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Shoreline Change Detection in the Niger Delta: A Case Study of Ibeno Shoreline in Akwa Ibom State, Nigeria

By Uwem Jonah Ituen, Imoh Udoh Johnson & Johnbosco Chibuzo Njoku

University of Uyo, Nigeria

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Abstract- This research presents remote sensing and Geographic Information System (GIS) based application in the analysis of Shoreline change in Ibeno L. G. Area, Akwa Ibom State. Satellite imageries of 1986, 2006 and 2008 were used to extract the shoreline through heads-up digitization. The rate of shoreline change was assessed using Linear Regression (LRR) and End Point Rate (EPR) methods. The shoreline change detection was conducted using the Digital Shoreline Analysis System (DSAS). The result however indicated that the rate of erosion is found out to be very high with maximum value of -7.8m/yr recorded at Itak Abasi community. On the other hand, some portions of the shoreline are accreting at an average rate of 2m/yr. Based on this result however, it is concluded that Ibeno shoreline is eroding at an average rate of -3.9m/yr. Areas mostly affected by accretion processes are identified near Qua Iboe River Estuary and ExxonMobil Jetty where sand filling is usually done for settlement purposes. This best explains the reason for the submersion of school buildings, residential buildings and the persistent inundation of large portions of land in the area. However, acquisition of high resolution satellite images which is believed will facilitate regular assessment, monitoring and modeling of the Nigerian shorelines has been recommended. This will help to model the scenario and proffer proactive measures towards curbing the menace by ensuring effective environmental management practices, timely emergency responses, and salvage the immediate physical environment.

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I. Introduction

Michalis, et al (2008) described shoreline as the line of contact between the land and a body of water. Shoreline is always very uncertain due to the fact that water level is always in a state of flux, constantly changing and very unstable. Changes in the shoreline occur due to actions of natural forces like wind, tides, waves, and the ocean currents etc thus, giving way to backward movement of sand towards the ocean and loss of land mass. These forces act everyday on the shorelines in the same and opposite directions which to some e xtent cause great changes in their shapes and leading to erosion or accretion (Fletcher et al, 2003). Erosion is the wearing down of the top surface, while accretion has to do with the building up of the loose materials at a place.

Owing to the persistent land use activities – intensive farming, uncontrolled construction and housing development in these areas, the resulting erosion or accretion is consequently accelerated. The rate at which erosion or accretion occurs depends solely on the interplay of the physical and the anthropogenic factors. The physical factors in this case include but not limited to the geological factors like the rock types, amount of sediment supply, changes in the earth's crust within the coastal region under consideration, amount and rate of coastal region sediment transport from lakes and rivers, water table position in coastal slopes, structural protection in rocks or sediments, onshore and offshore coastal topography. More so, depending on the geographical location of the affected area, some climatic factors, including winds, waves, changes in water level, and intensity/frequency of storms and tides, frequency and amount of rainfall play significant roles in the process. On the other hand, the anthropogenic factors equally contribute to erosion or accretion processes in the coastal regions. These are manifested in man-made structures like drainage control networks and other modifications intended to protect the coastal areas.

Occasionally, coastal erosion processes could be very expansive and devastating to invaluable properties, human lives and even the natural environment. Globally, this has generated much concern; interests with regard to the scourge are also on the increase in academic discourse. However, the coastline of Akwa Ibom State with particular reference to Ibeno Local Government Area is not an exemption. The natural action of winds and waves, together with the anthropogenic forces resulting from the continued desire for natural resources exploitation are constantly at work in this region. Although human actions may sometimes yield positive results, they cannot be completely exempted from facilitating and accelerating the extent of damage to the natural landscape. Upon the resulting effect/changes on the natural landscape of the Area however, there is a complete knowledge lag on the shoreline dynamics in Ibeno L. G. Area. The situation

Author α: Dept. of Geography and Natural Resource Management, University of Uyo, Uyo. e-mail: uwemituen@gmail.com
Author σ: Department of Geography, Benue State University, Makurdi. e-mail: imoh.johnson@gmail.com
Author ρ: Surveyor and Cartographer Exxonmobil Nigeria Unlimited, Eket. e-mail: johnbosco.njoku@exxonmobil.com

can therefore not facilitate any management practices in the event of an emergency or encourage any form of predictions. In the best circumstances, there is need for effective coastal management with a view to ensuring a safer environment for growth and development of the human society.

Since coastal areas are regions of high economic value, the prediction of shoreline positions depends solely on having a clear understanding of the shoreline parameters. Based on this argument therefore, an appreciable knowledge of the shoreline characteristics is of utmost importance and timely. This has become very essential and necessary to make informed decisions towards effective coastal management. If such parameters are put in place, it is believed that any information relative to shoreline characteristics will be readily accessible at any point in time. In the light of the foregoing, taking into consideration the high economic potentials of the area, this study seeks to extract Ibeno shoreline from the satellite imagery, determine the rate of shoreline change as well as the net shoreline movement in the area.

With the possibilities offered in the advent of Geographic Information Systems (GIS), image processing techniques, and quantitative analysis, to a reasonable degree of accuracy, any change(s) in shoreline due to erosion and/or accretion become(s) practically possible. In the context of this study, GIS mapping and change detection techniques prove quite useful (Srivastava, 2005). With regard to the methods of extracting shorelines, a number of methods are available for use. For instance Efe and Tagil (2001) made use of the on-screen digitization method due to its accuracy over the digitizing tablet. On the other hand, Scott et al (2003) proposed a semi-automated method for extracting the land-water interface. They successfully applied these methods to generate multiple shoreline data for the States of Louisiana and Delaware. Another approach of extraction is by automation. Many scholars have successfully applied this. Thus, Liu and Jezek (2004), Karantzalos and Argialas (2007) automated the extraction of coastline from satellite imagery by canny edge detection using Digital Number (DN) threshold while Li, et al (2001) compared shorelines of the same area that were extracted using different techniques, evaluated their differences and discussed the causes of possible shoreline changes. However, other methods of change detection in shorelines have been in use in recent times. Such methods include the End Point Rate (EPR) method (Liu, 1998); (Galano & Gouglas, 2000); the Average of Rate (AOR) (Thieler, et al, 2001) and (Dolan, et al, 1991); the Minimum Description Length (MDL) method, (Fenster, et al, 1993) and Crowell, et al, 1997); Ordinary Least Squares (OLS) method , (Seber and Lee, 2003) and (Kleinbaum, et al, 1998); Reweighted Least Squares (RLS) method, (Rousseeuw and Leroy, 1987) and the Average of Era (AOA) (Dolan, et al, 1991), etc. In shoreline change prediction modeling, the major challenge has always been to create models with robust spatio-temporal numerical analysis, which can generate testable predictions about the functioning of a coastal erosion system (Fletcher, et al 2003). Since the coastal erosion causing forces also vary according to geographical location and seasons, it becomes difficult to develop more generalized models with high level of applicability from one coastal area to another. In this context however, this study adopts a multi spatio-temporal technique to analyze Ibeno shoreline characteristics.

However, the result of the study revealed remarkable changes in Ibeno shoreline. On the average, the rate of change of -3.9m/year and 2m/year for erosion and accretion has been respectively recorded. The paper concludes that the severity and intensity of erosion and/or accretion process at the coastal region of Ibeno Local Government Area in Akwa Ibom State and other parts of the Niger Delta region of Nigeria is quite outstanding and alarming. Based on this revelations therefore, acquisition of high resolution satellite facilities, such that will support regular assessment and monitoring of the region is hereby recommended so as to model the scenario and proffer proactive measures towards curbing the menace by ensuring effective environmental management practices, timely emergency responses, and salvage the immediate physical environment.

II. Study Area

Ibeno shoreline is located on the south eastern part of Nigeria, it is sandy, a stretch of the coast along the Bight of Bonny spanning from a point at Atabrikang village, latitude 40 31 and 22.6198 N and longitude 70 49' 16.0114'' E to a point at Okposo village, latitude 40 34' 09.7667'' N and longitude 80 17' 52.6643'' E in Ibeno L. G. Area of Akwa Ibom State. Like other parts of southern Nigeria, the area is contingent on the movement of the Tropical Discontinuity (ITD). It is characterized by very high rainfall (annual total > 4,000mm, high temperature values of about 270C, high values of relative humidity with mean value of 80.3 percent. Apart from the shoreline and tidal mudflats which are in most areas covered by the invasion of Nypa friutcans, all other areas depict highly disturbed vegetation following persistent and increasing anthropogenic pressure. The common vegetation types are bush fallowing and small farmlands, secondary and riparian forests as well as grasslands. The area is gentle undulating sandy plains heavily incised by numerous creeks, shallow streams, and rivers. Generally, the relief or the area ranges from less than three meters above the sea levels on the beach, to about 45m inland. The area is drained by a number of rivers including the Cross River, and the Qua Iboe River. Underlain by one main geological formation, Ibeno L. G. Area is made up of coastal plain sands comprising largely of poorly consolidated sands. Mineral deposits comprise coarse –silt and fine sand fraction of the coastal plains indicating the dominance of quartz, iron oxide(FE203) and aluminum oxide(AL203) all constituting less than 10 percent in fraction . The advent of oil exploration and production by Exxonmobil at Qua Iboe Terminal brought about the densely populated settlements which have in turn resulted in the removal of the vegetative cover, thus exposing the soil to erosion and/or accretion.

III. Materials and Methods

In the process of carrying out this study, the use of satellite images and GIS tools to extract the shorelines for three different years of 1986, 2006 and 2008 became very necessary. In this case, Landsat Thematic Mapper (LTM) of 1986 and Enhanced Thematic Mapper (ETM) of 2006 both of 28.5 X 28.5 metres ground resolution were acquired from the United States Geological Surveys (USGS) and actually used for various analysis carried out. A high resolution Ikonos image of 2008 with about 1m ground resolution was obtained and used. These imageries cover a period of 22yrs. The range of time and years chosen was due to data availability.

The images were processed to delineate the shorelines for 1986, 2006 and 2008 with a view to determining their rate of changes over the study period. Large-scale aerial photographs of 2006 were also acquired and used in the accuracy assessment of the 2006 landsat imagery. The map of Akwa Ibom State obtained from the State's Ministry of Lands and Housing in an analogue format at a scale of 1:100,000 became useful as the study area map and the settlements therein were captured in the GIS. The Global Positioning System (GPS) was also used to acquire ancillary data during field work.

Different analogue maps collected were captured through scanning, geo-referencing, heads-up digitizing and database creation in ArcGIS 9.2 software. The captured data were eventually set to WGS 84, UTM Zone 32 north. The sites visited in the field were captured using GPS and the data were used to identify locations on the imagery during the ground truthing exercise.

a) Processes of Shoreline Extraction

To extract the shorelines from the satellite images, shapefiles were created in Arc catalog for each of the images. For easy data handling, the three images were spatially re-projected to Universal Transverse Mercator (UTM 1984). This was followed by the determination of shoreline reference feature where measurements were based. The high-water line (HWL) was therefore adopted since it was relatively easy to distinguish it on all the images as a wet/dry line especially on the Ikonos imagery. According to Parker (2003), the HWL is the legal shoreline of the United States, represented in NOAA nautical charts and considered as the most consistent reference feature. The extraction was then carried out using the heads-up digitizing method. This manual method was adopted in an attempt to avoid the difficulties associated with the use of automated methods of extraction. However, features from the landsat satellite imageries of 1986, 2006 and the 2008 Ikonos image were digitized along the dry-wet sand boundaries which could be recognized from different tones in the sand beach. Usually, the tonal differences are caused by the variation in moisture in the sands as a result of being previously immersed or washed by high water level.

b) Determination of Rate of Shoreline Change

After the shorelines were extracted, a base-line was created parallel to these extracted shorelines in order to cast perpendicular lines to the shorelines and also to serve as the origin for measuring distances of the shorelines in relation to the established base-line. The base-line was created through buffering method in ArcGIS 9.2 and this served as the starting point for generating transects. In this case, a 600 meter buffer was created just above the lines, resulting in a single buffer of 600 meters around the outermost line. This buffer was converted to a polyline and split on top left and top right directly above the end of the shorelines. The upper and side sections of the buffer were deleted resulting in a single line 600 meters from the shoreline. This line served as the base-line and was smoothened to remove the rough side of the line in order to cast perpendicular transects on the shorelines under consideration.

The base-line and shoreline data were imported into a geo-database in order for DSAS to recognize the data. Before running the DSAS program, spatial reference and feature type requirements of the shoreline files were reconciled. The multiple shapefiles of the shorelines were appended into a single feature class by using the Append tool from the ArcToolbox. The various attribute tables for the baseline and the appended shoreline file were created as shown in Tables 1 and 2 below. If no accuracy field value exist for a specific shoreline or Zero is used in the accuracy field, a default value specified in the Set data Accuracy section by the user could be used. The ID field was populated to control the order of transect casting along the baseline.

Table 1 : Shoreline Attribute Table

OBJECT ID*	SHAPE_LENGTH(m)	ID	DATE	ACCURACY
1	36127.98444	5	1/1/2008	0
2	392.953503	6	1/1/2008	0
3	9421.45049	7	1/1/2008	0
4	45782.27499	4	1/1/2006	0
5	3306.248434	1	1/1/1986	0
6	13003.19507	2	1/1/1986	0
7	29853.12538	3	1/1/1986	0

Table 2 : Base-line Attribute Table

BASE-LINE ATTRIBUTE TABLE, 3/8/2011				
OBJECT ID	SHAPE	ID	SHAPE_LENGTH(m)	CASTDIR
13	Polyline	1	44634.56799	1

The Digital Shoreline Analysis System (DSAS) was thereafter launched in ArcMap environment. The DSAS is an extension of the ArcGIS. According to Thieler, et al (2003) the purpose of this program was to measure historic shoreline changes by creating perpendicular transect to be used as measurement locations across multiple shorelines. The spacing between the transects along the base-line and the length of the transects was specified as shown in Figure 2. The DSAS generated transects lines that were created at each 100m segment perpendicular to the base-line and drawn to intersect all the three extracted shorelines as shown in Figure 1. Although the transect spacing had affected the accuracy of the result, smaller values gave more detailed and accurate analysis of the shoreline, while larger ones omitted some information thereby giving inaccurate analysis of the shoreline. Consequent upon this however, the nature of the shoreline needed to be considered before choosing a transect line spacing value. The intersected points were spatially joined to the base-line to create a field that calculated the shortest perpendicular distance from each point to the base-line. The transect-shoreline intersections were therefore used to calculate the rate-of-change statistics. To compute the shoreline rate of change, the End Point Rate (EPR) method and Linear Regression Analysis were used in DSAS. This was chosen over other methods due to the fact that it best proffers solution to shoreline change detection.

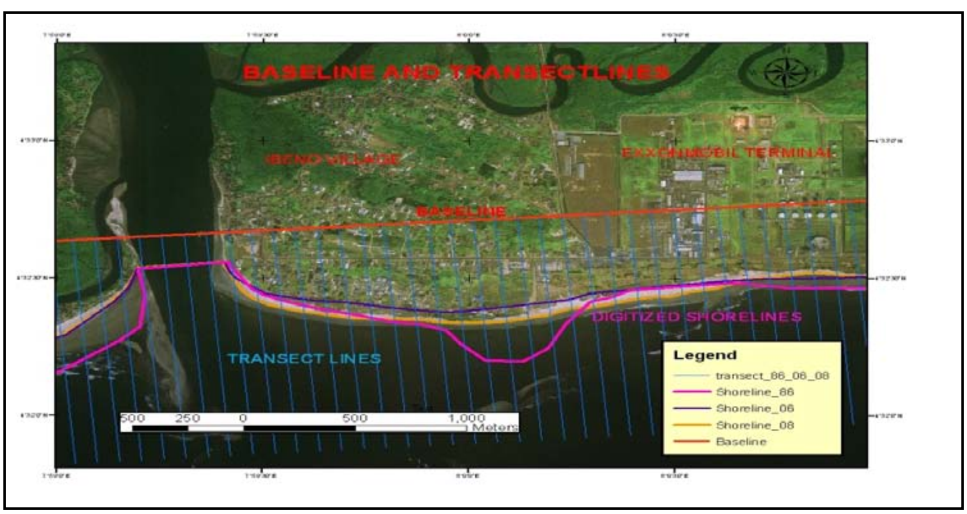

Figure 1 : Transect lines, Base-line and Extracted Shorelines

c) Determination of Net Shoreline Movement (NSM)

After the computation of the rate of change in shoreline, the End Point Rate method was used to calculate the distance of shoreline movement by subtracting between the earliest and latest measurements (i.e., the oldest and the most recent shoreline). The major advantage of the EPR is that, it is easy to compute with minimal requirements of shoreline data (two shorelines). One disadvantage of this method is that in cases where more than two shorelines are available, the information about shoreline behavior provided by additional shorelines is neglected. In the best circumstances, the EPR should be limited to Net shoreline movement. The linear regression rate-of-change statistic (LRR) was the second rate of change method used. This was done by fitting a least squares regression line to all shoreline points for a particular transects. The rate is the slope of the line. The linear regression method has the advantage that all the data are used, regardless of changes in the trend or accuracy in addition to the method being purely computational.

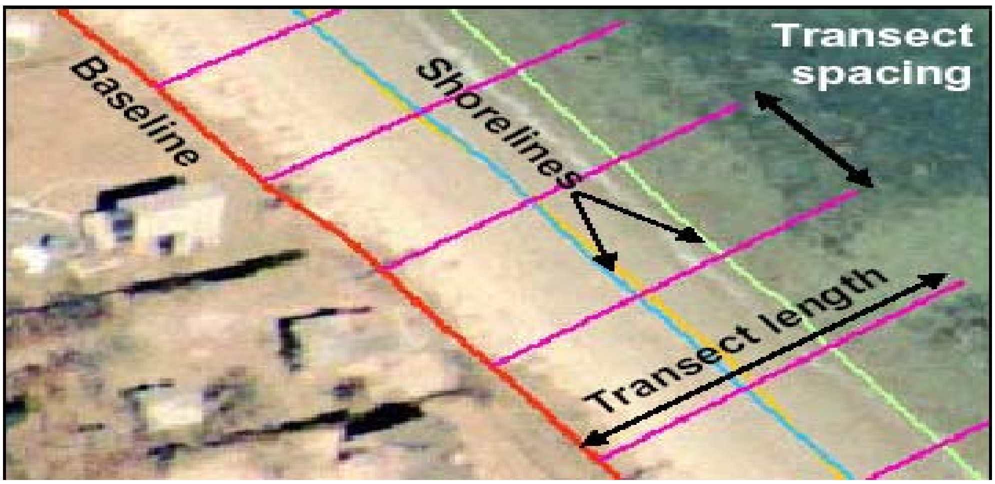

Figure 2 : Base-line, Shorelines, Transect length and Transect Spacing

IV. Results

a) The Extracted Shoreline

The total length of the extracted shoreline from 1986 landsat image is 46.162km and 45.811km for 2006 while that of 2008 Ikonos imagery is 45.942km. The shorelines are represented with different colors. A closer look at the digitized shorelines shows that there is a remarkable change in the shape of the shoreline over time as shown in Figure 3.

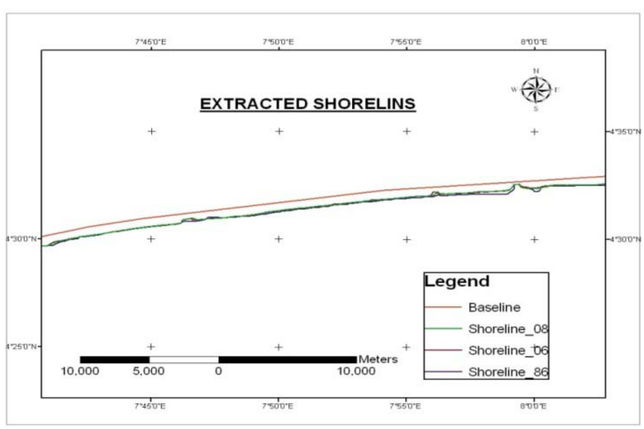

Figure 3 : Base-line and Shorelines Extracted

b) Changes in Shoreline over Time

The result of the analysis revealed remarkable changes in Ibeno Shoreline, the net change measured as the distance between the most recent and earliest shorelines, in this case the 1986, 2006 and the 2008 shorelines. The change that occurred between the timing of each available image is presented in Figures 4, 5, and 6. Table 3 below shows the sum total of the magnitude of Net Erosion and Accretion that occurred over the different periods under investigation.

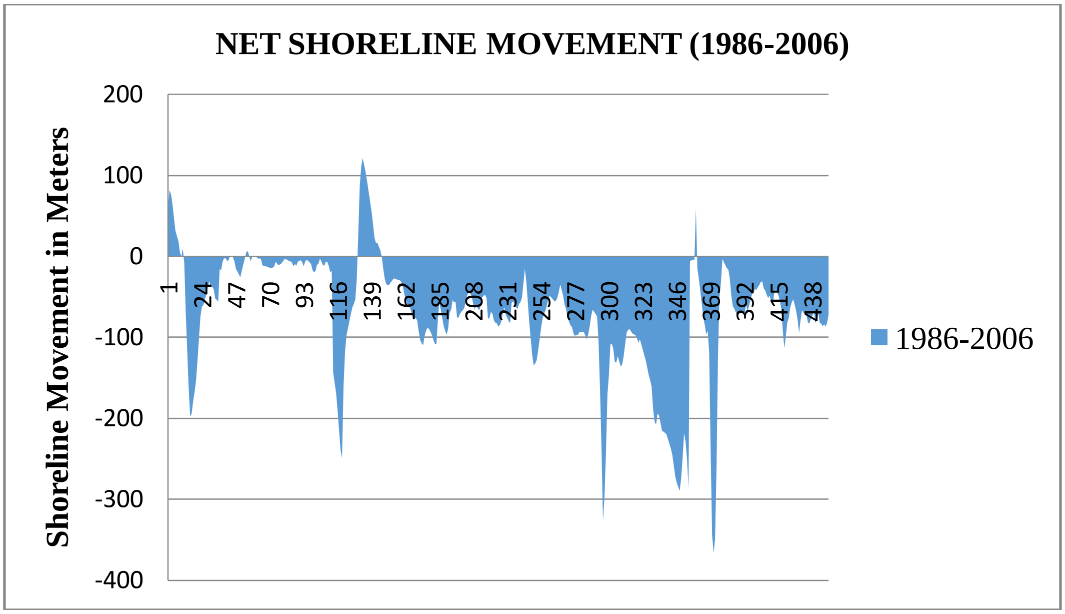

Figure 4 : Net Shoreline Movement (1986-2006)

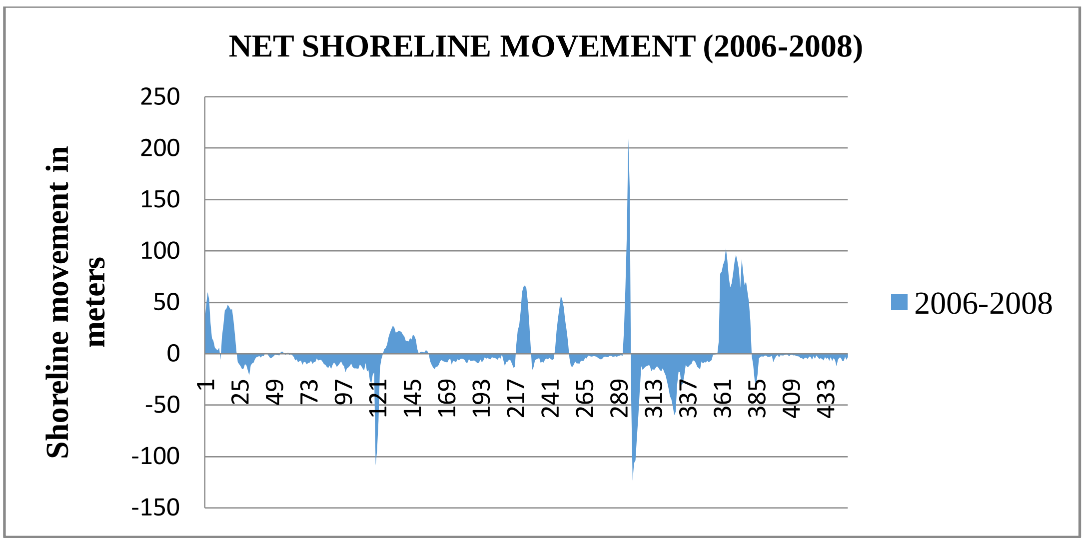

Figure 5 : Net Shoreline Movement (2006-2008)

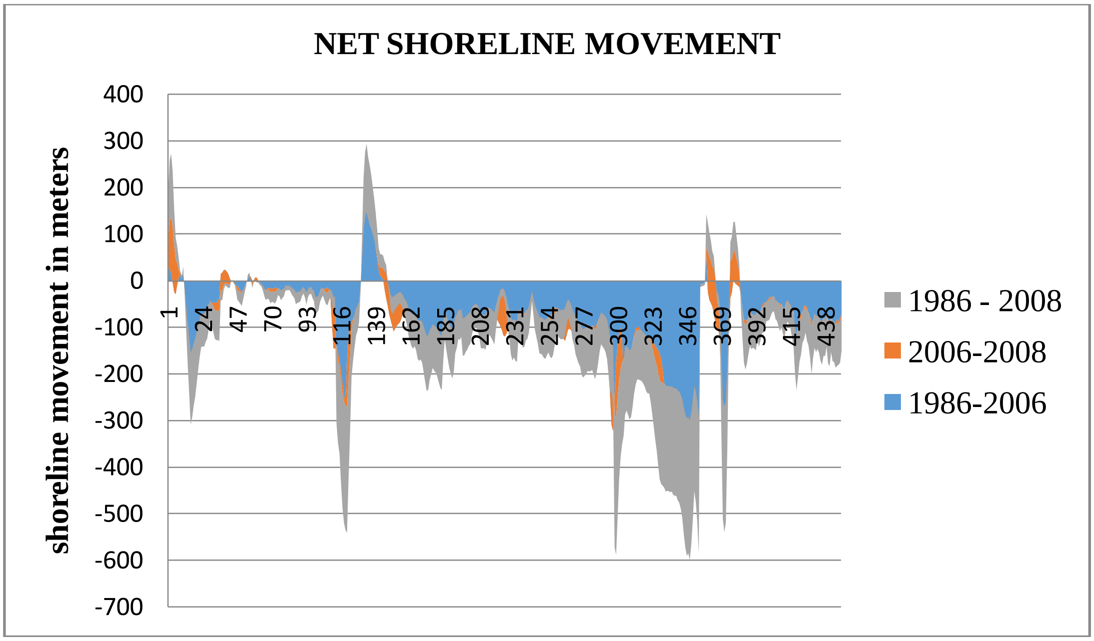

Figure 6 : Net Shoreline Movement (1986-2008)

Table 3 : Shoreline Erosion, Accretion and Net Change in Meters

PERIODS	ACCRETION (m)	EROSION (m)	NET CHANGE (m)
1986 - 2006	1472.42	-32905.2	-31432.78
2006 - 2008	4074.28	-3714.1	360.18
1986 - 2008	2618.38	-33691.2	-31072.82

In the rate of change analysis result, the zones were generated by identifying and selecting transects that show similar characteristics. Places with slightly the same rate of change are zoned together. (Please See Figure 7).

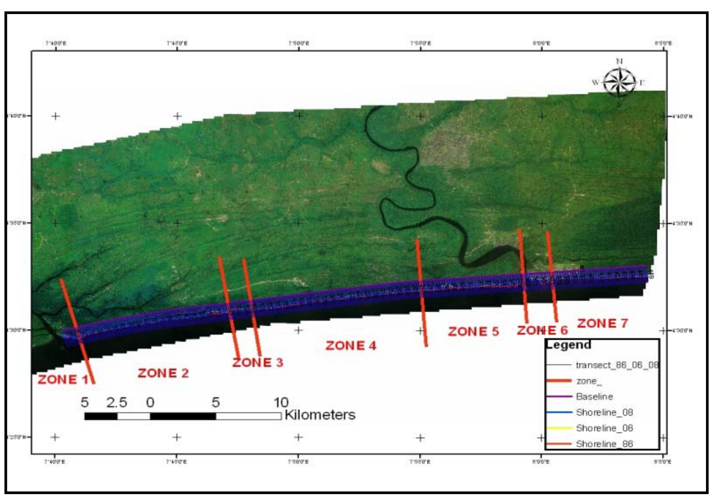

Figure 7 : Zoning of Shoreline in Ibeno L. G. Area

The rate of erosion and accretion in each zone is the average rate of the entire transects in that particular zone. The accretion process in **Zone 1** is very significant. This is largely due to human activities at the Imo River Estuary and the shoreline. This area is also characterized by thick vegetation and high sandy beach. On the average, the rate of accretion is 2.2m/yr in this zone. **Zone 2** is the region with the least rate of change and is characterized by narrow sandy beach with thick vegetation. The rate of change here is insignificant when compared to other places. The reason is that human activity around the region is relatively reduced. The average rate of change of erosion is -2.1m/yr. Zone3 on the other hand is covered with high vegetation. The high variation in transect is due to shoreline accretion which is caused by human activities at the river estuary in the region. Average rate of accretion is 3m/yr in this zone.

Zone 4 displays minimal net change in erosion. The area is limited to perched sandy beach with continuous thick vegetation. Human activities here are low and the average rate of erosion is -3.2m/yr. Zone 5 encompasses the main erosion. Sediments are completely stripped from the beach leaving an extensive land exposed, trees are destroyed and buildings damaged. Itak Abasi community in Ibeno Local Government Area is located in this region. Erosion is very severe such that a greater portion of the area is completely eroded (See plates 1, 2 and 3). The average rate of erosion in this region is -7.8m/yr.

Plate 1 : Destroyed Trees along the Shoreline

Plate 2 : Vacated School Near the Shore, Destroyed by Erosion

In Zone 6, variable change with high accretion is more apparent than erosion. This is caused by human activities going on at Qua Iboe River Estuary and sand filling from built up areas near the shore. This area is accreting at the average rate of 1.1m/yr. Zone 7 records minimal erosion with relatively wide, homogenous stretch of sandy beach. A large amount of deposited sediment is observed to move to and from the sea. Storm and high wave are some of the contributions of this erosion. The location of ExxonMobil terminal, built up places near the shore and other engineering activities going on in this area are the main cause of this slight erosion. On the average, erosion rate is -2.9m/yr.

Plate 3 : Engineering Activities (Pipe-laying) on the Shore

V. Discussions

In view of the result of this study, there are remarkable changes in the shape and length of Ibeno shoreline under consideration. The length of the shoreline captured from different images is 46.162km in 1986, 45.811km in 2006, and 45.94 in 2008. This result is in line with the findings of Liu and Jezek (2004); Scott et al (2003) and Efe and Tagil (2001) for their respective areas of study. It is however worthy to note that this finding has set the pace for data management and timely information delivery with regard to Ibeno shoreline activities which is very significant in terms of data requirement for assessment and monitoring of the coastal environment.

In consideration of the 1986, 2006 and 2008 shorelines parameters, the 1986 case was selected as the earliest date for comparison. Meanwhile, within the period of ten years considered for this study (1986-2006), accretion was calculated as 1472.42m, erosion as-32905.2m thus giving the change as -31432.78m (See Table 1). Within the period of two years (2006-2008), accretion was calculated to be 4074.28m, erosion -3714.1m while the net change was 360.18m. On the whole, between 1986 and 2008, accretion, erosion, and net shoreline values in Ibeno shoreline were 2618.38m, -33691.2m and -31072.82m respectively. However, within the period of this assessment, the highest accretion value was 147.07m while the lowest accretion value was 0.5m. On the other hand, the highest erosion value in the area was -299.19m while the lowest erosion value was -1.28m. Meanwhile and from the outcome of this analysis, it is worthy to note that there are more eroding portions than accreting portions across the entire shoreline in Ibeno Local Government Area. This implies that sediments are continually stripped from the beach leaving an extensive land exposed. Trees are completely destroyed and buildings damaged as shown in Plates 1, 2 and 3. However, Itak Abasi village in Ibeno Local Government Area is known to be adversely affected by this environmental challenge. This condition persistently subjects the socio- economic activities of the people in the affected area into jeopardy.

Interestingly, it is worthy of note that most places affected by minimal erosion are as a result of engineering activities going on in the area while some are caused by intensive human activities at the river estuary along the shoreline. The accretion near ExxonMobil jetty is as a result of sand fills done in the past for settlement purposes. On the average, the rate of change of shoreline in Ibeno L. G. Area is -3.9m/yr and 2m/yr for erosion and accretion respectively. The negative (-) sign represents erosion while the positive (+) sign represents accretion in the area. This revelation involving the rate of change in erosion and accretion processes in Ibeno L. G. Area known to be very useful in cases of future predictions to determine shoreline positions as in the case of U.S. Army Corps of Engineers (1992). Consequently, the implication is that areas affected by accretion will hinder free movement of people, support capsizing of fishing boats and the soften nature of the shifting sand bars will pose a threat when jetties are sited close to them. Furthermore, areas affected by erosion will experience flooding and the resultant effect from there.

VI. Conclusion and Recommendation

Based on the outcome of this study, it is concluded that there is a remarkable change in the shoreline under consideration. This trend is similar to other parts of the Niger Delta region of Nigeria. Erosion and accretion processes have been ongoing, outstanding, and very severe in the area. Specifically, it is worthy to note that these occurrences are very much peculiar to the coastal region of Ibeno Local Government Area in Akwa Ibom State. Based on this revelation however, acquisition of high resolution satellite facilities such that will support regular assessment and monitoring of the region is hereby recommended so as to model the scenario and proffer proactive measures towards curbing the menace by ensuring effective environmental management practices, timely emergency responses, and salvage the immediate physical environment.

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