socio-economic variables were extracted from census records and social and demographic statistics in conjunction with questionnaires administration and in-depth interviews (IDI) using stratified sampling technique. The study area was thus divided into five equal parts with one settlement/community chosen within each cluster (Oglogbo/Pengbo, Gbettrome, Asakpo, Gberefu and Yovoyan). The ranking order for occupation, settlement and housing type is shown in Table 2.

The seven (7) variables were then combined in GIS using the 'Spatial Join' option in the 'Overlay' module of 'ArcTool' menu to derive a Coastal Vulnerability Index (CVI) for the various segments of coast based on the relative importance of the variables using the equation 1. Table 3 shows the total vulnerability ranking / scoring.

$$CVI = 4m + 4s + 2c + t + sos \quad \ldots 1$$

where m is morphology, s is coastal slope, c is shoreline change, t is tidal range. and sos is socio-economic.

Table 1: Shows the detailed characteristics of the data used for the study

| S/N | Data Type | Date of Production | Source | Scale |
|---|---|---|---|---|
| 1 | Geo-eye Image | | lagos state government | |
| 2 | Landsat Image | 2000 and 2006 | Landcover.org | 30 meter |
| 3 | Administrative map of Badagry | 2009 | Badagry Local Govt | |
| 5 | Topographic map of Badagry | 1985 | Federal office of surveys | 1:25,000 |
| 6 | Population Figures of Lagos | 2006 | NPC | |
| 7 | Social statistics of Lagos | 2008 | NBS | |
| 8 | Tidal gauge | 2006 | Hydrographic Office | |

Table 2: Shows the Coastal Vulnerability Parameter Classification Scheme

| Variables | Very low (1) | Low (2) | Moderate (3) | High (4) | Settlement Type |
|---|---|---|---|---|---|
| Morphology | Rocky coasts | Indented Coasts | Beach ridges/ high dunes | Estuaries | Low Beaches |
| Slope (%) | 5.00 | 4.00 | 3.0 | 2.0 | 1.0 |
| Shoreline change (m/year) | 2.026 to 0.870 High accretion | 0.869 to 0.291 Low accretion | 0.290 to -0.289 No change | -0.290 to 0.870 Low erosion | -0.870 to - 2.026 High erosion |
| Mean spring tide range (m) | <1.0 | 1.0–2.0 | 2.0–4.0 | 4.0–6.0 | >6.0 |
| Occupation | Civil servants/Security officers | Transporters | Traders and Artisans | Tourism service providers | Fishermen and farmers |
| Housing type | No Settlement | Village | Small Town | Large Town | City |
| Housing type | Brick | Mud | Brick and palm frond | Palm fronds | Clothing/Zinc |

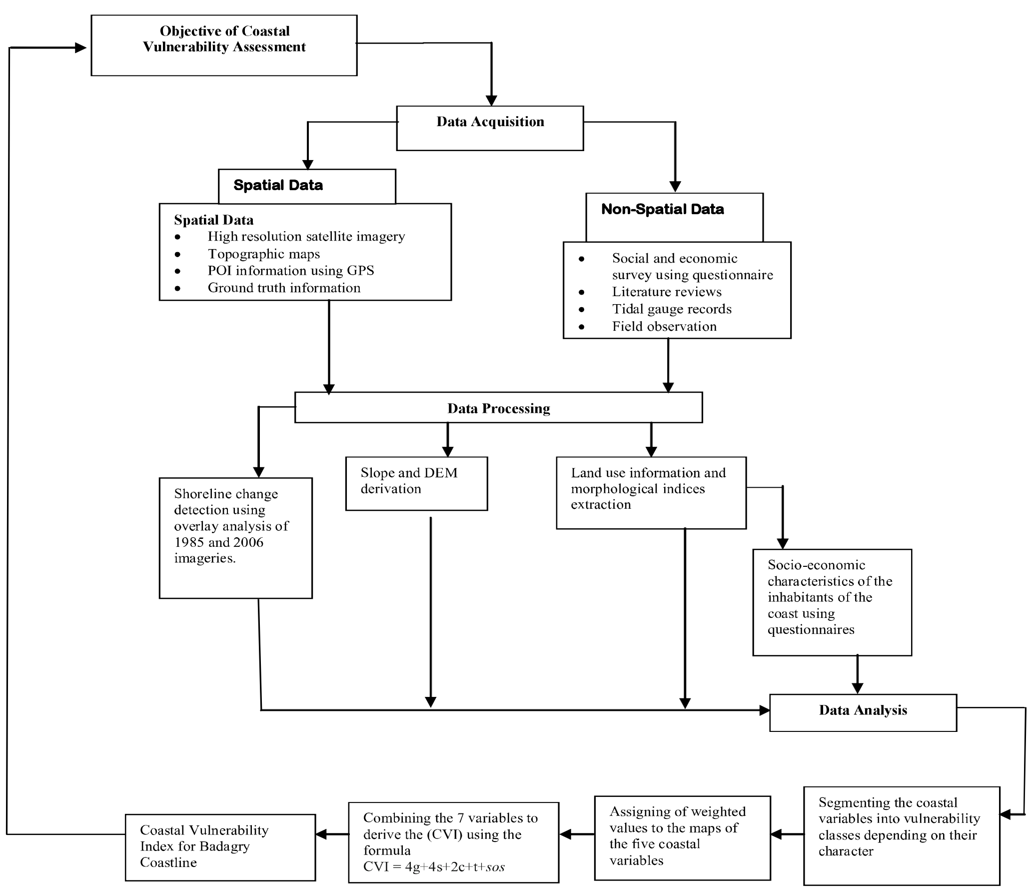


Figure 2: Methodological Framework

## 4.0 Result and Discussions

### 4.1 Analysis of the Morphological Characteristics of the Badagry Coast

The result derived from the coastal morphology analysis as shown in the Table 4 and Figure 3 indicates that, out of the total coastal length of 32.47591 km, 21.10934 km (65%) are covered by low beaches while 8.11898 km (25%) are covered by high vegetated beaches. 3.24759 km (10%) are however covered by Estuaries while no part of the coastal stretch has rock outcrops or pronounced indentations.

The implication of the result presented above is that larger part of the coastline (65%) fall within the very high vulnerability class covered by low sandy beach (plate 2 and 3) which can be easily washed away in the event of a storm surge or sea level rise. This part is followed by the high and moderate vulnerability classes having 25% and 10% respectively.

### 4.2 Analysis of the Coastal Slope

The derived slope values along the coast ranged from 1% to 5%. Coastal slope values around 3% covered the highest length 11.366.57 m while slope values around 1% covered the lowest length of 1.6238 km (see Table 5). It can thus be inferred that larger parts of the coastline belong to the moderate to very low vulnerability classes (about 80%) while a relatively small part fall within high and very high vulnerability classes. This is represented in Figure 4.

By implication, it can be inferred that since a large portion of the Badagry coast has steep slopes, the coast may not be easily inundated or flooded in the advent of an ocean surge or sea level rise. Plate 4 shows relatively steep slope parts of the Badagry coastline.

Plate 2: Sandy Beach of Asakpo Coast

Plate 3: Sandy Beach of Gbettrome Coast

Table 3: Total Coastal Vulnerability Classes

| Variables | Coastal Vulnerability Rank | | | | |
|---|---|---|---|---|---|
| | Very low (1) | Low (2) | Moderate (3) | High (4) | Very high (5) |
| Morphology | | | | | |
| Coastal slope | | | | | |
| Shoreline change (m/year) | | | | | |
| Mean spring tide range (m) | | | | | |
| Socio-economic characteristics | | | | | |
| • Settlement type | | | | | |
| • Occupation | | | | | |
| • Housing characteristics | | | | | |

Table 4: Vulnerability Analysis of Coastal Morphology (Landforms)

| **Variables** | **Very low (1)** | **Low (2)** | **Moderate (3)** | **High (4)** | **Very high (5)** |
|---|---|---|---|---|---|
| Morphology | Rocky coasts | Indented Coasts | Beach ridges/ high dunes | Estuaries | Low Beaches |
| Length (Km) | 0 | 0 | 8.1190 | 3.2476 | 21.1093 |
| % | 0 | 0 | 25 | 10 | 65 |

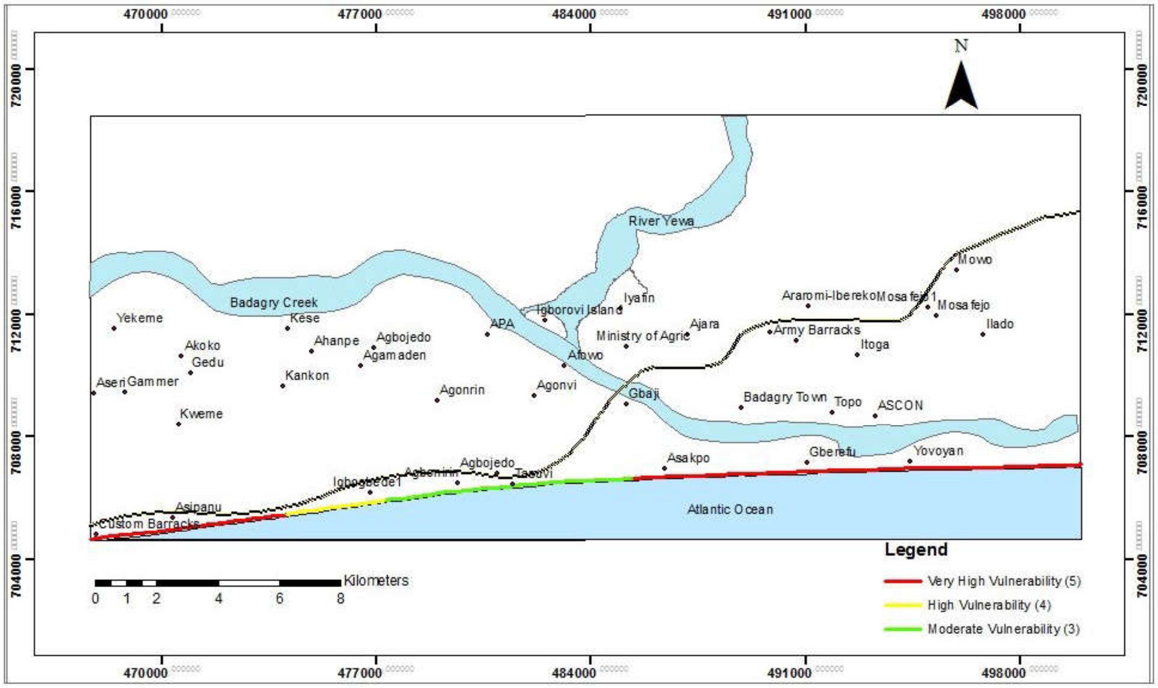


Figure 3: Vulnerability Analysis of Coastal Morphology (Landforms) Map of Badagry Shoreline

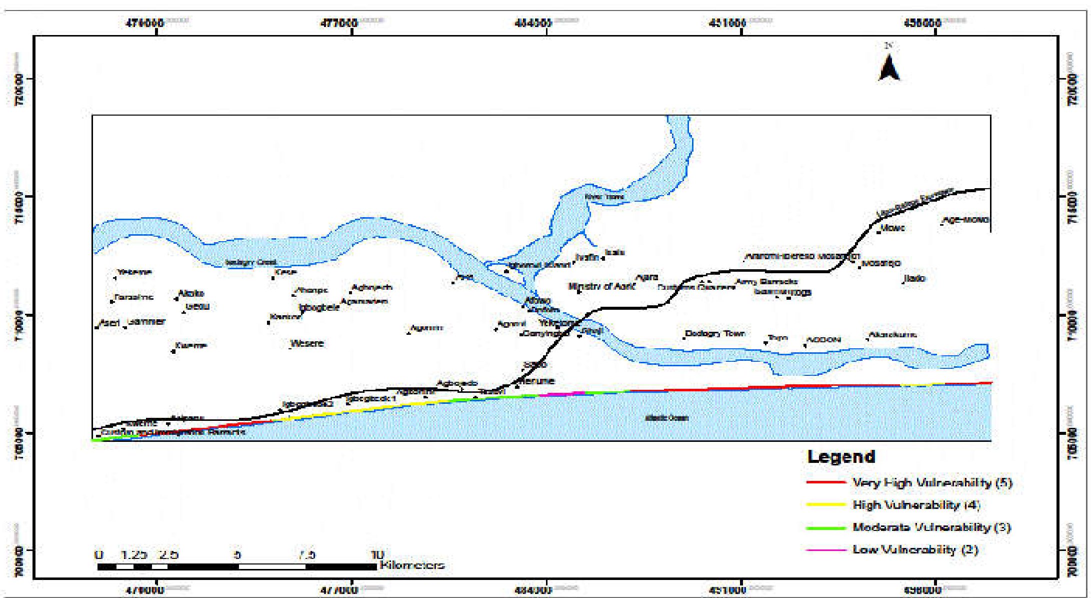


Figure 4: Vulnerability Analysis of Coastal Slope on Badagry Shoreline

Table 5: Vulnerability Analysis of Coastal Slope on Badagry Shoreline

| Variables | Very low (1) | Low (2) | Moderate (3) | High (4) | Very high (5) |
|---|---|---|---|---|---|
| **Slope (%)** | 5.00 | 4.00 | 3.0 | 2.0 | 1.0 |
| **Length (Km)** | 8.1190 | 6.4952 | 11.3666 | 4.8714 | 1.6238 |
| **%** | 25 | 20 | 35 | 15 | 5 |

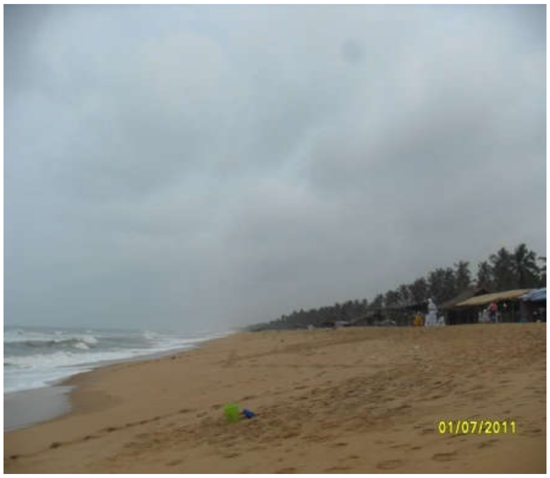


Plate 4: Coastal slope at Sitho

## 4.3 Shoreline Change Analysis

The results derived from the shoreline change analysis were divided into the classes as shown in Table 12 to illustrate areas where erosion, accretion or no changes have occurred.

As shown in Table 6 there is a large part (about 70%) of the coastline falling within the moderate to very high vulnerability classes while the remaining part fall within the very low to low vulnerability classes. This implies that substantial parts of the coastline shoreline are vulnerable to sea level rise based on geomorphic processes of erosion, transportation and depositional activities along the study area as shown in Figure 5.

## 4.4 Mean Spring Tide Range Analysis

The spring tide range data for the study area acquired from the hydrographic office was summed up and the mean tide range calculated. Since just one tide station (Apapa) cover the study area, the same mean tide range value was recorded for all the segments of the coastline.

As shown in Table 7, the entire coastline fall within the mean tide range of less than 1 (0.9143). By implication the entire coastline stretch fall within the very low vulnerability class covering 32.47591 kilometers as shown in Figure 6.

## 4.5 Analysis of the Socio-Economic Characteristics of the Residents of the Coast

The result of the socio-economic analysis as presented here is based on the survey of the five settlements chosen as the samples for the study.

## 4.6 Occupational Characteristics of the Inhabitants of the Coast

The occupational characteristics of the residents of the study area as collected through the surveys conducted are categorized using Table 8.

It was revealed that majority of the inhabitant of the study area are fishermen which is understandable because of the proximity of the area to the Ocean. Others are engaged in the fishing businesses like boat construction, net mending, and fish roasting among others. Apart from fishing (Plate 5), the residents in their spare time also engaged in cloth-weaving (Plate 6), tourism (Plate 7) and farming activities (Plate 8). Thus, farm lands of various sizes were found in the study area. Government officials (like Custom, Immigration, Port Health, Quarantine, NDLEA and Border patrol officers) were also found in their numbers especially in Pengbo/Oglogbo (Seme) community. In fact an extensive staff quarters

Table 6: Shoreline Change Analysis

| Variables | Very low (1) | Low (2) | Moderate (3) | High (4) | Very high (5) |
|---|---|---|---|---|---|
| Shoreline change (m/year) | 2.026 to 0.870 | 0.869 to 0.291 | 0.290 to -0.289 | -0.290 to 0.870 | -0.870 to -2.026 |
| Length (Km) | 3.24759 | 6.49518 | 11.36657 | 4.87139 | 6.49518 |
| % | 9.9 | 19.9 | 35 | 15 | 19.9 |

Table 7: Mean Tide Range

| Variables | Very low (1) | Low (2) | Moderate (3) | High (4) | Very high (5) |
|---|---|---|---|---|---|
| Mean spring tide range (m) | <1.0 | 1.0–2.0 | 2.0–4.0 | 4.0–6.0 | >6.0 |
| Length (Km) | 32.4759 | 0 | 0 | 0 | 0 |
| % | 100 | 0 | 0 | 0 | 0 |

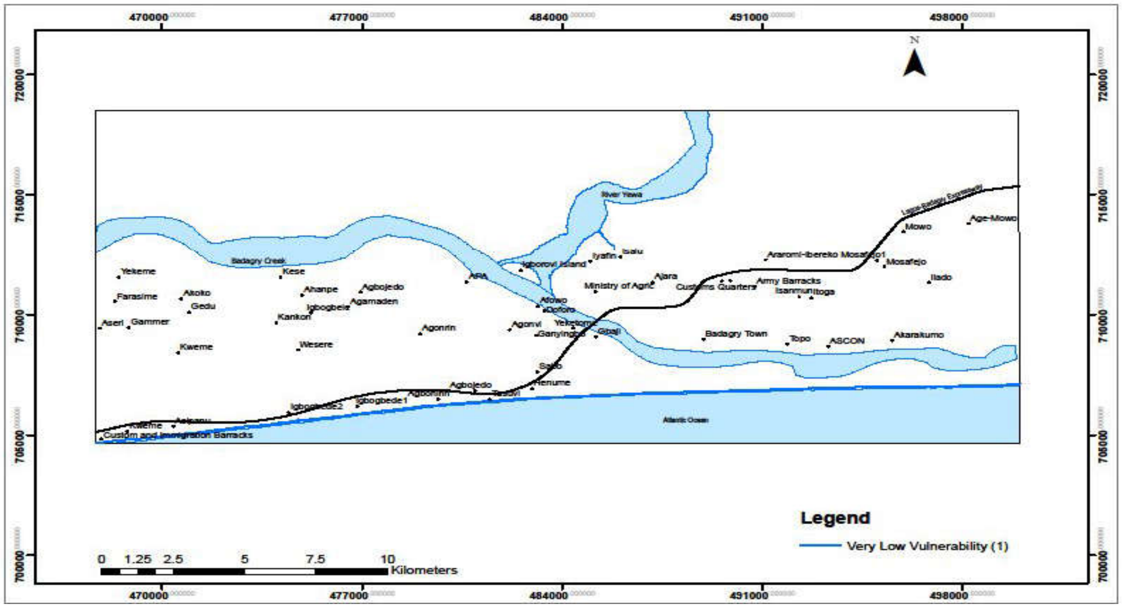


Figure 6: Vulnerability of Tidal Range along Badagry Shoreline

Plate 5: Fishing Activities on the Coast


Plate 7: Tourist Activities on the Coast

Plate 6: Cloth-Weaving Activities on the Coast

Plate 8: Agricultural Activities on the Coast

Plate 9: Commercial Activities on the Coast (Seme).

inhabiting these officials is located in the study area. Also living very close to the security officers are traders and transporters who have businesses at the border town (Plate 9). In Asakpo community, artisans engaged in clothe weaving were found while tourist sites in form of beach resorts dots the area.

The different types of occupation as found along the shoreline and their level of vulnerability to sea level rise is shown Figure 7. The occupational characteristic as revealed above indicates that about sixty percent (60%) of the inhabitants of the shoreline are engaged in an occupation (fishing and farming) which is very highly vulnerable to sea level rise. About 30% of the inhabitants are however engaged in an occupation which is between moderate and low vulnerability to sea level.

### 4.7 Analysis of the Settlement Characteristics of the coast

The Badagry Shoreline is dotted with different types of settlements. While some parts are unoccupied, some others are covered by settlements ranging from villages to towns.

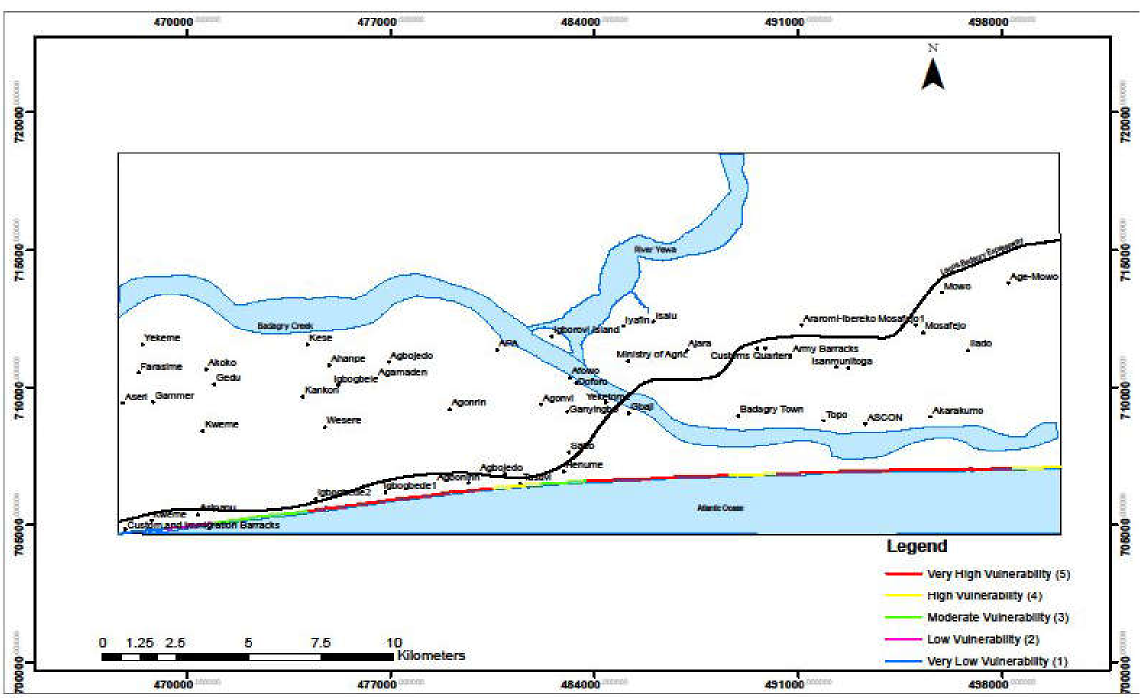


Figure 7: Vulnerability of the Occupational Characteristics of the inhabitants of Badagry Shoreline to sea level rise.

Table 8: Analysis of the Occupational Characteristics of the residents of the coast

| Variables | Very low (1) | Low (2) | Moderate (3) | High (4) | Very high (5) |
|---|---|---|---|---|---|
| Occupation | Civil servants/Security officers | Transporters | Traders and Artisans | Tourism service providers | Fishermen and farmers |
| Length (Km) | 1.6238 | 1.6238 | 4.8714 | 4.8714 | 19.4855 |
| % | 5 | 5 | 15 | 15 | 60 |

The surveys revealed that about 70% of the settlements are villages, while about 5% is covered by a relatively large town (Seme). Unoccupied parts of the coast also abound especially in areas not connected to expressway. Analysis of shoreline vulnerability to sea level rise is shown in Table 15

Plate 10: A typical Coastal Settlement at Gbettrome

Plate 11: Security Officer's Quarters at Seme

Plate 12: Storey building on the Coast at Asakpo

and Figure 8. Since there is no city in the study area, the most vulnerable area is the large town (Seme) which is home to large number of people. The most extensive are areas (Villages) belonging to moderate vulnerability.

### 4.8 Analysis of the Housing Characteristics of the Coast

Settlements in the study area are constructed using different materials. Table 16 and Figure 9 characterized the materials of buildings along the shoreline to levels of vulnerability.

The most prominent housing type found in the study area, are houses built with palm fronds (see Plate 10). Houses built with brick can however be found within the security quarters (see Plate 11) especially at the border town (Seme) and at beach resorts (Suntan and Fashola) dotting the shoreline. Also located on the coast is Asakpo community which has one storey building and other buildings built with brick (see Plate 12) on the coast.

It can be inferred from Table 16 and Figure 9 that substantial parts (70%) of the residents of the shoreline live in houses built with materials (palm fronds) that are highly vulnerable to sea level rise while just a few reside in buildings (built with brick) whose vulnerability to sea level rise is low.

### 4.9 Coastal Vulnerability Index (CVI)

The combination of the seven (7) coastal vulnerability variables using the spatial join option in the overlay module in ArcGIS revealed the total coastal vulnerability of the study area. The CVI values thus obtained ranged from 45 to 62 which were divided into four equal parts (Diez et al., 2007; Gornitz 1991), each indicating certain risk level of the coastline to sea-level rise. The lower range of CVI values indicate low-risk, followed by moderate-risk, high-risk and finally the upper range of values indicating the coast at very high-risk level.

The derived CVI revealed that out of the total coastal length of 32.4759 Km, about 11.3556 Km (35%) fall within the very high risk class, 4.8714 Km (15%) fall within the high risk class, 9.7428 Km (30%) fall within the moderate vulnerability class, while 6.4952 Km (20%) fall within the low vulnerability class (see Table 17 and Figure 10).

Table 9: Analysis of the Settlement Characteristics of the coast

| Settlement Type | Very low (1) | Low (2) | Moderate (3) | High (4) | Very High (5) |
|---|---|---|---|---|---|
| Housing type | No Settlement | Village | Small Town | Large Town | City |
| Length (Km) | 4.8714 | 22.7332 | 3.2476 | 1.6238 | 0 |
| % | 15 | 70 | 10 | 5 | 0 |

Table 10: Vulnerability Analysis of the Housing Characteristics to sea level rise

| Variables | Very low (1) | Low (2) | Moderate (3) | High (4) | Very high (5) |
|---|---|---|---|---|---|
| Housing type | Brick | Mud | Brick and palm frond | Palm fronds | Clothing/Zinc |
| Length (Km) | 4.8714 | 1.6238 | 1.6238 | 22.7332 | 1.6238 |
| % | 15 | 5 | 5 | 70 | 5 |

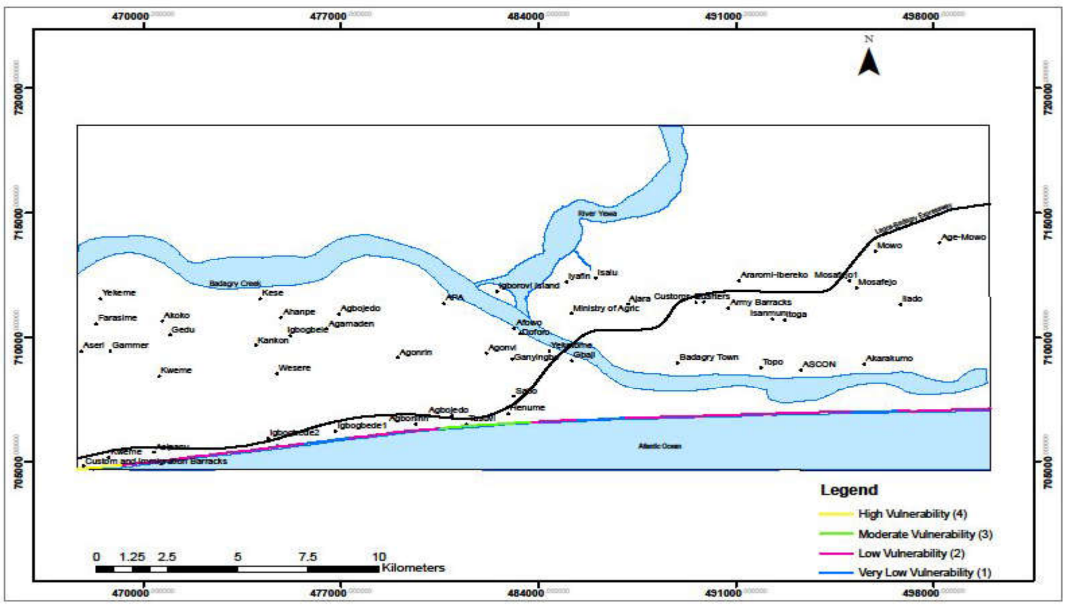


Figure 8: Vulnerability of settlement characteristics to seal level rise in the study area

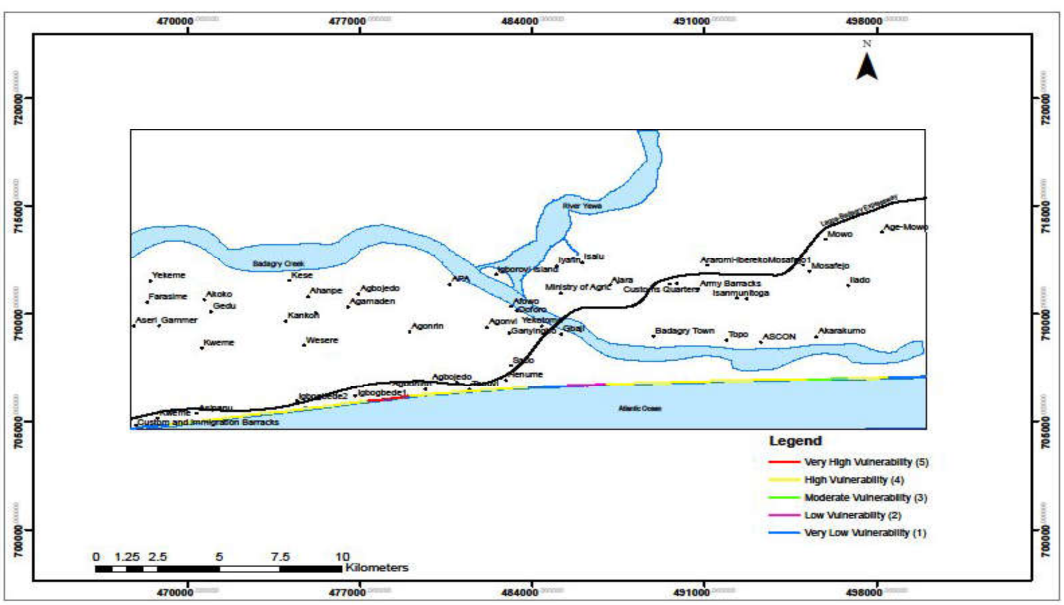


Figure 9: Vulnerability analysis of the housing characteristics to sea level rise

Table 11: Coastal Vulnerability Analysis

| Variables | Coastal Vulnerability Rank | | | |
|---|---|---|---|---|
| | Low Risk(1) | Moderate Risk (2) | High Risk (3) | Very high Risk (4) |
| Length [Km (%)] | 6.4952 | 9.7428 | 4.8714 | 11.3556 |
| % | 20 | 30 | 15 | 35 |

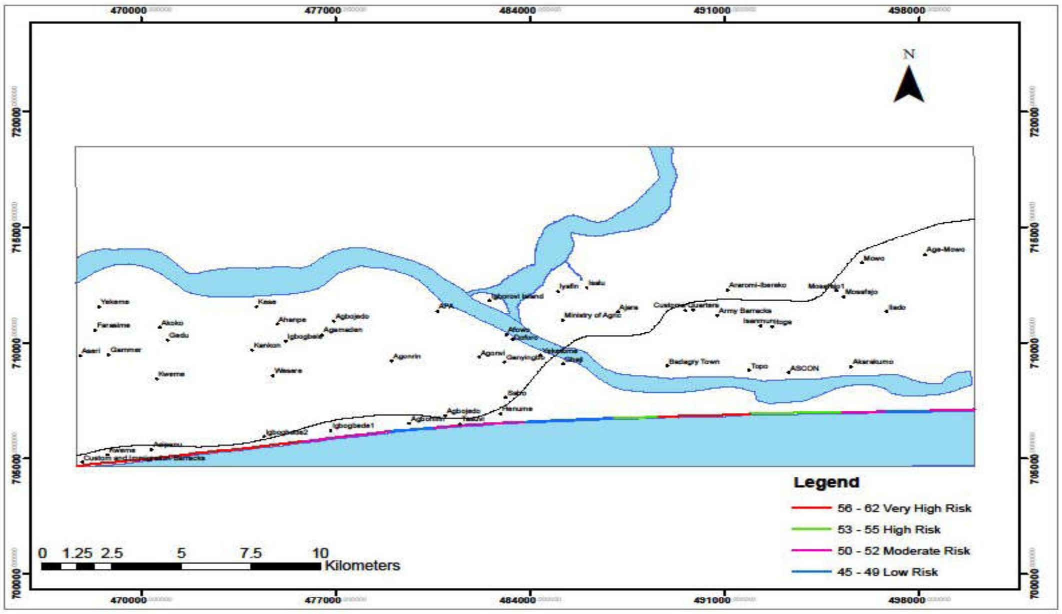


Figure 10: Total Coastal Vulnerability Analysis of the study area

## 4.10 Implication of the Findings

The risk classification as derived above shows that 35% of the Badagry shoreline is very highly vulnerable. This length covers about 11.3556 Km, and is in communities like the Security staff quarters, Pengbo, Oglogbo, Gbethrome and Asipa. The area is covered by low beach morphology, indicating very low resistance to the advancement of the sea. The area has also been experiencing high coastal erosion over the 21 year period (eroding between 0.87 to 2.07 meters/year).

Even though the tidal range and slope of the area reflects low vulnerability (slope being 5% and tidal range being 0.9143), the occurrence of a violent storm surge will wash away most settlements in the area bearing in mind that most of the settlements are built with palm fronds and most of the inhabitants rely heavily on the environment (Fishermen and farmers). With the exception of security personnel residing in this area, other inhabitants may not recover easily in the event of a violent storm or sea level rise.

Interviews conducted with the residents and traditional leaders of these areas revealed that they do not feel threatened by the ocean since they rarely experience storm surges. They however noted that their observations have shown that the sea is gradually approaching them and they have been moving in response to the threats. The last ocean surge experienced was once during the rainy season of 2010, where few houses (see Plates 13 and 14) were destroyed while others with the threat of the event have been abandoned or moved.

The high vulnerability class covering 15% of the coastline which is a length 4.8714 Km covers areas like Gberefu and Yovoyan communities. Just like most other parts of the study area, areas belonging to this vulnerability class are covered by beaches, with coastal slope of 5%. The area is also occupied by individuals who are engaged in fishing and farming. The area has however not being experiencing change in the shoreline which makes it less vulnerable than the very high vulnerability class. The area is also scantily settled also justifying the reason for it coming after the very high vulnerability class because few people in temporary settlements will be affected in the event of sea level rise or violent storm.

Plate 13: A destroyed house at Pengbo

Plate 14: A deserted building at Oglogbo

The moderate vulnerability class covering 30% of the coastline with a length of 9.7428 Km can be found in areas like Sitho, Asakpo, Tasuvi and Igbogbede among others. The area is covered by morphology ranging from low beaches to estuaries to high beaches. The area also falls within the 5% slope limit dotted with villages. The inhabitants of this part of the coastline do not however rely entirely on the environment as artisans who are engaged in cloth weaving were found in their numbers there. Tourist sites operators managing beach resorts were also found in the study area. By implication the inhabitants of this area may not be severely affected by sea level rise or violent storms since they have other things to fall on. The area also has lots of brick buildings which in relation to other parts of the coast may give the advantage of being able to withstand the onslaught of violent storms.

The low vulnerability areas covering 20% of the coastline which is about 6.4952 km can be found in communities like Agonrin and Gbaji among others. The morphology of the area is low beach with villages as the main settlement types. Apart from fishing and farming, the residents of this area also indulge in trading and tourist services. This area has also been experiencing accretion over the 21 years period considered in this study which is at the rate of between 0.291 and 0.870 meters per year.

## 5.0 Conclusion and Recommendation

The vulnerability assessment carried out for the Badagry coastline shows that major parts of the coast are at risk to sea level rise and storm surges. The populations at risk are mostly fishermen and farmers who live in small villages with houses built with palm fronds. Large tracts of priceless land covered with coconut trees are also at risk of being washed away by the impending sea level rise or storm surge. Tourist sites and security personnel quarters located in the study area are also at risk of being washed away.

The following are recommended:

- The highly vulnerable buildings (palm frond houses) of the majority of inhabitants of the coast must be improved upon to make them withstand the unforeseen circumstances
- Appropriate coastal management through beach nourishment is needed in areas noted to have been eroding over the years.
- Total dependence on the coast can also be reduced by the provision of alternative economic activities for the inhabitants of the coast.
- The provision of essential infrastructural facility and the training of the inhabitants to reduce their total reliance on the coast resources thereby enhancing their coping capacity and recovery status.
- It is also recommended that the vulnerability analysis of the entire Nigeria coastline is carried out.

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