SHORELINE CHANGE DETECTION AT THE ELEM TOMBIA SECTION OF THE NEW CALABAR RIVER USING GEOSPATIAL TECHNIQUES

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Abstract

The shoreline change detection analysis is an important task but its delineation is always difficult and time consuming when using traditional ground survey techniques. However, the advents of Remote Sensing and Geographic Information System (GIS) techniques have made it relatively easy with the use of satellite imageries. This study set out to identify the rate of the shoreline changes in the Elem Tombia section of the New Calabar River. The shoreline changes were compared between the years interval of 1989, 1999, 2009 and 2019 using satellite imageries within Geographical information system (GIS) environment. The transact approach was adopted to delineate the entire shoreline. 500meters spacing across the entire length was applied to detect all the changes that have occurred along the shoreline. From 1989 to 2019, the average shoreline extracted measurement on the left are: 1989 = 51.183m, 1999 = 35.968m, 2009 = 18.651, 2019 = 7.703 While, to the right are 1989= 16.048m; 1999= 9.684m; 2009 = 7.031m; 2019 = 3.832m. The 500m transacts of the shoreline from 1989 to 2019 shows a 75.575% land – sea lost (erosion) ranging from the base year 1989 as 33.615m to 5.768m in 2019. From the statistical models employed, position of 2039-predicted value to be -2.138m of erosion from the present position.

Keywords: Shoreline, Geospatial, Imageries

I. INTRODUCTION

The shore is known to be an area that has provided riparian settlements with a multitude of benefits ranging from food, drinkable water, job recreation, protection from hurricanes, transportation of oil and natural gas resources (Ekow,2016). It gives natural room for harbors, beaches and shorelines which attract residents for tourism, wetlands and estuaries that are critical for sustained fisheries. The shoreline ecological systems help to mitigate floods and serve as buffers from coastal storms that bring high winds and salt water inland and erode the shoreline (Addo & Addo, 2015).

Shoreline is therefore considered to be the boundary of land and sea or ocean (Richmond, 1997. The shoreline shows the formations and destructions occurring along the shore (Moore, Ruggiero & List., 2000).

Shoreline is constantly changing and it shows clearly how the position of the shoreline moves with respect to time (Western Indian Ocean Marine Science Association (WIOMSA), 2010). Two main factors are responsible for the changing of the shoreline namely, human activities and natural processes as repeated opined by (Richmond, 1997; Keqizhang& Leatherman, 2004; Boak, & Turner, 2005; Hanslaow, 2007; Paterson, O'Donnell and Loomis& Hom, 2010). Fletcher (2003) also pointed out that these forces which are primarily responsible to the great changes in shapes of the shoreline are acting everyday on the shorelines leading to erosion (wearing down of the top surface) or accretion (building up of the loose materials at a place). Erosion and accretion are problems that are associated with many beaches around the world (Hanslaow, 2007). Paterson, O'Donneil & Homs Loomis,(2010) define shoreline erosion as the process of natural influences by which materials are worn away from the earth's surface. In addition to these natural processes, human activities such as the destruction of mangrove forests, harvesting of sea grass bedsexposes the shoreline to actions which leads to erosion and in some cases, tourism development that is aimed at controlling erosion also changes the shoreline (Williams & Gutierrez, 2009).

The use of satellite remote sensing and geographic information systems (GIS) techniques for the identification, mapping and analysis of shoreline changes over time have gained prominence in recent years as high-resolution satellite data have become more readily available. The future position of the shoreline can be predicted using the End Point Rate model by using the historical rate of change data.

Aim of the Study

The aim of this study is to provide geospatial information on the shoreline rate of change at the Elem Tombiasection of the NewCalabar River.

Objectives of the study

The objective of the study focuses on determination and evaluation of the shoreline changes over the past 30years (5 epochs)using satellite imageries and prediction for the next 20 years using the End Point Rate and the Time series statistical models

II. AREA OF THE STUDY

Elem - Tombia is a very beautiful community located in the South-east of Degema Local Government Area, Rivers state located in the Niger Delta region of Nigeria. The area is a stretch of coastal area along the New Calabar river at the Bright of Bonny on the Atlantic Ocean(Oyegun, 2007). It has a shoreline approximately 12.7 km in length and spans from a point at Elem Ifoko village on latitude 4˚23' 0" N and longitude 7˚0' 0" E to Elem Bekinkiri village on latitude 4˚32' 10" N and longitude 6˚58'52"E. The area has two distinct seasons namely the wet or rainy and the dry season, but weighty rainfall is commonly experience during the rainy season (April to

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October). The climate is categorized by very high rainfall (annual totals >4000 mm), high temperatures values of about 32˚C, and high values of relative humidity with mean value of 66.3% (Michael 2011).

Fig.1.0. Map of Nigeria

Fig.1.1: Map of Rivers State

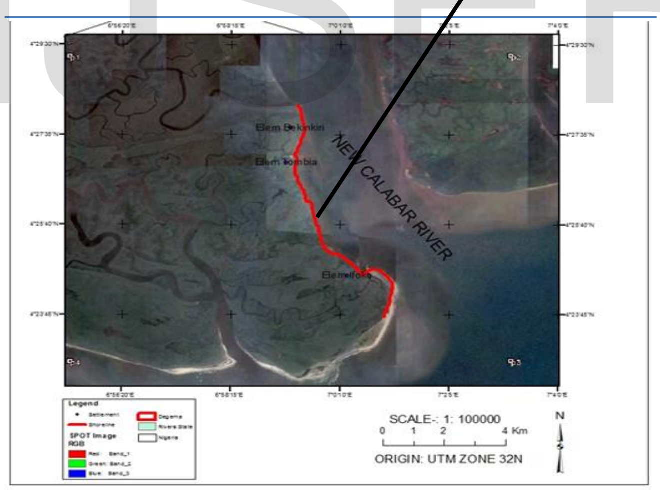

Fig. 1.2: Map of the Study Area Showing New Calabar River.

III. METHODOLOGY

This research methodology involves the quantitative approach and materials adopted. It mainly explains the data sources and types, methods of field data collection and statistical analysis used to achieve the research objectives.

Remote Sensing

Remote sensing could be said to be the expertise of measuring the features of an object or surface without physically having a contact with the object.It is the technology that is used in gathering of spatial information used for identifying, classifying, mapping, monitoring, planning, mitigation and management of natural resources (Igbokwe, 2010). Remote sensing systems or sensors basically measure and record electromagnetic energy emitted or reflected from the object of study. Electromagnetic wave can be described in terms of their velocity, wavelength and frequency. This can be explained with the following model:

$V = \lambda f$ … eqtn.1

Where;

V = Velocity of electromagnetic energy in a vacuum (299,793 km per second or $3x\ 10^8$ m per second).

f = frequency of the energy

λ = wavelength of the energy.

Time Series model

Time Series constitute a sequence of data points generated by measurements over time. In other words, the arrangement of data in accordance with their time of occurrence is a time series. It is the sequential arrangement of data where time (hours, days, months or years) is used to relate the entire phenomenon to suitable reference points. Times Series forecasting therefore, could be said to the process of making predictions about future points based on a model created from the observed data.

Theformula to calculate future prediction given the current position and the change rate is:

$Y_{future} = [X_{present} * (1 - i)^n]$ …eqtn.2

Where;

Y_{future} =Predicted position of the shoreline

$X_{present}$ = Present position of the shoreline

i = rate of change

n = number of years to be predicted

Data acquisition

Four satellite imageries of the years 1989, 1999, 2009 and 2019. Landsat MSS and TM-5 data sets were acquired from USGS [webhttp://glovis.usgs.gov] and the SPOT image was sourced from the Office of the Surveyor General of the Federation (OSGOF).

Data analysis

The capabilities of GIS and remote sensing (RS) were used to determine the changes of the shoreline in the study area. The satellite imageries of the New Calabar river acquired for the years 1989 to 2019 (30 years) of 10years epochs was imported into GIS software environment where further processing was carried out in order to make the acquired imageries useful for analysis. The satellite imageries underwent series of geo – processing in order to make them suitable for further analysis. These imageries were then overlaid and smoothened in order to obtain the sharp boundary between the land and the sea which serves as the shoreline. Thereafter, the shoreline for each year was digitized as polylines. These imageries were processed, analyzed and were able to show clearly the various shoreline changes of different periods with the view to determine their rate of change.

IV.RESULTS AND DISCUSSION

The results contain tables and charts showing the extracted shoreline and river width measurements of different epochs and the graphical presentation of the shoreline changes and prediction using the End Point Rate and Time Series.

GIS extracted Shoreline ranging from the year 1989 – 2019.

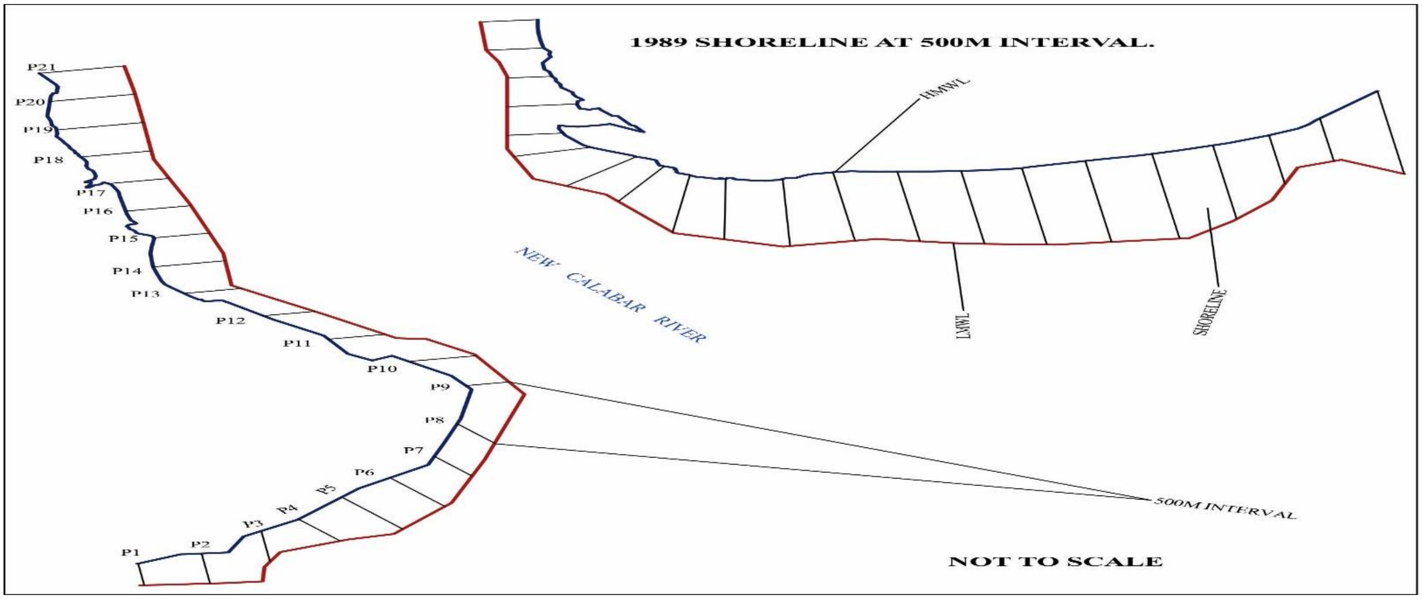

Fig 2: Transact for the Shoreline Measurements at 500meters in the Year 1989.

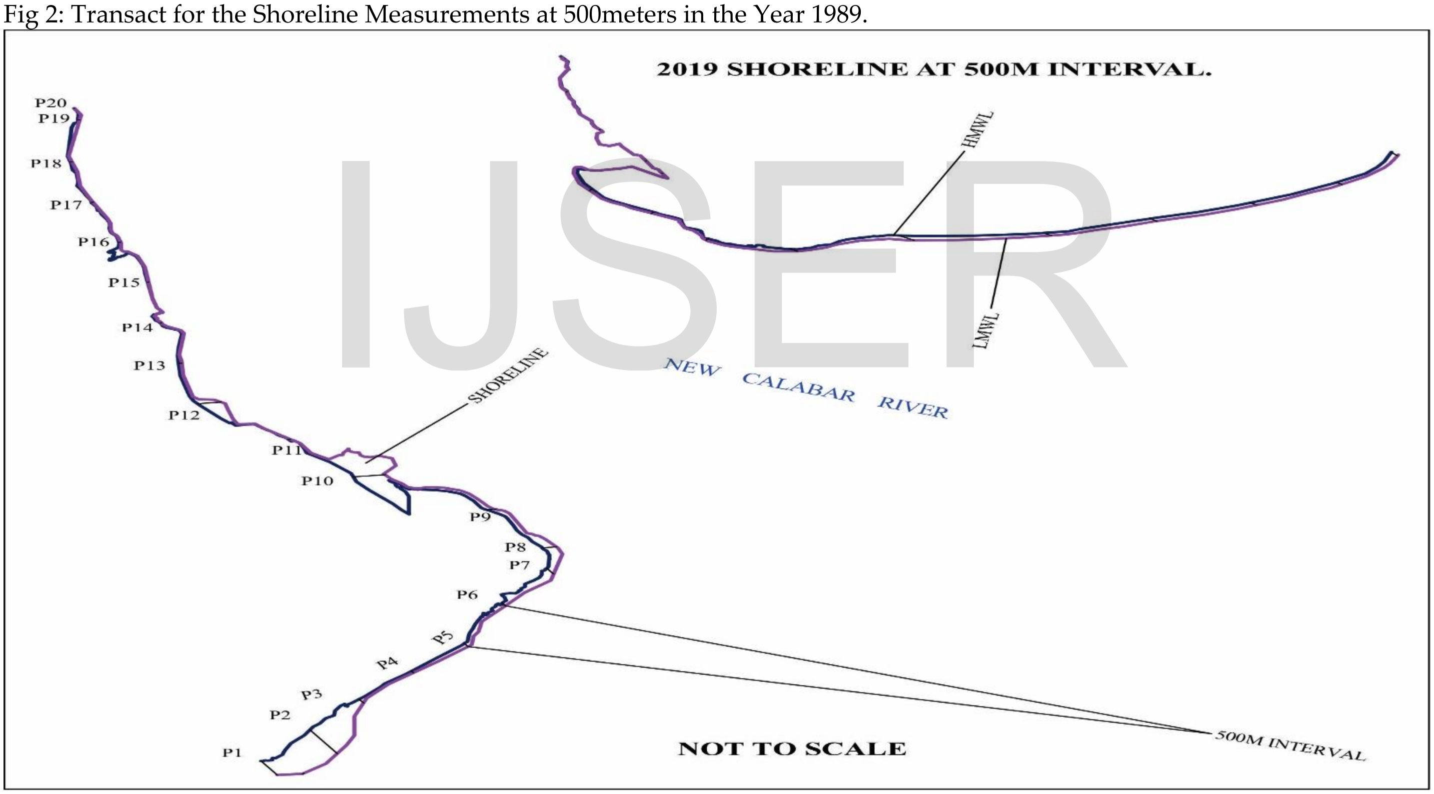

Fig.3. Transact for Shoreline Measurements at 500meters in the Year 2019

Summary of shoreline extracted measurements @ 500m intervals.

Table 1: Showing the extractedtransact P1 – P20 measurements of the shoreline for 1989 – 2019

EXTRACTED LEFT SHORELINE MEASUREMENT					EXTRACTED RIGHT SHORELINE MEASUREMENT			
TRANSACT/YEAR	**1989**	**1999**	**2009**	**2019**	**1989**	**1999**	**2009**	**2019**
P1 - P1A	38.389	31.906	26.660	20.290	31.306	15.722	11.272	6.213
P2 - P2A	53.049	40.554	24.145	34.659	26.123	13.679	8.001	4.617
P3 - P3A	54.375	35.575	19.805	5.397	30.149	15.661	9.552	5.656
P4 - P4A	49.751	26.788	17.858	2.376	23.430	16.023	10.964	5.880
P5 P5A	72.909	59.976	36.756	4.649	25.538	15.210	11.860	6.843
P6 P6A	65.443	60.374	48.527	3.995	24.878	15.850	13.567	12.20
P7 - P7A	45.030	44.710	39.704	8.272	24.808	13.219	8.921	6.073
P8 - P8A	44.677	23.798	4.178	10.199	26.547	16.344	7.433	2.479
P9 - P9A	33.456	18.466	3.466	6.564	32.392	21.039	13.052	2.182
P10 - P10A	52.203	37.532	4.055	22.834	13.420	11.739	8.660	2.247
P11 - P11A	44.021	29.300	11.315	1.505	10.415	8.853	3.841	0.165
P12 - P12A	39.869	41.468	2.044	17.026	8.907	5.559	2.097	0.667
P13 - P13A	44.747	40.727	46.772	2.233	6.862	3.485	1.157	NO BUFFER
P14 - P14A	55.996	32.849	14.398	8.483	6.018	3.277	0.934	NO BUFFER
P15 - P15A	43.180	19.091	8.007	0.639	5.638	3.983	0.758	NO BUFFER
P16 - P16A	50.674	36.475	9.067	1.125	7.635	5.006	0.433	NO BUFFER
P17 - P17A	47.281	28.610	13.506	1.090	4.198	2.979	0.314	NO BUFFER
P18 - P18A	54.992	31.182	6.421	1.028	3.720	1.714	0.113	0.167
P19 - P19A	67.642	37.025	11.551	1.200	4.374	1.599	NO BUFFER	0.775
P20 - P20A	65.969	42.951	17.190	0.295	4.597	2.739	NO BUFFER	1.319

Table 2: Showing result spread of the rate of change of the shoreline @ 500m interval

	DIFFERENCE IN TRANSACTS							
	SHORELINE LEFT				SHORELINE RIGHT			
TRANSACTS	**1989 - 1999**	**1999 – 2009**	**2009 - 2019**	**1989 – 2019**	**1989 – 1999**	**1999 - 2009**	**2009 – 2019**	**1989 – 2019**
P1 - P1A	-6.483	-5.246	-6.370	-18.099	-15.584	-4.450	-5.059	-25.093
P2 - P2A	-12.495	-16.409	10.514	-18.390	-12.444	-5.678	-3.384	-21.506
P3 - P3A	-18.800	-15.370	-14.408	-48.978	-14.488	-6.109	-3.896	-24.493
P4 - P4A	-22.963	-8.930	-15.282	-47.175	-7.407	-5.059	-5.084	-17.550
P5 P5A	-12.933	-23.220	-32.107	-68.260	-10.328	-3.350	-5.017	-18.695
P6 P6A	-5.069	-11.850	-44.532	-61.448	-9.028	-2.283	-1.367	-12.678
P7 - P7A	-0.320	-5.006	-31.432	-36.758	-11.589	-4.298	-2.848	-18.735
P8 - P8A	-20.879	-19.620	6.021	-34.478	-10.203	-8.921	-4.944	-24.068
P9 - P9A	-14.990	-15.000	3.098	-26.892	-11.353	-7.987	-10.870	-30.210

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P10 - P10A	-14.671	-33.477	18.779	-29.369	-1.681	-3.079	-6.413	-11.173
P11 - P11A	14.721	17.985	9.810	-42.516	-1.562	-5.012	-3.676	-10.250
P12 - P12A	1.599	-39.424	14.982	-22.843	-3.348	-3.462	-1.430	-9.574
P13 - P13A	4.020	6.045	-44.539	-42.514	-3.377	-2.328	No changes	-6.862
P14 - P14A	-23.147	-18.451	-5.915	-47.513	-2.741	-2.343	No changes	-6.018
P15 - P15A	-24.089	-11.084	-7.368	-42.541	-1.655	-3.225	No changes	-5.638
P16 - P16A	-14.199	-27.408	-7.942	-49.549	-2.632	-4.573	No changes	-7.638
P17 - P17A	-18.671	-15.104	-12.416	-46.191	-1.219	-2.979	No Changes	-4.198
P18 - P18A	-23.810	-14.761	-5.393	-53.964	-2.006	-1.714	0.167	-3.553
P19 - P19A	-30.617	-25.474	-10.351	-66.442	-2.775	No changes	0.775	-3.599
P20 - P20A	-23.018	-25.761	-16.895	-65.674	-1.855	No changes	1.319	-3.275

Summary of measurements @ 500m intervals

Table 3: Showing resultsof averagemeasurements @ 500m intervals from1989 – 2019.

Year	**1989**	**1999**	**2009**	**2019**
Average left shoreline	51.183m	35.968m	18.271m	**7.703m**
Average right shoreline	16.048m	9.684m	7.031m	**3.832m**
Average shoreline	33.615m	22.826m	12.651m	**5.768m**

Table 4: Showing result of shoreline measurement difference @ 500m intervals from 1989 – 2019

Year interval	**1989 – 1999**	**1999 – 2009**	**2009 – 2019**	**1989 - 2019**
Diff. in Average left shoreline	-16.100m	-18.399m	-17.651m	**-43.48m**
Diff. in Average right shoreline	-6.364m	-4.059m	-2.750m	**13.240m**
Diff. in Average shoreline	**-10.789m**	**-10.175m**	**-10.175m**	**-27.847m**

Table 1 to table 4 shows the extracted values of the shoreline at 500m for 1989, 1999, 2009, and 2019 respectively.

From 1989 to 2019, the average extracted measurement of the shoreline on the left are: 1989 = 51.183m, 1999 = 35.968m, 2009 = 18.271m, 2019 = 7.703

While, to the right are 1989=16.048m; 1999= 99.684m; 2009 = 7.031m; 2019 = 3.832m. This indicates that the width of the river is responding to the changes on the shoreline. This is demonstrated with the fact that as the shoreline is reducing in measurement over the years because of erosion; the corresponding river width is increasing.

From the analysis, it shows that there is a high degree on land loss (erosion) on both sides of the shore.

Prediction of the shoreline position using the Time series

Theformula to calculate future prediction given the current position and the change rate is:

$$Y_{Future} = [X_{Present} * (1 - i)^n] \quad \text{...eqn.3}$$

Where;

Y_{Future} =Predicted position of the shoreline

$X_{Present}$ = Present position of the shoreline

i = rate of change

n = number of years to be predicted

From the above analysis,

Prediction of the shoreline position in 2039 (20 years)

Y_{Future}=?

$X_{Present}$(2019) = 5.768m

i = -75.575

n = 20

$Y_{Future} = [X_{Present} x (1+ i)^n]$

$Y_{Future}= \{5.768 \times [1 + (-75.575)]^{20}\}$

$= [5.768 \times (-3.694563344 \times 10^{37})]$

Therefore, 2039 shoreline position = **-2.131m**

From the present average shoreline measurement of 2019, is 5.768m, a land to sea loss movement (erosion) of the entire shoreline will be recorded. The prediction indicates that the movement will erode beyond the high mean water level into the dry land by – 2.131m.

Prediction of the shoreline position using the End Point Rate Model

Theformula to calculate future prediction given the current position and the change rate is:

Future Position = $\frac{Time * intercept}{Slope}$…eqtn.4

Where,

S = Slope = Rate of Change

T = Time interval between present and predicted shoreline

I = Intercept

The formula for the projection intercept is;

I = $(\frac{X}{Y_{2-}Y_1})M_{EPR}$ …eqtn.5

Where,

Y_2 = Present position

y_1 = Base year position

X = Time interval (Date)

M_{EPR} = Rate of shoreline change

I = $(\frac{X}{Y_{2-}Y_1})M_{EPR}$

Where;

Y_2 = 5.768. The present position of the shoreline

y_1 = 33.615. The base year position

X = 20

M_{EPR} =75.515%. The rate at which the shoreline changes

Using the parameters given above, the projection intercept is determined thus;

I = $\left(\frac{20}{5.768-33.615}\right)(-75.575)$

= $\left(\frac{20}{-27.847}\right)(-75.575)$

= -0.10690043 x (-75.575)

I = 8.079

Prediction of the shoreline position in 2039 (20 years)

Future Position = $\frac{Time * intercept}{Slope}$

Where,

I= intercept = 8.079

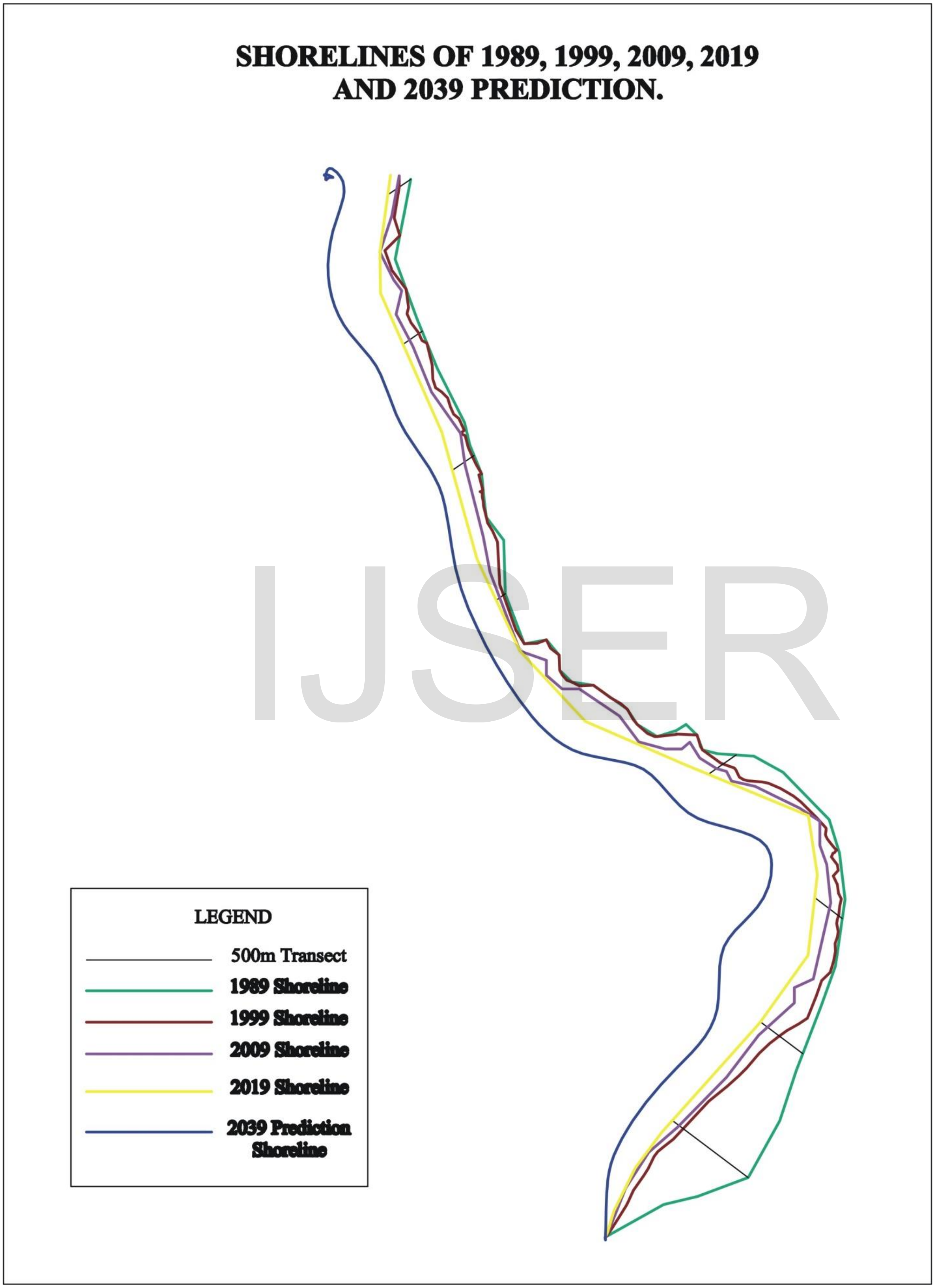
T = Time = 20

S = Slope / rate of change = -75.575

2039 position = $\frac{20 * 8.079}{-75.575}$

Therefore, 2039 shoreline position **=** $\frac{161.580}{-75.575}$**= -2.138m**

From the present average shoreline measurement of 5.768m in 2019, a land to sea loss movement (erosion) of the entire shoreline will be recorded in 2039 bringing the position of the shoreline at -2.138m beyond the high mean water level into the dry land.


SHORELINES OF 1989, 1999, 2009, 2019
AND 2039 PREDICTION.
LEGEND
500m Transect
1989 Shoreline
1999 Shoreline
2009 Shoreline
2019 Shoreline
2039 Prediction Shoreline

Results Discussion

The result of this research is discussed based on the objectives of the research as followed;

From 1989 to 2019, the average extracted measurement of the shoreline on the left are:

1989 = 51.183m, 1999 = 35.968m, 2009 = 18.271m, 2019 = 7.703 while, to the right are 1989=16.048m; 1999= 99.684m; 2009 = 7.031m; 2019 = 3.832m. From the analysis, it shows that there is a high degree on land loss (erosion) on both sides of the shore.

Furthermore, the results shows that there were no shoreline movements at transact P19 and P20 for the year 2009 and between P13 – P17 for the year 2019.

There was massive erosion rate and a handful of accretion between1989 – 1999. The study indicated erosion along the shoreline except between transact P11 to P13 that recorded accretion. The same for the period 1999 – 2009, where massive erosion dominated the entire shoreline except transact P13 where an accretion of 6.045m was recorded on the left and no shoreline change was indicated between P19 and P20 on the right.

For the period 2009 – 2019, erosion was dominant on both shorelines but accretion observed between transacts P18 to P20 and no changes were recorded between transact P13 to P 17 on the right shoreline.

From the table that shows the average shoreline measurements both on the left and on the right. It is observed for the years under study that 1989, 1999, 2009 and 2019 recorded 33.615m, 22.826m, 12.651m and 5.768m respectively. This shows the changes and movement of the shoreline.

The result analysis for the 10 years interval rate of change of the shoreline is as follows; 1989 – 1999, 1999 -2009, 2009 – 2019 the left shoreline recorded -16.100m, -18.399m, --17.651m while the right shoreline recorded -6.364m, -4.059m, -2.750m respectively.

In conclusion, taking a holistic analysis of the shoreline changes from 1989 – 2019, there is a percentage rate of change as -75.575% land – sea lost (erosion) ranging from the base year 1989 as 33.615m to 5.768m in 2019.

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For the prediction of the shoreline in year 2039 (20 years)

The prediction shows that there will be an increase in erosion adding to the present position of the shoreline.

Position of 2029= position of 2019-predicted value

Position of 2039 = 5.768 – (-2.135)= 7.903m

There will be a land to sea loss (erosion)from the present position of the shoreline of **7.903m.** The prediction indicates that the movement will erode beyond the high mean water level into the dry land by – 2.135m.

V. CONCLUSION AND RECOMMENDATIONS

Conclusion

The study showed the massive erosion process occurred in the Elem Tombia shoreline. Almost the whole stretch of the shoreline have undergone high rate of erosion. Accretion has been seen in only a small portion. Various reasons are responsible for the erosion. This study confirms the usefulness of image processing techniques and GIS tools applied on multi-temporal and multispectral Landsat images for assessment of the changes along the New Calabar river shoreline as the results obtained are fairly in agreement with those of in situ measurements. The Elem Tombia section of the New Calabar River has been subjected to a number of significant changes in the last four decades (1989–2019). Within this 12.8km coastal strip, all possible trends have been observed.

Recommendations

The Nigerian shoreline is a very dynamic one and for that reason there is the need to pay proper attention to the processes ongoing along our shorelines. It is with these problems in mind that the following recommendations are made.

1. A constant monitoring of the shorelines through geospatial techniques should be setup in Nigeria. Hence a monitoring unit is recommended that would have it as its responsibility to monitor our shorelines.
2. To address this risk, there should be an increase in the height of vulnerable coastal edges with bulkheads, beach nourishment and other measures over time.
3. A conscious effort should be employed by the government either by enacting a law to control the activities within the Nigerian Shorelines. There should be an off limit as to where people are permitted to carry out any development project and activities.

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