



Spatio-temporal Analysis of Shoreline Positional Change of Ondo State Coastline Using Remote Sensing and GIS: A Case Study of Ilaje Coastline at Ondo State in Nigeria

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Abstract

Shoreline changes have been a major environmental concern to coastal geomorphologists, engineers' as well coastal ecologists as a result increased alteration in the ecological system of many coasts of the world. It is causing major coastal structure damage and requires harbour dredging. The current study aimed at integrating remote sensing, geographical information system, and statistical methods to monitor and quantify spatio-temporal shoreline dynamics along Ilaje Local Government, Ondo State, Nigeria over 31 years (1986–2017). Four multi-temporal and spectral Landsat satellite images were used to examine the shoreline changes for a long-term period (1986–2017), besides three short-term time intervals. Images were classified using supervised classification to map the land use land cover changes in the study area. Integrating the Digital Shoreline Analysis System version 4.3 tool within ArcGIS facilitated the quantification of shoreline changes via the End-Point Rate and Net Shoreline Movement statistical techniques. The study revealed a coastal length of about 80 km with both accretion and erosion processes actively shown along the coastline. About 40 km of the coastline was found to be accreting with an average of + 1.08 m/year followed by 35.4 km of coastal erosion with an average of – 1.40 m/year and 4.6 km of the coast more or less appears stable. The overall shoreline changes fall within high accretion ($> + 1$ to $\leq + 2$) to high erosion ($< - 1$ to $\geq - 2$) of shoreline classification. The results show significant erosion, which could impact high economic, social, and environmental costs. The study provides baseline information on shoreline dynamism in the coastline areas of Ilaje Ondo State which will serve as a veritable data for the sustainable control of coastal erosion in the study area and other shoreline with similar characteristics.

Keywords Shoreline dynamics · Remote sensing · Geographic Information System · Coastal erosion · Nigeria

1 Introduction

Analysis of shoreline changes and their potential impacts are paramount to developing policy for ocean protection and disaster risk reduction (Mirza et al. 2020; Adebola et al.

2017). Shoreline change involves both erosion (towards the land) and accretion (towards the sea). This change is caused by both natural (as increase in tropical storms, local waves regimes, extreme flood events, presence of sub marine crayons) and human factors (as human supply and extraction of sand). Sea level rise (SLR), one of the major driving forces affecting the stability of the coastline, threatens coastal settlements especially in urban areas (with very intense exposures) and low-lying rural areas (with major agricultural activities) (Adegoke et al. 2010).

As a result of its margin between the land and sea, shorelines are often prone to unceasing variation due to the dynamism of ocean and sea movement and environmental settings (Mirza et al. 2020). This movement often results in sea level rise and intense erosion along the coastline, thereby causing increasing vulnerability and risk of human

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activities within coastal area (Mirza et al. 2020). The Intergovernmental Panel on Climate Change (IPCC) predicted that about 75 to 250 million people would be vulnerable to coastal flooding by 2020 due to SLR. Besides by the end of the twenty-first century, low-lying and densely populated coastal areas would face the challenge of sea level rise and would cost between 5 and 10% of Gross Domestic Product (GDP) to adapt (IPCC 2014; Agboola and Ayanlade 2016). In general, a rise in the sea level would increase the flooding depth and extend the area that stays wet in the dry season (Brammer 2013).

Globally, there is increasing disaster threats in coastal environment as a result of sea-level rise along the shoreline, with much impact in developing countries, such as Nigeria. The consequences of the increasing sea level rise are floods, submergence, surface and groundwater pollution, erosion and loss of wetland (Komolafe et al. 2019). Coastal flood disasters in Nigeria have become frequent in recent years, and have resulted in both economic and environment damages, especially in the coastal boundaries and agricultural communities. The impacts of the disasters are the results of the continuous demand for physical developments, which hassled to indiscriminate and unplanned structures in the waterways and low-lying areas along the coast. Hence, the excessive misuse of biodiversity, natural resources, wetlands and forests, which are meant to be conserved for balancing the ecosystems and to serve as agents for disaster reduction in coastal environment (Ogunwaye 2009; Ogundele et al. 2011; Diop et al. 2011). Understanding the nature and potential vulnerability of coastal urban as a result of the shoreline changes are major steps in environmental protection and risk reduction (Agboola and Ayanlade 2016).

Flooding and other natural disasters often results in a lot of damages of the coastal environment; there is, therefore, need to monitor the rate of expansion of the water over land to prevent future submergence of the sea shores and coastal inhabitants, especially in highly dense coastal environment due to increase in population. The projected sea-level rise and climate change are challenges that should be of great concern to the policy makers and the researchers to ensure adequate analysis of the historical and spatial data to understand potential social, economic and environmental vulnerability of the people, and implementation of the appropriate measures for safeguarding the shorelines and coastal habitat (Brammer 2013; Agboola and Ayanlade 2016). Adequate geographic information on flood vulnerability and shoreline changes is required for stakeholders and policy makers to prepare for disasters and predict possible changes in years to come (Ajide et al. 2016; Nguyen et al. 2015).

Coastal erosion and related flood and landslide phenomena normally generate very high economic, social and environmental costs. To prevent and avoid these costs, it is necessary to have a good and detailed information about the

real impacts in the past and in the present. Study of long-time-term changes in shorelines according to Moran (2003), is necessary for medium to large-scale coastal planning and management decisions. Modeling shoreline changes is very important in the design of coastal protection, prediction of sea level rise, flood hazard mapping and policy development for coastal management. Despite growing concerns about coastal erosion and the benefits of modeling shoreline changes, studies on shoreline change analysis, particularly in the study area, have only recently begun.

Historical data are significant in the bid to determining changing shoreline segments spatially and temporarily; also, they are valuable in the analyses of erosion or accretion rates, for shoreline position modeling and forecasting. Most data collection on coastline in Nigeria is largely reliant on traditional methods (Adegoke et al. 2010; Fadahunsi et al. 2013). These are slightly costly, time-consuming, labor-intensive, and limited to small areas (Appeaning Addo et al. 2008). The gathering of data through field survey is time consuming and economically expensive. However, the integration of Geographic Information System (GIS) and remote sensing (RS) techniques with historical data such as topographical maps, aerial photographs, and satellite images has improved detailed and effective spatio-temporal analysis of historical changes along coastlines as well as the determination of potential risk. Remote sensing and GIS analysis and delineation of past, present and future shorelines can be carried out accurately and consistently (Nwilo et al. 2005; Psuty and Silveira 2011; Misra and Balaji 2015) for effective monitoring and management of coastlines. The aim of this study is to understand changes that has occurred along Ilaje coastline of Ondo State in relation to its changing shoreline position and the effect of this changes on the population. It seeks to apply remote sensing and GIS techniques with some statistical methods to find out the changes that have occurred along the Ilaje coast in South-west Nigeria over the past few years.

2 Study Area

Ilaje is a Local Government Area in Ondo, one of Nigeria's 36 states, located in the country's southwest zone of the country. It is a coastal settlement which lies within 5° 50' 34" and 6° 40' 58" North of the Equator and 40° 27' 00" and 5° 8' 59" east of the Greenwich meridian and covers an area of about 3000 km. Ilaje land is only about 75 km from Lagos and is a suitable environment for tourism (Fig. 1). The study area is characterized by both hot and humid meteorological conditions with the relative humidity of 68% and mean annual rainfall between 1500 and 2000 mm. The mean temperature is about 30.3 °C (Akinsemolu et al. 2018).

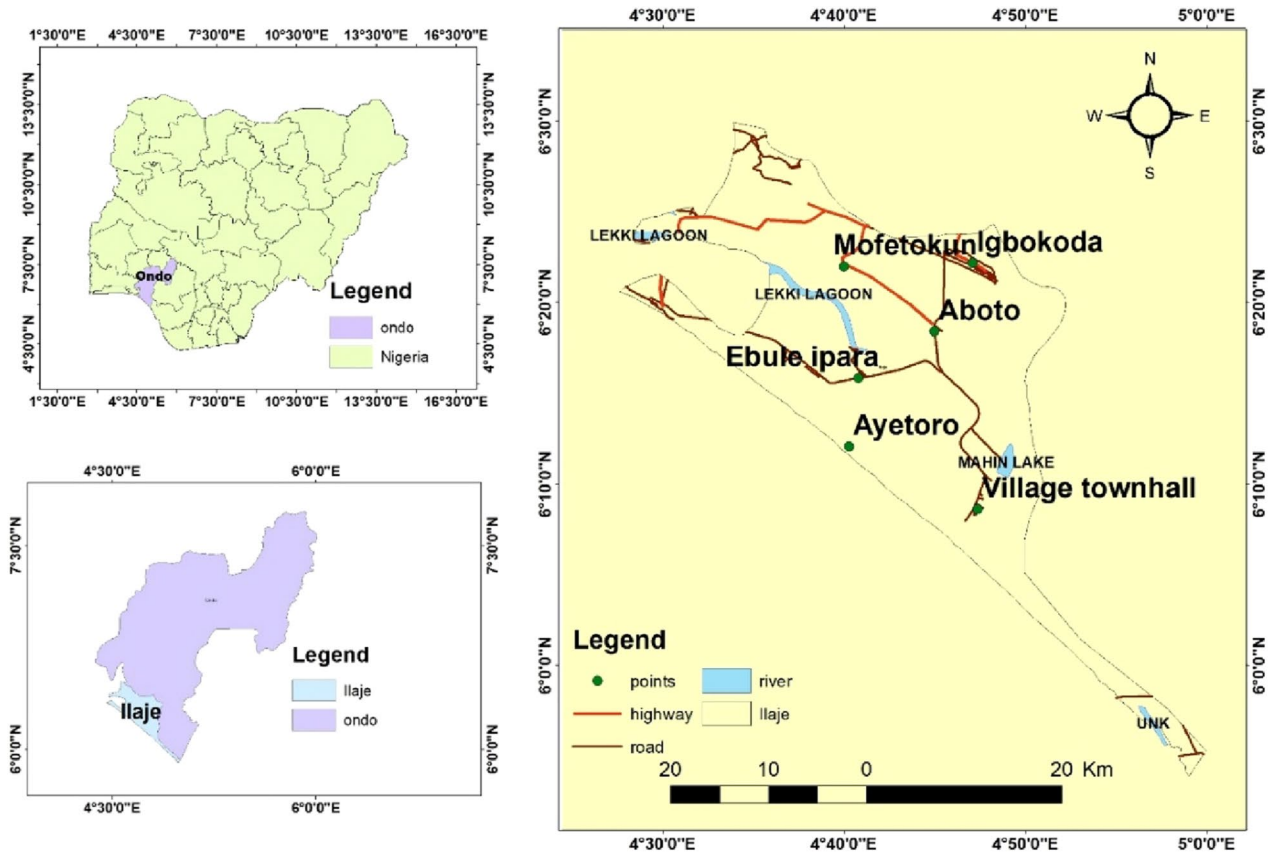


Fig. 1 Study area

The population is projected to be 350,000 people about 260,000 in the 2006 census with less accuracy due to inability to get to some areas because of inaccessibility by road. Fishing and farming are the main preoccupations of inhabitants of the area. These activities also serve as the predominant economic activities in the area, with over 60% of the working-age deriving their income from it. The natural environment of Ilaje land is particularly suitable for the development of large-scale rice plantations and the salt industry. Other occupational activities of the Ilajes include canoe making, lumbering, net making, mat making, launch building, and trading.

3 Materials and Methods

In this study, multi-temporal earth observational data were employed to extract the shoreline changes and their implications on the inhabitants of the Ilaje river communities in Ondo State, Nigeria for the selected periods (1986, 1999, 2011 and 2017). Images were classified using supervised classification to map the land use land cover (LULC) in the study area. The shorelines were extracted from the derived

Landuse change and water indices for the selected years; these were further analyzed using Digital Shoreline Analyzes System (DSAS); the rate of change of computed using the End Point Rate (EPR) methods. Vulnerability of the people to the shoreline changes was determined by extracting the buildings within potential the risk zones (Fig. 2).

3.1 Data and Sources

One Landsat TM (1986), two Landsat ETM+ (1999 and 2011), and one Landsat OLI/TIRS (2017) satellite images (Path 190/ Row 056) were used to study shoreline dynamics along Ilaje Local Government, Ondo State, Nigeria during 1986–2017, that is, covering a time span of 31 years (Table 1). All images were chosen to be at near acquisition dates to remove the effects of seasonal differences. They were provided from the United States Geological Survey (USGS). Landsat images were cloud-free (less than 5%) and corrected to the Universal Transverse Mercator (UTM) map projection system, zone 31 north on the World Geodetic Datum of 1984 (WGS 84). Accessory images were exported from the Google Earth for better interpretation.

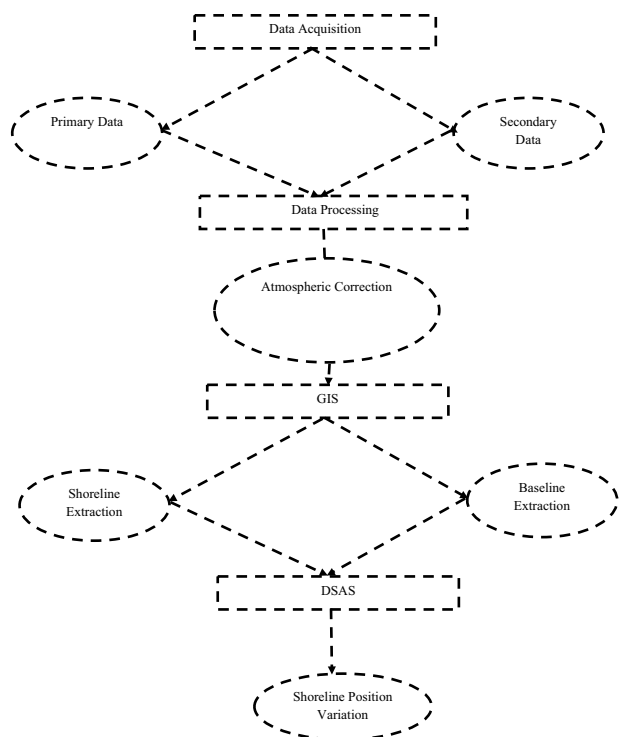


Fig. 2 Methodological flow chart

3.2 Data Processing and Change Detection

The LULC map of the basin area was derived from Landsat imageries (Thematic Mapper™, Enhanced Thematic Mapper (ETM+), Landsat 8 (OLS &TIRS) (Table 1). Satellite images were pre-processed to extract useful data for simpler interpretation (Iqbal and Khan 2014). Geometric and atmospheric corrections were done in the GIS environment to ensure spatio-temporal comparability of the data (Olorunfemi et al. 2018). Further pre-processing activities such as composite bands, and extraction of the image on the basis of study area were performed in ArcGIS 10.3. Band combinations of 543 and 432 colour composite images for Landsat 8 (OLS &TIRS) and Landsat Enhanced Thematic Mapper (ETM+)/Thematic Mapper (TM), respectively, were done for visual interpretation and delineation of training areas.

LULC analysis was carried out using Maximum Likelihood (ML) Supervised Classification in ArcGIS classification tool. Classification is a process of grouping an image into a smaller number of individual classes, based on the reflectance values. The aim of image classification is to extract landscape information from the satellite images. ML is the most powerful and commonly used algorithm for image classification (Nicholas 2005); it makes use of both variances and covariance of the class

Table 1 Characteristics of images and sensor used

Satellite sensor/imagery characteristics	Thematic Mapper™	Enhanced Thematic Mapper (ETM+)	Landsat 8 (OLS &TIRS)
Platform	Landsat 5 (launched 1 march 1984)	Landsat 7 (launched 15 April, 1999)	Landsat 8 (launched 1 February 2013)
Orbit/Revisit period	16 days/705 km	16 days/705 km	16 days/705 km
Equatorial crossing	10:00 am	10:00 am	
Swat width	185 km	185 km	185 km
Bands(um)	1. (0.45–0.52) 2. (0.52–0.63) 3. (0.63–0.69) 4. (0.76–0.90) 5. (1.55–1.75) 6. (10.4–12.5) 7. (2.08–2.35)	1. (0.45–0.52) 2. (0.52–0.63) 3. (0.63–0.69) 4. (0.76–0.90) 5. (1.55–1.75) 6. (10.4–12.5) 7. (2.08–2.35) Panchromatic band 8 (0.50–0.90)	1. (0.433–0.453) 2. (0.45–0.515) 3. (0.525–0.600) 4. (0.630–0.680) 5. (0.845–0.885) 6. (1.560–1.660) 7. (2.100–2.300) 8. (0.500–0.680) 9. (1.360–1.390)
Spatial resolutions	30 m (band 1–5,7) 120 m (band6)	30 m (bands 1–5,7) 60 m (band 6) 15/18 m (band 8)	30 m (Bands 1–7,9) 15 m (Bands 8)
Radiometric resolutions	8 bits	Best 8 of 9 bits	16 bits
Date of image acquisition	15/01/1986	14/12/2011 13/12/1999	04/01/2017
Path and row	190/056	190/056	190/056
Cloud cover	Covers the whole study area with no cloud cover	Covers the whole study area with minimal cloud cover (2011)	Covers the whole area without any cloud cover
Pre-processing history	LIG (Geometric corrected)	LIT (terrain corrected)	LIT (terrain corrected)

signatures to assign each cell to classes in the signature file. The maximum likelihood classification module in multivariate module of spatial tool analysis was employed in ArcGIS for the supervised classification of the study area. The false color composite was produced using the same ArcGIS 10.3 version for all the time-series images. The classification process for each of the image series begins with collecting the training samples for each of the land use classes, and then the trained samples were evaluated using the Histogram, Scatterplot and statistics option to ensure the samples are well spectrally separated. Training classes were generated from the existing and Google map and classification was done interactively Image A signature file is then created from the trained samples, and classification is carried out (Adebola et al. 2017). The six (6) land use and land cover classes identified in the study area include ocean, water body, vegetation (Thick and Light), bare ground, and Built-up (Table 2). Analysis was carried out for images from 1986 to 2017 to detect potential changes in the shorelines of the study area.

3.3 Shoreline Extraction

Shoreline extraction involves the selection of the best algorithm to separate Land from water and distinguish shoreline in satellite images out of the numerous algorithms available. The current study applied the Automated Water Extraction Index (AWEI) to delineate the land–water boundary. AWEI is mainly aimed at maximizing and enhancing separation between water and non-water pixels in an image using band rationing and differencing (Feyisa et al. 2014). The algorithm makes important use of the band 5 and 7 effectively using Eq. 1 (Feyisa et al. 2014):

$$4 \times (GREEN - SWIR) - 0.25 \times NIR + 2.75 \times SWIR. \quad (1)$$

After the index was calculated using the raster calculator, the shoreline was extracted through heads up digitizing in GIS environment.

3.4 Shoreline Rate-of-Change Analysis

The study utilized DSAS version 4.3 to quantify the spatio-temporal changes of Ilaje's shoreline over 31 years (1986–2017). DSAS is a freely available toolbox extension to ESRI ArcGIS v.10 that calculates rate-of-change statistics from multiple historic shoreline positions through vector data (Thieler et al. 2009). The process of analyzing data using DSAS involves three steps: first, constructing a baseline parallel to the shoreline from which transects will originate perpendicularly; second, setting transects parameters that split shoreline into intervals; and finally, setting and calculating the rate-of-change statistics at each transect. Prior to shoreline analysis, the study created geodatabase including the digitized shoreline vectors (for the years 1986, 1999, 2011, and 2017) besides the hypothetical onshore baseline buffered 2000 m from the shoreline position for the year 1986. DSAS cast was used to generate 501 transects orthogonal to the onshore baseline at 150 m intervals seawards to intersect all the digitized shoreline positions. The study carried out the analysis along Coastline with a total length of 84 km.

Rate of shoreline change was calculated using the Digital Shoreline Analysis System (DSAS) tool as an extension ArcGIS. This software used automated technique that allows user to determine the rate of change statistics from historical shoreline positions. We created the baseline feature in the DSAS geodatabase. This requires some essential attributes before it can be recognized, which must be created within the baseline feature class. DSAS uses a measurement baseline method to calculate rate-of-change statistics for a time series of shorelines. The baseline is constructed by the user and serves as the starting point for all transects cast by the DSAS application. The generated transects intersects each shoreline at the measurement points used to calculate shoreline-change rates. With this, users can calculate the statistics of the rate of changes of shoreline from different Series of time of shoreline locations. The extension was designed to assist the analysis of historical changes to the beach. The DSAS system work through the establishment of perpendicular segments (transect) (Chand and Acharya 2010; Sebat

Table 2 Classes delineated on the basis of supervised classification

Land use classes	General description
Built-up area	Commercial and residential buildings, industrial sites, construction sites, Institutional areas, roads and other man-made structures
Water body	Creeks, Rivers, lakes, water reservoirs, ponds, and streams
Thick Vegetation	Evergreen and Deciduous Broadleaf forests, medium and less dense forests
Light Vegetation	Commercial and small-scale farms, irrigated and non-irrigated farms, fallow lands, sparsely vegetated lands
Bare ground	Hills, earth and sand land in-fillings, excavation sites, barren and bare lands
Ocean	Large body of salt water

and Salloum 2018) and then calculate the rate of changes and statistics associated with the chart of data. DSAS calculates a lot of statistical indicators, such as LRR–JKR–EPR (Sebat and Salloum 2018). The baseline was delineated by buffering some distance (about 2000 m) on-shore away from the shoreline due to the complexity of the shoreline, and then both the shoreline as well as baseline was appended into a geo-database as a feature class in order for DSAS to recognize it having satisfied all required inputs format. Transects were casted at a length of 3000 m and statistical parameters were calculated.

In addition, we employed the End Point Rate (EPR) to determine the rate at which the coastline is being eroded/accreted. The endpoint rate is calculated by dividing the distance of shoreline movement by the time elapsed between the oldest and the most recent shoreline. The major advantages of the EPR are the ease of computation and minimal requirement of only two shoreline dates. The major disadvantage is that in cases, where more data are available, the additional information is ignored. Changes in sign (for example, accretion to erosion), magnitude, or cyclical trends may be missed (Himmelstoss et al. 2009). After the computation of rate of change in shoreline, the Net Shoreline Movement (NSM) was calculated by subtracting between the earliest and latest measurement (i.e., the oldest and the most recent shoreline). In general, the net shoreline movement is a distance, not a rate. It is associated with the dates of only two shorelines. It reports the distance between the oldest and youngest shorelines for each transect. This represents the total distance between the oldest and youngest shorelines. (If this distance is divided by the number of years elapsed between the two shoreline positions, the result is the End Point Rate) (Himmelstoss et al. 2009).

According to Natesan et al. (2015), the study categorized the current results of erosion/accretion rates into seven classes as follows: very high accretion: $> +2$; high accretion: $> +1$ to $\leq +2$; medium accretion: > 0 to $\leq +1$; no change: 0; medium erosion: < 0 to ≥ -1 ; high erosion: < -1 to ≥ -2 ; and very high erosion: < -2 ". The rate of changes (accretion and erosion) along the coast over the study period was, therefore, categorized as high accretion ($> +1$ to $\leq +2$) to high erosion (< -1 to ≥ -2).

4 Results and Discussion

4.1 Land-Use/Land-Cover Change

Figures 3 and 4 show the LULC change in the study area between 1986 and 2017. LULC results revealed a very significant change over the past 31 years. The percentage area covered by built-up in 2017 stands at 19% against the initial 0.02% in 1986. The increase in the area covered by built-up

with respect to the increase in years most essentially indicates that more people have migrated to this area for settlement. The purported increase in built-up for 31 years was not so significant compared with the total area extent covered by the study area; this indicates the local government is still widely underdeveloped. The slow development in the study area can be attributed to the fact that most of the waterways are blocked and thus inhibits the free flow of business, because the major means of transportation in the area is through boats and ferries (locally made). The encroachment of settlements near the shoreline and the increasing population due to the migration of people for fish farming makes the dwellers more prone to disaster arising from the change in shoreline.

Wetlands decreases with years in the study area from 24% in 1986 to 18% in 2017, this must have been affected by the land use change, especially the increase in riverine settlement. This development poses great threats to the environment as it undermines the potential benefits of the wetlands in the study area. The Importance of wetland in the coastal area cannot be overemphasized. Most importantly among other benefits is that wetland closed to rivers and ocean provides reduces flood risk, because they can easily regulate and slow down the flow of floodwaters. Area covered by water bodies did not show a significant increase through the years, but decrease in the recent years. This can be attributed to the settlement encroachment to the water ways as a result of fishing activities, which are predominant in the study area. The bare ground showed a sharp decrease between 1986 and 2017; this can be due to the predominantly agricultural activities and increase in built-ups. The increase in vegetation (light and dense) in the study area reveals the slow level of development. Although the percentage reduces in recent years, it is still very significant; the light vegetation shows that farming practices is also predominant in the area. The ever-presence of thick vegetation in the land also indicates its level of underdevelopment.

There was an increase in the thick vegetation from 1986 to 2017 (Fig. 4). This might be due to natural growth of the forest/mangrove. The increase in thick forest has beneficial impact on the coastal preservation. Forested areas are less susceptible to erosion than bare grounds (Olorunfemi et al. 2020). The dense vegetation cover is critical in preventing topsoil layer detachment from the direct impact of raindrops and ocean currents (Olorunfemi et al. 2020). As a result, appropriate actions are required to protect and preserve the study area's remaining natural vegetation resources and reforested areas.

4.2 Analysis of Shoreline Change

Tables 3 and 4 show the general overview of the erosional and accretional changes that has occurred in the coast over

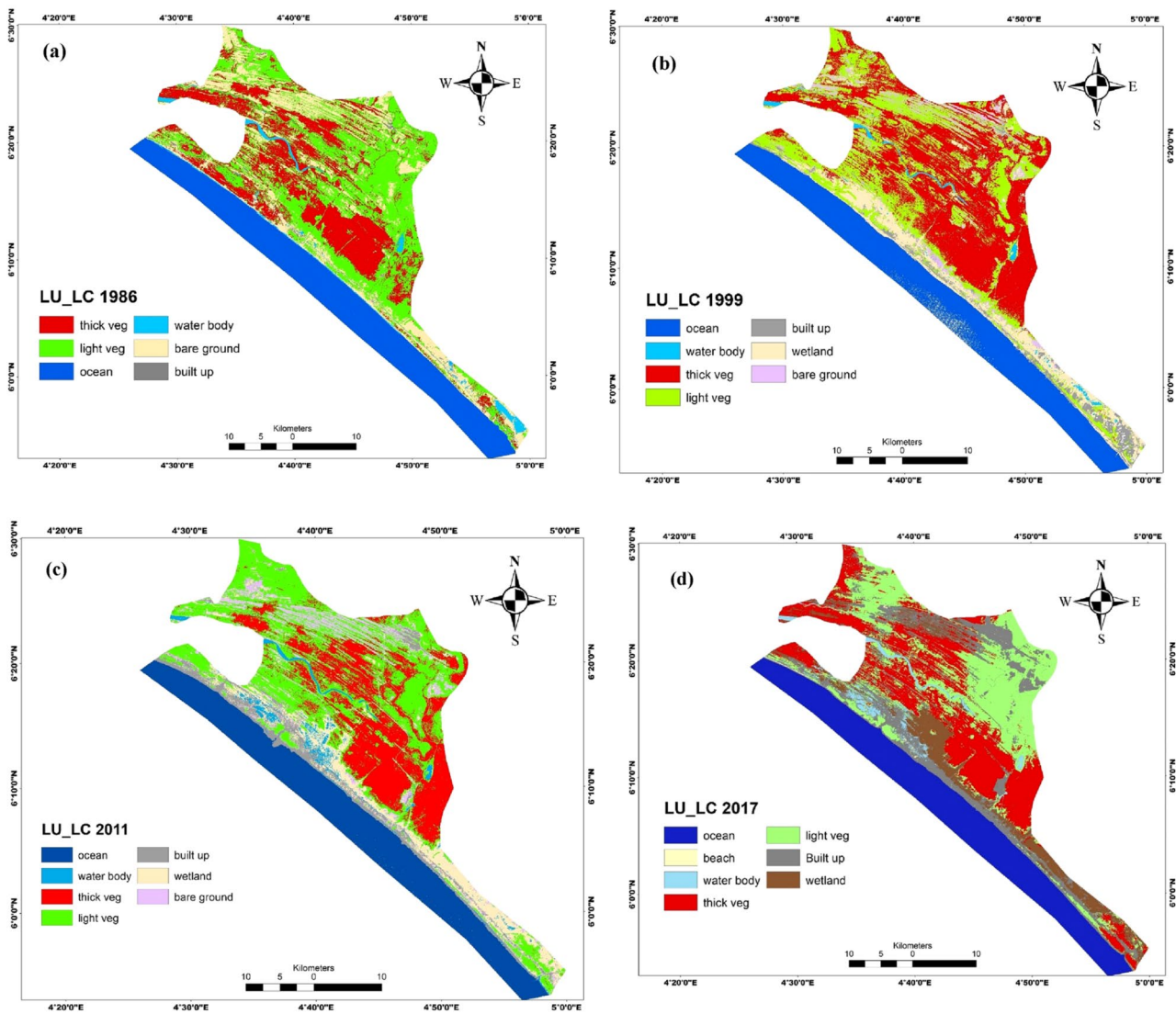


Fig. 3 Land use Land cover maps of the study area for the study period a 1986, b 1999, c 2011 and d 2017

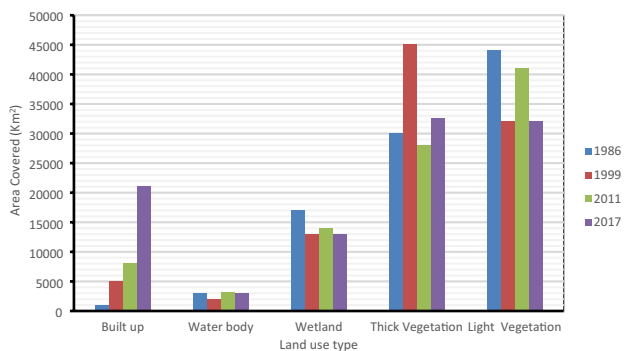


Fig. 4 Graphical representation of the area covered by LULC types from 1986 to 2017

the periods considered. It indicates the overall change that has occurred in the shoreline position from 1986 to 2017 (Fig. 5). Over the whole period of time, the coast has experienced more of erosion although some areas also show to have been accreting (Table 4). The erosion rate is high but more focused in some areas than others. The average erosion rate per year stands at about -2.5 m/y and accretion stand at an average of about 1.8 m/y. Akinluyi et al. (2018) discovered a linear regression rate (LRR) in their study. The shoreline result shows a mean of -0.59 m/year, with 73.1% of the transect subject to erosion and 61.8% subject to accretion. The rate, causes and the negative impact of coastal erosion as a result of shoreline changes have been the focus of this study. There is clear evidence to show that erosion is occurring and is having negative effects on the area, and this requires immediate intervention of the stakeholders

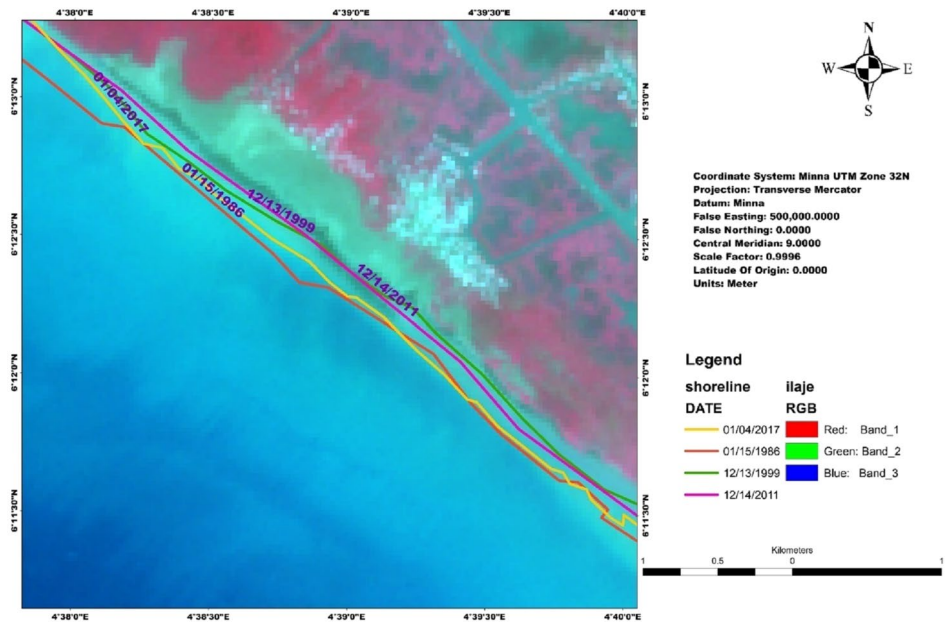
Table 3 Amount of shoreline position change determined by NSM method for Ilaje’ shoreline 1986 to 2017

Period	Min (T#)	Max (T#)	NSM (m)	Erosion	
				Shoreline length (km)	Percentage (%)
				Accretion	Stable
1986–1999	2.6 (35)	931.84 (480)	8	87.7	4.3
1999–2011	0.13 (260)	885 (70)	3	92	5
2011–2017	0.48 (182)	835.2 (422)	5	84.5	10.5
1986–2017	2.97 (23)	1014.09 (501)	4	89	7

Table 4 Analysis of EPR along Ilaje’s shoreline

Period	Accretion(m/year)		EPR(m/year)	Erosion(m/year)		Av. (SD)	Ave (m/year)	Overall trend
	Min	Max		Av. (SD)	Min			
1986–1999	0.22	71.68	35.95	–0.2	–42.68	–21.35	–4.7	Erosion
1999–2011	0.01	42.76	21.39	–0.02	–73.75	–36.89	3.07	Accretion
2011–2017	0.08	139.2	69.64	–0.39	–64.53	–32.46	–9.6	Erosion
1986–2017	0.09	30.73	15.41	–0.12	–21.24	–10.68	0.16	Erosion

Fig. 5 RGB colour composite of Landsat imagery showing the delineated shorelines from 1986 to 2017



and policy makers. Ekong (2017) and Badru et al. (2017) discovered varying erosion rates and magnitudes in their studies in the southern part of Nigeria. In this study, the rate of erosion in the coast is seen to have spread across the study area more predominantly in the Aiyetoro, Araromi sea-side and the Oogoro community area. The net shoreline movement showed evidence that there was prevalent coastal erosion during the period (31 years) studied. The make-up of the Ilaje coastal area also played an important role in this susceptibility to erosion; the coast has an extensive spread of sandy beach which erodes at higher rates as compared to rocky or hard cliff sections. Distinct signs of coastal erosion

are evident in the Aiyetoro, Araromi and Oogoro area as the exposure of underlying rocks and extensive sandy beaches can be seen. Also, the increasing human settlement and development along the coast coupled with sea-level rise without any probable action to stop or try and recede the advancing ocean keep this area eroded and susceptible to ocean surge.

The issues of sea level rise have been a global discourse and of great concerns as regard its impacts on the shoreline change (Markiewicz et al. 2016; Parthasarathy et al. 2018). The shoreline is time dependent and it shows short term variability. The sea level rise happening due to global

warming contributes to the long-term recession experienced along the world’s coast. Though sea level rise in itself lacks the capacity to move sand directly, a rise in the water level requires the adjustment of the beach through shore recession except for situations, where there are abundance amounts of sand available. According to Leatherman (2003), sea level rise can induce beach erosion or accelerates ongoing shore retreat. Higher water level enables waves to break closer to shore with more power and current forcing its way into the land. With higher water level, waves and currents act further up the beach profile, causing a readjustment of that profile (Jonah et al. 2018). Possible sand mining activity along this coast allows waves and current to act more upward the beach which accelerates natural shore recession (Kannan 2016). This act lowers the beach and allows high water volume up the beach profile. If this keeps increasing over a period of time, it affords waves the chance to wear cliff toes and increases vertical erosion and recession rates.

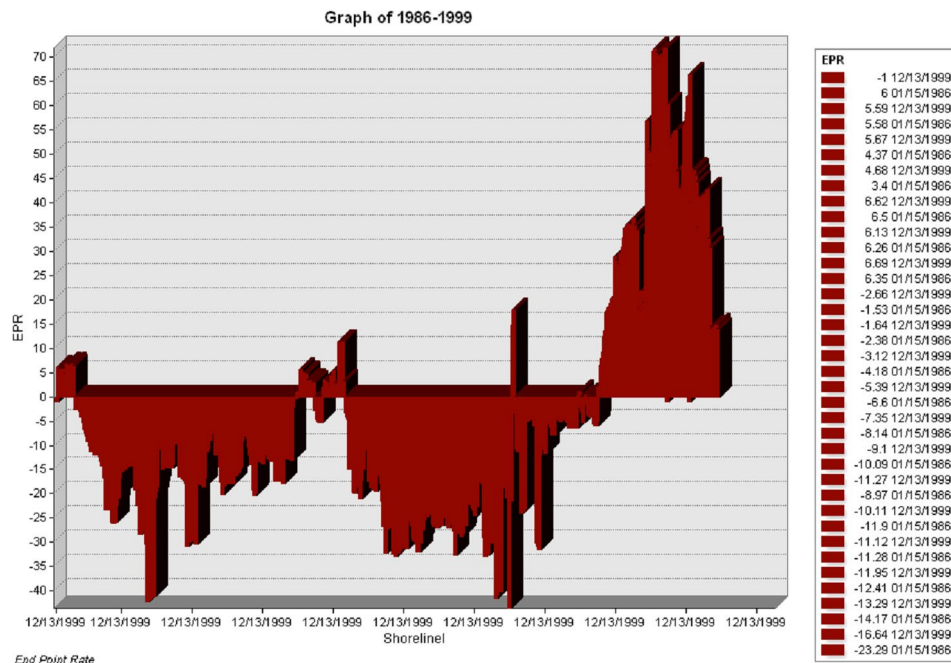
From the study, the coastline experienced high coastal erosion during the 1986 to 1999 period as compared to the rate observed during 1999–2011 and 2011–2017 periods, this is in terms of the whole coastline but there was observed a constant rate of erosion along the Aiyetoro and Araromi sea-side part of the coast. The northern part of the coast towards the Badagry (Lagos) coastline has been experiencing some consistent accretion over the years, same goes for the southern part towards Warri, but the rate of water flux into the land part of Ilaje (Aiyetoro, Araromi and Ogogoro community) is alarming. To make things worse, most areas that have been lost to the ocean are considered as creeks that are useful for transportation purposes which due to

underdevelopment are covered with tick water lettuce making them inaccessible and useless, and this allows the ocean to continue to surge in without much attention being paid to its ever-increasing expansion and continuing increase in shallowness (depth).

To further analyze the shoreline change, the years were divided into three periods (1986 to 1999; 1999 to 2011; 2011 to 2017). In this analysis, the rate of erosion of the shoreline between 1986 and 1999 was high, the maximum erosion stands at -6175.41 m, while accretion stands at 3358.84 m. Within this period, however, the maximum accretion value stands at $+71.68$ m and lowest value is 0.22 m, while maximum erosion value stands at -42.67 m and minimum stands at -0.2 m. The Net shoreline movement for this period of (13 years) stands at $-35,953.66$ m. The maximum shoreline erosion during this period was experienced at the part of the shoreline which falls between transect 255–348 and 353–394, while the maximum accretion falls within transects 206–216 and 417–505 (Tables 2 and 3). Major part of the shoreline was lost under water during this period and this caused a huge erosion to occur in the affected parts of the shoreline with the average movement of -4.7 m/year (Fig. 6).

In between 1999 and 2011, it can be observed that the shoreline in some parts gained on the water, i.e., there was water retreat during this period. The maximum accretion stands at 3613.05 m, while erosion stands at -1913.34 m. However, major parts of the shore remained stable during this period with no or marginal changes occurring. The maximum accretion value stands at 42.76 m and minimum is 0.01 m, while maximum erosion value is -73.75 m

Fig. 6 Graphical representation of the changes in the shoreline position in terms of erosion and accretion for the period of 1986 to 1999, the negative movement indicates erosion and this clearly reveals how that erosion was prevalent during this period of time along the coastline



and minimum is -0.02 m. The Net shoreline Movement for the period (12 years) is around $20,902.18$ m (Table 2, Fig. 5). The erosion that occurred between transects 50–79 and 221–234 and the accretion occurred within transects 260–301 and 412–491 (Fig. 7).

The movement of the shoreline during this period 2011 to 2017 is not different from the previous period as the total erosion calculated stands at -3545.45 m, while the total accretion stands at 8633.18 m. The maximum and minimum

accretion rate during this period is around 139.23 m and 0.08 m, respectively, while the maximum and minimum erosion rate is around -64.53 m and -0.39 m, respectively. The net shoreline Movement during this period (6 years) is around $27,013.9$ m. Significant erosion occurred between transects 77–115 and 234–278, while significant accretion occurred between transects 117–214 and 289–427 (Fig. 8). There is evidence of stable movement of the shoreline, which is highly infinitesimal changes that can be ignored.

Fig. 7 Graphical representation of the changes in the shoreline position in terms of erosion and accretion for the period of 1999 to 2011, the graph shows there was a relative movement of both erosion and accretion during this period of time. Positive movement indicates accretion and this clearly reveals how that erosion and accretion was prevalent during this period of time along the coastline. There were also stable zones along the coast that were not eroded or accreted during the time

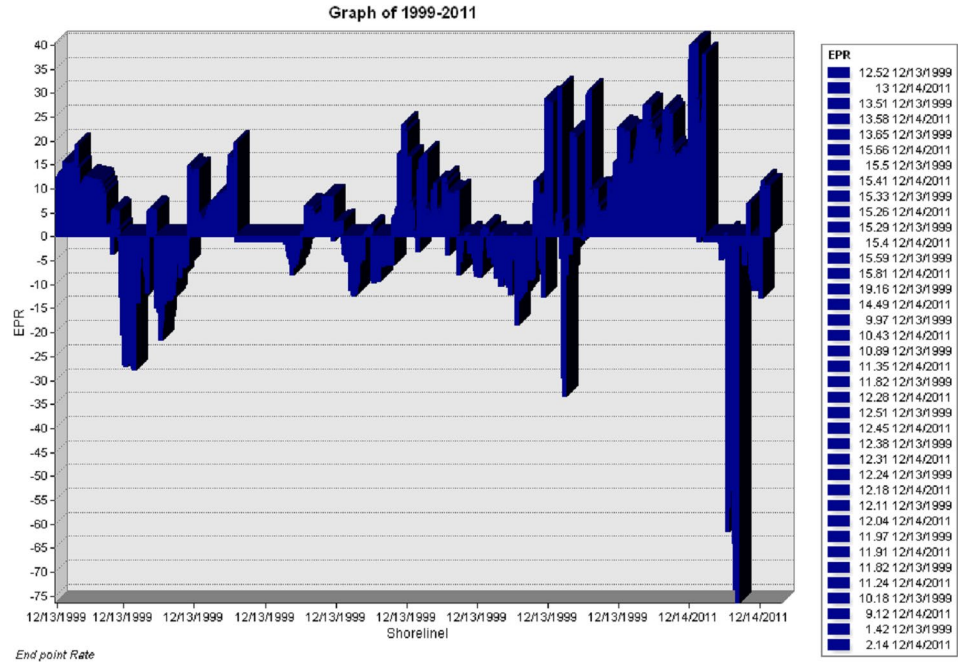
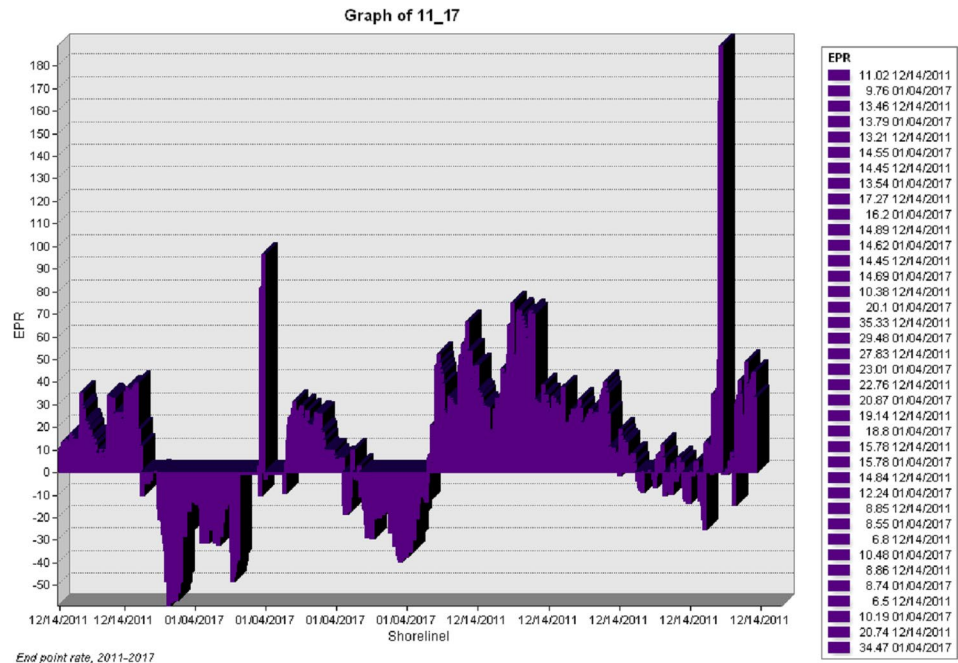


Fig. 8 Graphical representation of the changes in the shoreline position in terms of erosion and accretion for the period of 2011 to 2017, the graph shows there was a relative movement of both erosion and accretion during this period of time. Positive movement indicates accretion and this clearly reveals accretion was prevalent during this period of time along the coastline. There were also stable zones along the coast that were not eroded or accreted during the time



It is clear that the drastic movement of the shoreline in the first period has not been consistent as the land has somewhat been gaining back on the water, although some areas are still undergoing constant erosion.

4.3 Storm Surge Vulnerability

The coastal area has become increasingly occupied with built-ups as an increase in population and development surges high. This increase towards the coast, however, is very vulnerable to ocean (storm) surge, which can lead to the destruction of life and properties (Omenai and Ayodele 2014). This storm surge brings about an influx of seawater pushed up to the shore by strong winds in a storm. It leads to what is generally referred to as nuisance flooding. However, intense storms can create a surge huge enough to destroy homes and businesses near the coast. The depth of a storm surge is relative to the elevation of the land. Coastal areas that have shallow elevation changes between inland and the shoreline can see the ocean push an incredible distance beyond the coast.

The Ayetoro and Ogogoro axis of the Ilaje coast were considered in this study to determine the number of buildings that are vulnerable to this ocean surge. The buildings were digitized from the high resolution Google earth image and then buffering operation of 1000 m (1 km) extent to the shore was done (Fig. 9). Depending on the intensity of the storm and the elevation of the inland, the storm surge can travel quite a sizable distance inland. In all, a total of 3584 buildings were digitized, while 3164 of the digitized buildings fall within the 1 km buffering extent. These buildings which comprise of both residential and industrial buildings are vulnerable to storm surge.

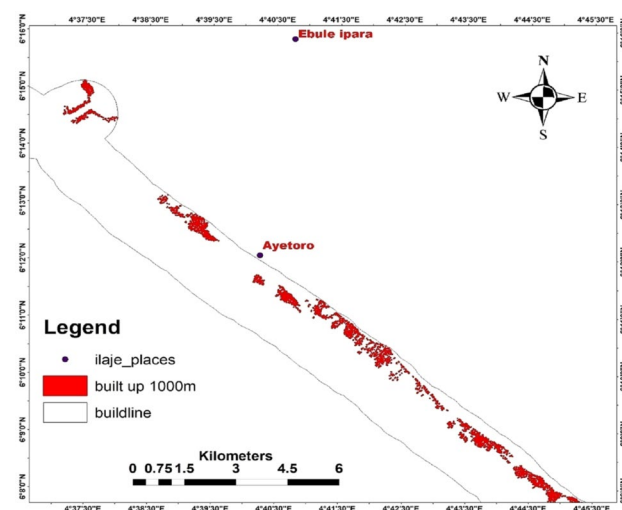


Fig. 9 Vulnerable buildings along the shorelines

4.4 Shoreline Management and Policy

The coastal area of Nigeria in which the study area is an integral part contributed meaningfully to the revenue of the country particularly in oil and gas (Ringim et al. 2016). Thus, resulting to economic development which primarily resulted to migration and settlement of people in form of towns, villages and hamlets along the coast (World bank 2020). The consequences of these processes led to the depletion of trees, exposure of coastline to severe environmental problem coupled with assort from geomorphic and climatic processes. The level of urban development around the coast, also alter drainage patterns along shorelines this development threatens natural habitats within coastal environments which give rise to increased sea level rise (Komariah, 2017) and erosion problem. In the developing countries, such as Nigeria, where neglect or lip services are paid to environmental management left the coastal zone of the country to severe environmental degradation. The effects of erosion and accretion in coastal management is that erosion and accretion affect the elevation of the beach profile causing changes of the beach slope elevation either higher or lower depending on the gravity of either erosion or accretion. Hence, alteration of coastal landform and processes are caused by both anthropogenic and natural factors. Based on the analysis in this research, eroding and accreting can be attributed to both human and natural factors. The storm surge vulnerability analysis confirmed the potential impact of the shoreline changes on lives and properties. Therefore, planning and management of the shoreline must consider the effect of human intervention on coastal erosion on habitat destruction and shoreline changes. Lack of effective legal and effective management policy can lead to a greater consequence with large impacts livelihoods businesses and agriculture.

Over the years, apart from government of Nigeria been signatory to many treaties relating to environmental issues (Ahmed-Hameed 2016), has formulated various policies (e.g., Land use decree 1978) and creating agencies (e.g., Nigeria Delta Development Commission (NDDC), Oil Producing Development Commission (OPADEC) for the enhancement of sustainable environment in the country. Despite the above measures, the environmental problem in the coastal area of the country seems unabated due to some factors identified by Famuditi et al. (2014); which among other factors are lack of effective monitoring and nonexistence of political will to enforce policies.

Having noticed the short comings of all the policies as regards the management of coastal erosion and flood, the Federal Government has established a Department of Erosion, Flood and Coastal Zone Management, under the Federal Ministry of Environment. The department is saddled with the responsibility of managing and averting the inland and coastal hazards, such as erosion, flood and land

degradation. However, the lack of cooperation and coordination between the federal and the state government often prevent active implementation of policy and strategies for management coastlines, hence, the continual exposure and vulnerability to coastal related hazards along the coastlines (Famuditi et al. 2014).

The objectives of the coastline management should, therefore, include: (i) the establishment of the effective flood early warning system; (ii) identification of potential threats and issues related to hazards; (iii) construction of sustainable flood protection and shoreline defense against potential hazards; (iv) effective Landuse management and strict prevention of encroachment of human to the potential flood hazards and risk zones; (v) at the moment, Nigeria lacks the involvement of the public environmental management regulations; this has impacted greatly on the people's interest and active participation in the ocean management. Hence, there should be regular and effective collaborations with government, public and private stakeholders in ensuring ocean habitat preservation and human adaptation and resilience to potential threats from the ocean surge. In addition, there should be evaluation and monitoring of the coastline, as in the case of this study, to provide baseline information to enhance proper implementation plans and strategies.

5 Conclusions

The coastal zone is known for its dynamic nature and is usefulness to the growth and development of humans. The area is a national asset as it provides a range of essential service and products that boasts the nation's economy. The intervention of humans in the coastal zone has a direct impact on the response of the zone. The study demonstrated the importance of remote and geographical information systems in assessing land use land cover and shoreline dynamics. This study has shown Remote sensing and GIS as a useful tool that can yield valuable information on the dynamic behavior of shorelines in terms of their shifting and changes. There was an increase in the thick vegetation from 1986 to 2017 in the study area might be due to natural growth of the forest/mangrove. Over the whole period of time, the coast has experienced more of erosion although some areas also show to have been accreting. The significant communities affected mostly from this study are the Aiyetoro, Araromi and Ogogoro which are the closest to the shore. They are constantly threatened by ocean surges, which cause property destruction. Continuous monitoring of these shoreline changes is required to comprehend the changes occurring on the Ilaje coastline. This study has shown that most of the buildings in Aiyetoro, Araromi and Ogogoro settlement of Ilaje area located at about 500 m and more and these are dangerously prone to adverse environmental effect of ocean

surge that can be destructive in terms of life and property loss. Therefore, it is recommended that the Government and stakeholders should: (i) engage in building sea wall to protect the beach, (ii) use wire mesh revetment to control erosion; (iii) build a sea defense project that includes a well-arranged boulder to stop the ocean surge.

Declarations

Conflict of Interest Authors declare no conflict of interest.

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