

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

Index terms— shoreline, geographic information system, environmental management, change detection, erosion and accretion.

1 Introduction

ichalis, 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 extent 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

3 STUDY AREA

42 region sediment transport from lakes and rivers, water table position in coastal slopes, structural protection in
43 rocks or sediments, onshore and offshore coastal topography. More so, depending on the geographical location of
44 the affected area, some climatic factors, including winds, waves, changes in water level, and intensity/frequency
45 of storms and tides, frequency and amount of rainfall play significant roles in the process. On the other hand,
46 the anthropogenic factors equally contribute to erosion or accretion processes in the coastal regions. These are
47 manifested in man-made structures like drainage control networks and other modifications intended to protect
48 the coastal areas.

49 Occasionally, coastal erosion processes could be very expansive and devastating to invaluable properties, human
50 lives and even the natural environment. Globally, this has generated much concern; interests with regard to the
51 scourge are also on the increase in academic discourse. However, the coastline of Akwa Ibom State with particular
52 reference to Ibeno Local Government Area is not an exemption. The natural action of winds and waves, together
53 with the anthropogenic forces resulting from the continued desire for natural resources exploitation are constantly
54 at work in this region. Although human actions may sometimes yield positive results, they cannot be completely
55 exempted from facilitating and accelerating the extent of damage to the natural landscape. Upon the resulting
56 effect/changes on the natural landscape of the Area however, there is a complete knowledge lag on the shoreline
57 dynamics in Ibeno L. G. Area. The situation can therefore not facilitate any management practices in the event of
58 an emergency or encourage any form of predictions. In the best circumstances, there is need for effective coastal
59 management with a view to ensuring a safer environment for growth and development of the human society.

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

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

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

2 II.

3 Study Area

101 Ibeno shoreline is located on the south eastern part of Nigeria, it is sandy, a stretch of the coast along the Bight of
102 Bonny spanning from a point at Atabirikang village, latitude 40 31 and 22.6198 N and longitude 70 49' 16.0114"

103 E to a point at Okposo village, latitude 40 34' 09.7667" N and longitude 80 17' 52.6643" E in Ibena L. G. Area of
104 Akwa Ibom State. Like other parts of southern Nigeria, the area is contingent on the movement of the Tropical
105 Discontinuity (ITD). It is characterized by very high rainfall (annual total > 4,000mm, high temperature values
106 of about 270C, high values of relative humidity with mean value of 80.3 percent. Apart from the shoreline and
107 tidal mudflats which are in most areas covered by the invasion of *Nypa fruticans*, all other areas depict highly
108 disturbed vegetation following persistent and increasing anthropogenic pressure. The common vegetation types
109 are bush fallowing and small farmlands, secondary and riparian forests as well as grasslands. The area is gentle
110 undulating sandy plains heavily incised by numerous creeks, shallow streams, and rivers. Generally, the relief
111 or the area ranges from less than three meters above the sea levels on the beach, to about 45m inland. The
112 area is drained by a number of rivers including the Cross River, and the Qua Iboe River. Underlain by one
113 main geological formation, Ibena L. G. Area is made up of coastal plain sands comprising largely of poorly
114 consolidated sands. Mineral deposits comprise coarse silt and fine sand fraction of the coastal plains indicating
115 the dominance of quartz, iron oxide(Fe₂O₃) and aluminum oxide(Al₂O₃) all constituting less than 10 percent in
116 fraction. The advent of oil exploration and production by Exxonmobil at Qua Iboe Terminal brought about the
117 densely populated settlements which have in turn resulted in the removal of the vegetative cover, thus exposing
118 the soil to erosion and/or accretion.

119 4 III.

120 5 Materials and Methods

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

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

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

137 6 a) Processes of Shoreline Extraction

138 To extract the shorelines from the satellite images, shapefiles were created in Arc catalog for each of the images.
139 For easy data handling, the three images were spatially re-projected to Universal Transverse Mercator (UTM
140 1984). This was followed by the determination of shoreline reference feature where measurements were based.
141 The high-water line (HWL) was therefore adopted since it was relatively easy to distinguish it on all the images
142 as a wet/dry line especially on the Ikonos imagery. According to Parker (2003), the HWL is the legal shoreline of
143 the United States, represented in NOAA nautical charts and considered as the most consistent reference feature.
144 The extraction was then carried out using the heads-up digitizing method. This manual method was adopted
145 in an attempt to avoid the difficulties associated with the use of automated methods of extraction. However,
146 features from the landsat satellite imageries of 1986, 2006 and the 2008 Ikonos image were digitized along the
147 dry-wet sand boundaries which could be recognized from different tones in the sand beach. Usually, the tonal
148 differences are caused by the variation in moisture in the sands as a result of being previously immersed or washed
149 by high water level.

150 7 b) Determination of Rate of Shoreline Change

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

7 B) DETERMINATION OF RATE OF SHORELINE CHANGE

160 The base-line and shoreline data were imported into a geo-database in order for DSAS to recognize the data.
161 Before running the DSAS program, spatial reference and feature type requirements of the shoreline files were
162 reconciled. The multiple shapefiles of the shorelines were appended into a single feature class by using the Append
163 tool from the ArcToolbox. The various attribute tables for the baseline and the appended shoreline file were
164 created as shown in Tables 1 and 2 below. If no accuracy field value exist for a specific shoreline or Zero is used
165 in the accuracy field, a default value specified in the Set data Accuracy section by the user could be used. The
166 ID field was populated to control the order of transect casting along the baseline. The Digital Shoreline Analysis
167 System (DSAS) was thereafter launched in ArcMap environment. The DSAS is an extension of the ArcGIS.
168 According to Thieler, et al (2003) the purpose of this program was to measure historic shoreline changes by
169 creating perpendicular transect to be used as measurement locations across multiple shorelines. The spacing
170 between the transects along the base-line and the length of the transects was specified as shown in Figure 2.
171 The DSAS generated transects lines that were created at each 100m segment perpendicular to the base-line and
172 drawn to intersect all the three extracted shorelines as shown in Figure 1. Although the transect spacing had
173 affected the accuracy of the result, smaller values gave more detailed and accurate analysis of the shoreline, while
174 larger ones omitted some information thereby giving inaccurate analysis of the shoreline. Consequent upon this
175 however, the nature of the shoreline needed to be considered before choosing a transect line spacing value. The
176 intersected points were spatially joined to the base-line to create a field that calculated the shortest perpendicular
177 distance from each point to the base-line. The transect-shoreline intersections were therefore used to calculate
178 the rate-of-change statistics. To compute the shoreline rate of change, the End Point Rate (EPR) method and
179 Linear Regression Analysis were used in DSAS. This was chosen over other methods due to the fact that it best
180 proffers solution to shoreline change detection. After the computation of the rate of change in shoreline, the End
181 Point Rate method was used to calculate the distance of shoreline movement by subtracting between the earliest
182 and latest measurements (i.e., the oldest and the most recent shoreline). The major advantage of the EPR is
183 that, it is easy to compute with minimal requirements of shoreline data (two shorelines). One disadvantage of this
184 method is that in cases where more than two shorelines are available, the information about shoreline behavior
185 provided by additional shorelines is neglected. In the best circumstances, the EPR should be limited to Net
186 shoreline movement. The linear regression rate-ofchange statistic (LRR) was the second rate of change method
187 used. This was done by fitting a least squares regression line to all shoreline points for a particular transects.
188 The rate is the slope of the line. The linear regression method has the advantage that all the data are used,
189 regardless of changes in the trend or accuracy in addition to the method being purely computational. In the
190 rate of change analysis result, the zones were generated by identifying and selecting transects that show similar
191 characteristics. Places with slightly the same rate of change are zoned together. (Please See Figure 7). The
192 rate of erosion and accretion in each zone is the average rate of the entire transects in that particular zone. The
193 accretion process in Zone 1 is very significant. This is largely due to human activities at the Imo River Estuary
194 and the shoreline. This area is also characterized by thick vegetation and high sandy beach. On the average,
195 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
196 by narrow sandy beach with thick vegetation. The rate of change here is insignificant when In Zone 6, variable
197 change with high accretion is more apparent than erosion. This is caused by human activities going on at Qua
198 Iboe River Estuary and sand filling from built up areas near the shore. This area is accreting at the average rate
199 of 1.1m/yr. Zone 7 records minimal erosion with relatively wide, homogenous activities going on in this area
200 are the main cause of this slight erosion. On the average, erosion rate is -2.9m/yr. stretch of sandy beach. A
201 large amount of deposited sediment is observed to move to and from the sea. Storm and high wave are some of
202 the contributions of this erosion. The location of ExxonMobil terminal, built up places near the shore and other
203 engineering satellite facilities such that will support regular assessment and monitoring of the region is hereby
204 recommended so as to model the scenario and proffer proactive measures towards curbing the menace by ensuring
205 effective environmental management practices, timely emergency responses, and salvage the immediate physical
206 environment.

1 2

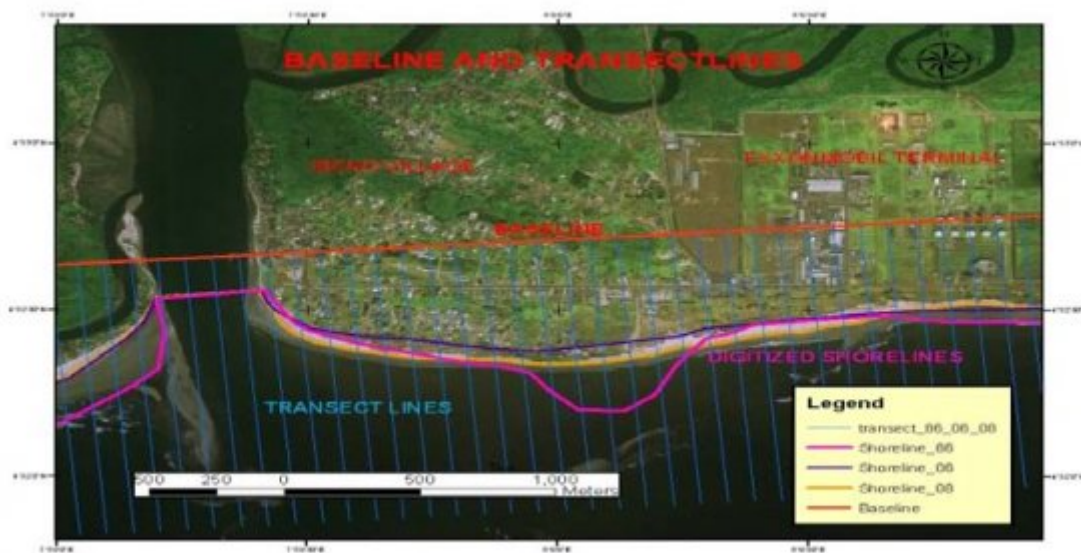
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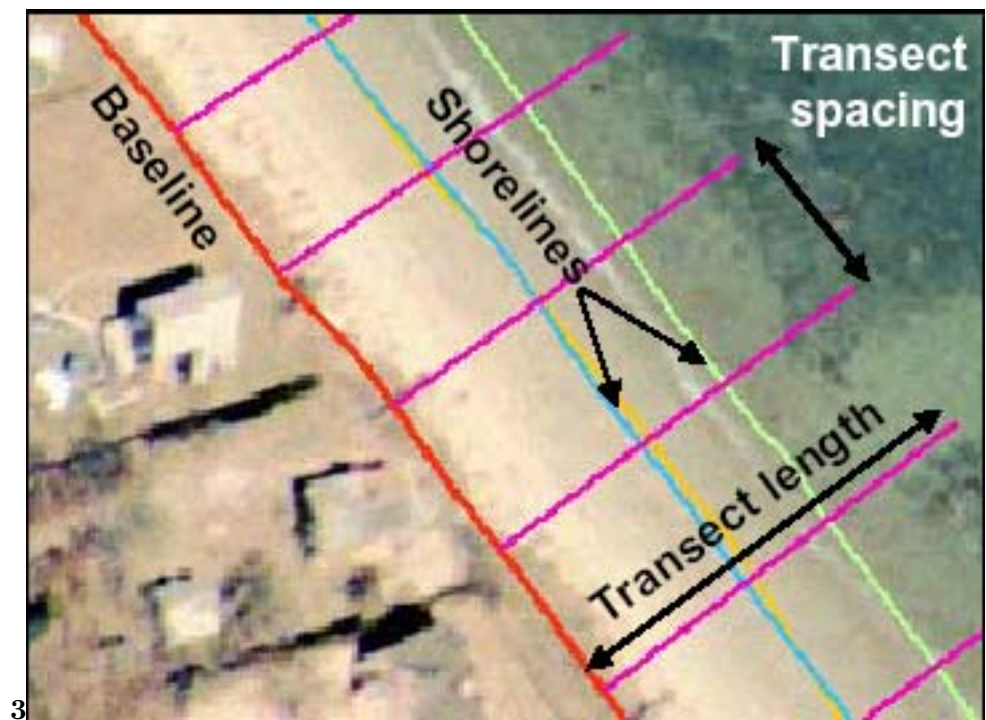
1

Figure 1: Figure 1 :



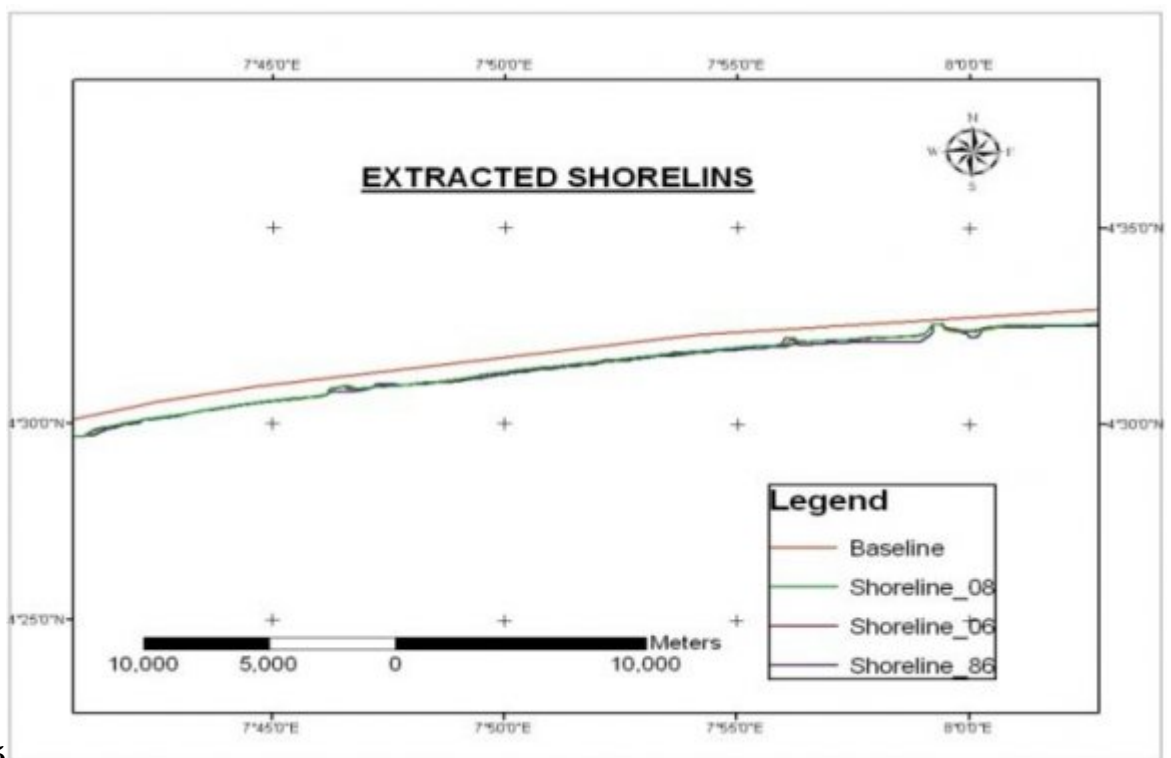
2

Figure 2: Figure 2 :



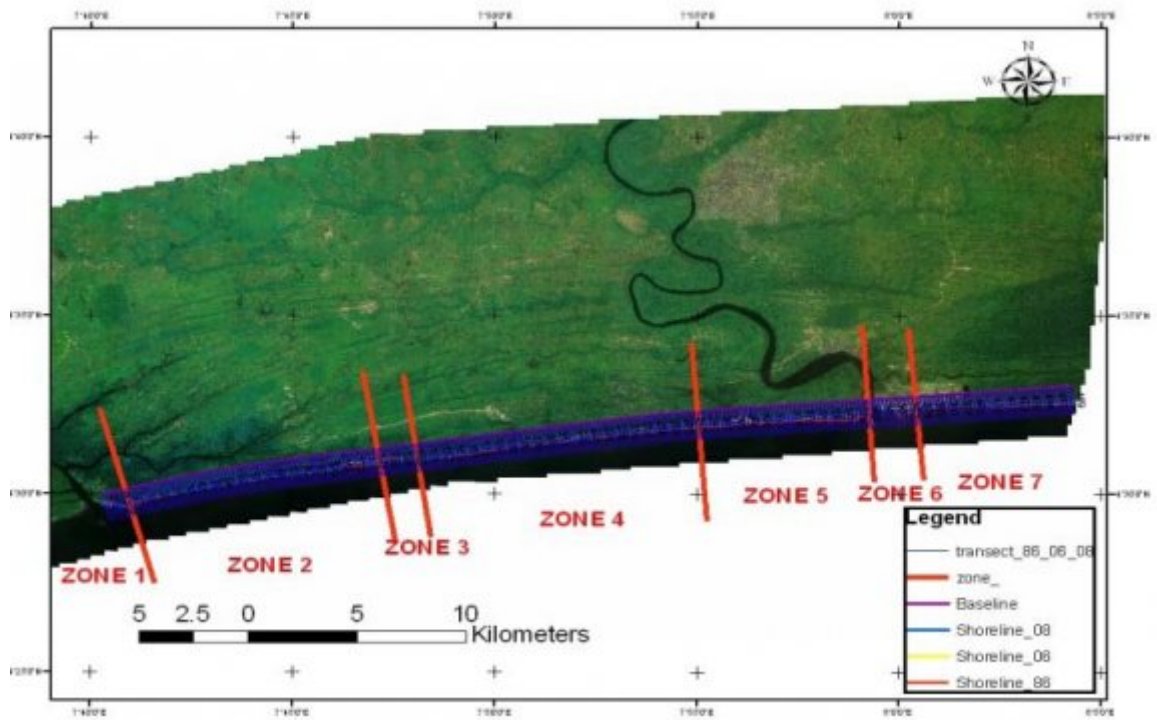
3

Figure 3: Figure 3 :



45

Figure 4: Figure 4 :Figure 5 :



6

Figure 5: Figure 6 :



7

Figure 6: Figure 7 :



Figure 7:



Figure 8:

1

| OBJECTSHAPE_LENGTH(m) ID* | 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 |

Figure 9: Table 1 :

2

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

Figure 10: Table 2 :

3

| 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 |

Figure 11: Table 3 :

7 B) DETERMINATION OF RATE OF SHORELINE CHANGE

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

208 .1 Discussions

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

215 In consideration of the 1986, 2006 and 2008 shorelines parameters, the 1986 case was selected as the earliest
 216 date for comparison. Meanwhile, within the period of ten years considered for this study , accretion was calculated
 217 as 1472.42m, erosion as-32905.2m thus giving the change as -31432.78m (See Table ??). Within the period of
 218 two years ??2006) ??2007) ??2008), accretion was calculated to be 4074.28m, erosion -3714.1m while the net
 219 change was 360.18m. On the whole, between 1986 and 2008, accretion, erosion, and net shoreline values in Ibena
 220 shoreline were 2618.38m, -33691.2m and -31072.82m respectively. However, within the period of this assessment,
 221 the highest accretion value was 147.07m while the lowest accretion value was 0.5m. On the other hand, the
 222 highest erosion value in the area was -299.19m while the lowest erosion value was -1.28m. Meanwhile and from
 223 the outcome of this analysis, it is worthy to note that there are more eroding portions than accreting portions
 224 across the entire shoreline in Ibena Local Government Area. This implies that sediments are continually stripped
 225 from the beach leaving an extensive land exposed. Trees are completely destroyed and buildings damaged as
 226 shown in Plates 1, 2 and 3.

227 .2 However, Itak Abasi village in Ibena Local Government

228 Area is known to be adversely affected by this environmental challenge. This condition persistently subjects the
 229 socio-economic activities of the people in the affected area into jeopardy.

230 Interestingly, it is worthy of note that most places affected by minimal erosion are as a result of engineering
 231 activities going on in the area while some are caused by intensive human activities at the river estuary along the
 232 shoreline.

233 The accretion near ExxonMobil jetty is as a result of sand fills done in the past for settlement purposes. On
 234 the average, the rate of change of shoreline in Ibena L. G. Area is -3.9m/yr and 2m/yr for erosion and accretion
 235 respectively. The negative (-) sign represents erosion while the positive (+) sign represents accretion in the area.
 236 This revelation involving the rate of change in erosion and accretion processes in Ibena L. G. Area known to be
 237 very useful in cases of future predictions to determine shoreline positions as in the case of U.S. Army Corps of
 238 Engineers (1992). Consequently, the implication is that areas affected by accretion will hinder free movement of
 239 people, support capsizing of fishing boats and the soften nature of the shifting sand bars will pose a threat when
 240 jetties are sited close to them. Furthermore, areas affected by erosion will experience flooding and the resultant
 241 effect from there.

242 .3 VI. Conclusion and Recommendation

243 Based on the outcome of this study, it is concluded that there is a remarkable change in the shoreline under
 244 consideration. This trend is similar to other parts of the Niger Delta region of Nigeria. Erosion and accretion
 245 processes have been ongoing, outstanding, and very severe in the area. Specifically, it is worthy to note that
 246 these occurrences are very much peculiar to the coastal region of Ibena Local Government Area in Akwa Ibom
 247 State. Based on this revelation however, acquisition of high resolution

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