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Analysis of Shoreline Dynamics within a Section of Orashi River: Rivers State, Nigeria

Ishiagwoh Ben Temple
Department of Surveying and Geomatics, Rivers State University Port Harcourt: Nigeria
Ishiagwohtemple0101@gmail.com
Lawrence Hart
Department of Surveying and Geomatics, Rivers State UniversityPort Harcourt: Nigeria
lawrence.hart@ust.edu.ng
Eze Promise Ikenda
Department of Surveying and Geomatics, Rivers State University, Port Harcourt: Nigeria
promise.eze@ust.edu.ng
Corresponding Author: Lawrence Hart (lawrence.hart@ust.edu.ng)

Abstract:
The Orashi River under study has shown an uncontrolled change in geometry along the River Channel at different spots and locations due to several factors which includes persistence anthropogenic activities and natural interferences, Among others are, the proximity of the riparian dwellers to the shore of the river channel, the effects of erosion, the continuous sediment lose due to source depletion along the river, heavy annual rainfall and over flooding occasioned by the release of water from Dams. The study is aim to analyze the shoreline dynamics in the study area for a period of thirty years with the objectives of determining the change in magnitude at 200m distances along the transects for each epoch and rate of change. Remote Sensing techniques was utilized to achieve the study aim and objectives, LANDSAT MSS (L5), LANDSAT TM (L7), and LANDSAT OLI (L8) aerial imageries of the year 1992, 2002, 2012 and 2022 were acquired from United State Geological Services, ESRI'S Arc-GIS 10.3 software was used to extract the shoreline and provide interface for digital shoreline analysis system (DSAS) to give statistics of the change, DSAS Version 4.3 software was used to cast transects and compute shoreline rate.The imageries were geo-referenced to UTM Zone 32N projection system, WGS- 84 datum. Linear measurements were carried out onscreen on each transect of the left and right shore using the point, line and polygon spatial features to determine the positions and extent of each transect in the left and right hand side of the shoreline. The study revealed that an average rate of change of 23.734m and 33.102m in the left-hand side and right hand side of the shoreline respectively. The geometry of the shoreline also changed and varies within epoch under study and the average rate of change indicates more shoreline changes on the right-hand side of the river going through Akinima town towards Odiereke axis than the left-hand side of the Orashi river channel. River banks in sections of the shoreline were been collapse and seriously impacting on already tarred roads. Shore protection project is needed in the study area to forestall further collapse of river banks, flood and erosion.

Key Words: Shoreline, Orashi, Spatial, Dynamics, Transects

1. Background of Study

Shoreline dynamics refers to the changes that occur on the shoreline between a periods of time, it is the movement in the land and water interface for a given coastline, the occurrence of this change leads to inundation and coastal erosion. Shoreline change is also an indicator of coastal erosion/accretion. The shoreline is dynamic in nature and it occurred as a result of some oceanographic and geomorphic stresses and anthropogenic factors. The shoreline feature is most commonly indicated on maps and aerial photos as the visible High-Water Line (HWL) along the coast; other datum-based indicators such as the Mean Water Line (MWL) or the Mean High-Water Line (MHWL) may also serve as indicators for the shoreline on maps (Boak& Turner, 2005; Mague& Foster, 2008).

Shoreline change refer to the loss or gain of land area, or change to the landscape on the marine edge (Dehouch, 2004). It's an important indicator of environmental threat at coastal areas. This is also caused by various factors, There are many factors responsible for change in shoreline over a period of time scale, especially the effects of sand mining, annual rainfall, stream avulsion, source depletion, climate change, land use and land cover, over flooding of river catchment, erosion, accretion, the displacement of sediment transportation affecting the river flow pattern, mass and velocity of the river flow rate dynamics and other anthropogenic causes like channeling of drainage and canal system into the river, dredging and constructions along the coastline. The assessment of the geometry of the river channel helps in monitoring the shoreline position which is necessary for the effective management of the environments and communities' proximity to the shoreline along the Orashi region of Rivers State(Anderson,2014). .

Ekong,(2017), opined that coastal are a is a highly dynamic environment with many physical processes suchastidalflooding,sealevelrise,landsubsidenceanderosion/sedimentation. These physical processes play an important role in shoreline change and development of the coastal landscape. This is peculiar to the study area, the shoreline under study area has witnessed uncontrolled change in geometry and size along the river channel at different spots and locations due to the daily human activities and natural interference within the study area. There is also the case of high annual rainfall resulting to persistence over flooding and occasioned by release of water from Dams, earth drainage construction channeled to the river, the type of soil in the area and the river flow pattern in terms of mass and velocity are some of the indicators contributing positively or negatively to the change in shoreline position and its environment as shown in (Plate 1.1 and plate 1.2) respectively. Anthropogenic activities and natural interferences have also resulted to collapse of river banks, dilapidation of tarred roads, erosion and sedimentation within the shoreline and environs. The absence of government presence, policies and plans or inadequate implementation and closely monitoring of the changes in the coastal area and mitigating sanctions to help regulates and govern the area poses the danger of environmental degradation and the ecosystem. The significance of this study is such that it will provide basic data information for planning, design, construction and management of a shore protection project in the study area.

Plates 1. (A & B): Deplorable road embankment due to shoreline change along Joinkrama road and Riparian dwellers proximal to the shoreline under study Area.
Source: Author Field Data, 2023.

The aim of the study was to determine the Dynamics of the Shoreline Changes in the study area. The objectives of the study was to Identify the shoreline positions in three epochs of 1992 - 2002, 2002 - 2012, and 2012 – 2022,determine the magnitude of the shoreline changes at chainage of 200m for each epoch and examine land use land cover change detection study of the area and sound mining activities.

Study Area Description

The area of the study is the shoreline between the Mbiama - Odiereke axis of the Orashi River channel, in Ahoada West Local Government Area of Rivers State, Nigeria. Geographically located point (P1) lat. 005º 3' 30" N, long. 006º 27' 0" E and (P2) lat. 005º 9' 0" N long. 006 º 32' 30" E, the river is bounded on the East by Ahoada East Local Government Area, North by Ogba/Egbema/Ndoni Local Government Area, West by Bayelsa State and South by Abua/Odual Local Government Area. The shoreline under study covers a length of 10.40km, and stretches from Mbiama – Odiereke axis of the Orashi River channel with a width of approximately135m**.**
Orashi region is in the rainforest zone, Southeastern Nigeria. Crop cultivation, Oil Palm and fishing are the major occupation of the people and source of livelihood. The zone may be termed an 'oil palm bush. The forest zone is characterized by abundance of plant species, sometimes exceeding one hundred and fifty different species per hectare. Orashi Region, which includes Njaba River basin, holds over 35% of the Oil Wells in the Niger Delta States of Imo and Rivers.it is an ancient trade and cultural route has provided means of transportation and migration for indigenous communities who moved from one town to another by canoe for cultural, social or economic purposes on market days(ObowuandTamunoene2014).

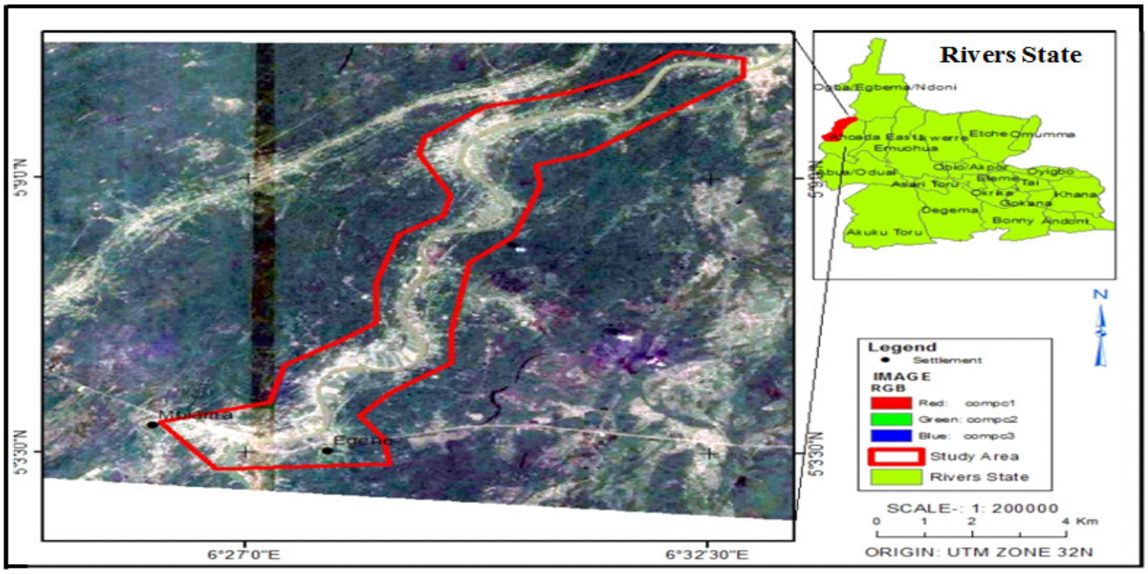


Figure 1.1: Imagery of Rivers State and the Study Area
Source: [http://glovis.usgs.gov] March, 2022.

2. Materials and Methods

The study adopted quantitative approach of data collections. The remote sensing technique was effectively utilized to achieve the aim of the study using the stated objectives. This technique is a non-contact method that is used to observe and measure the characteristics of objects on the earth surface from a distance without having contact with the scene; the technique is fast, reliable and cost effective**.**

Software / Hardware Selections

The software and hardware resource for this study include the following:
i.) HP 620 Laptop Computer with 4Gig Ram, 64-bits (Core-i3) operating system
ii.) ENVI 5.0 used for image preprocessing
iv.) ESRI'S Arc-GIS 10.3 software was used to extract the shoreline and provide interface for digital shoreline analysis system (DSAS) to give statistics of the change
v.) DSAS Version 4.3 software was used to cast transects and compute shoreline rate.
The shoreline was extracted from the vectorized shoreline positions.
(vi.) Garmin 78s Global Positioning System (GPS) Handheld Receiver

Data Sources

Primary Data:

The primary data for this study are made up of spatial and attribute datasets collected from field observation, this includes ground coordinates of points use for geo-rectification, linear measurements used for validating the information from obtained satellite imageries and names of community, roads, river and shoreline under study. The collection of ground-truth data was necessary to enable geo-referencing of the imageries and calibration of remote sensing data, which helps in the interpretation and analysis of what was being sensed

Secondary Data:

LANDSAT Imagery of (1992, 2002, 2012 and 2022) remotely sensed data of the study area. LANDSAT (MSS (L5), TM (L7), and OLI (L8) Aerial Imagery of year 1992/03/24, 2002/03/28, 2012/03/20 and 2022/03/22 downloaded in a raster format from United State Geological Surveys website: [http://glovis.usgs.gov], with spatial resolution of between 30m – 60m were obtained.

Methods

Reconnaissance Survey: In the course of this research, the site was thoroughly visited to examine the physical outlook and the present state of the study area. This assisted greatly planning and the choice of satellite imagery suitable for the study.

Table 3.3: Properties of LANDSAT data used for shorelines change analysis.

Sensor	Path/ Row	Imagery Date	Resolution (m)	BANDS
Landsat MSS (L5)	189/ 56	03/24/1992	60 x 60	B432
Landsat TM (L7)	189/ 56	03/28/2002	30 x 30	B432
Landsat OLI (L8)	189/ 56	03/20/2012	30 x 30	B543
Landsat OLI (L8)	189/ 56	03/22/2022	30 x 30	B543

Where
MSS (L5) i.e., Multispectral Scanner System
TM (L7) i.e., Thematic Mapper
OLI (L8) i.e., Operational Land Imager

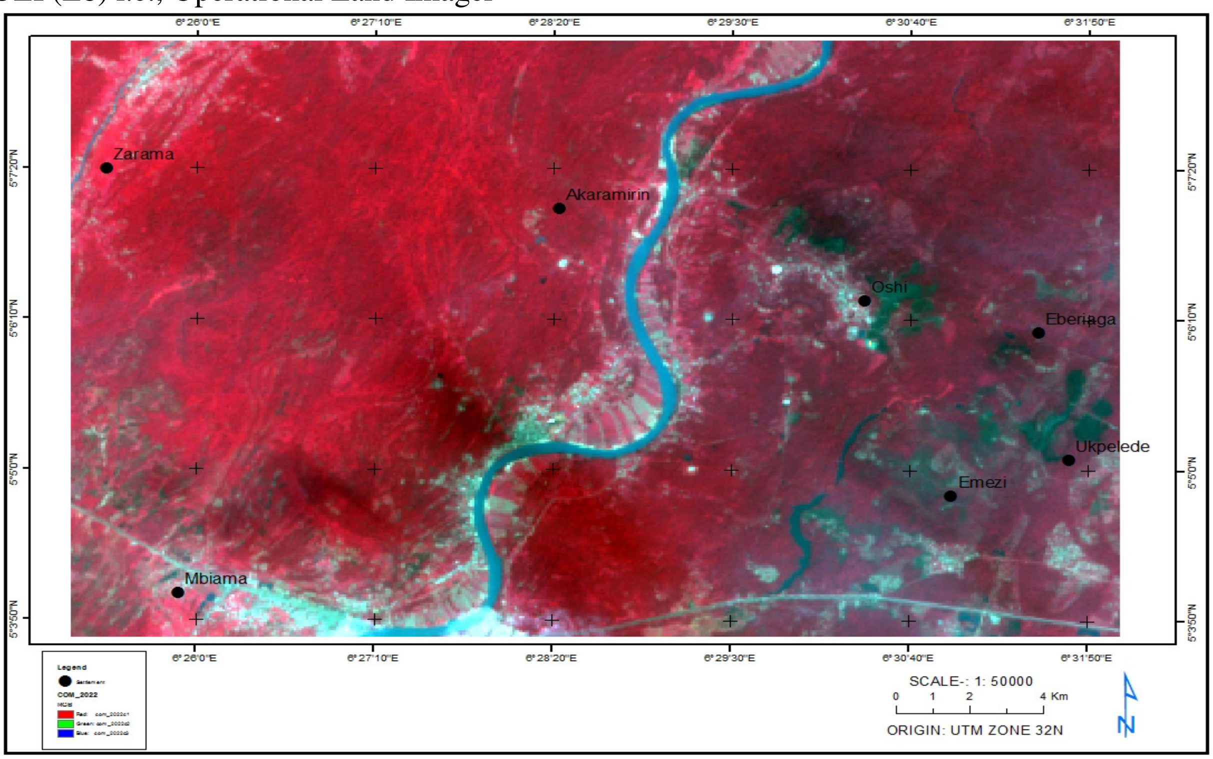


Figure 2.1: composite satellite imagery of the study area
Source: [http://glovis.usgs.gov], 2022

Data Processing

Image data processing of satellite data can be primarily grouped into three categories, Image rectification and restoration Enhancement and Information extraction. The image rectification is the pre-processing of satellite data for geometric and radiometric corrections. Enhancement is applied to the image data in order to effectively display data for subsequent visual interpretation. Information extraction is based on digital classification and is used for generating digital thematic map. The Satellite imageries obtained were corrected and geo-referenced in (WGS84) datum, UTM, ZONE, 32N coordinate system for optimum results in line with the aim of the research. This helps in classifying and orienting the satellite imagery based on its arbitrary state to correspond with the true ground positions, focusing its proper stages to correct the tilt in the relative coordinates on the map which is due to the altitude, motion, focal length and relief of the terrain. Three bands of infrared, red, green for each Landsat were used to form composite image showing the river channel.

Digital Shoreline Analysis System (DSAS)

Digital Shoreline Analysis System (DSAS) can be used to calculate rate of change using linear regression, endpoint, average of rates, jack knife and weighted linear regression methods. The Linear regression method is the most statistically robust method and widely accepted by coastal researchers for computing long term rates of shoreline changes inceit consistently gives better long-term fore casting results than other techniques. Digital Shoreline Analysis System (DSAS) is a GIS tool explored into HTA to examine past or present shoreline positions of a given geometry.

Shoreline Analysis

The shoreline for each epoch was analyzed using the GIS enabled DSAS-HTA for the month of March for the year 1992, 2002, 2012, and 2022. The month was used for the analysis due to its less atmospheric challenges and respond to the various indicators (rainfall, flooding etc) that contribute to shoreline change. Each epoch covers a period of 10 years and the analysis was for the period of 1992 – 2002 epoch, 2002 – 2012 as epoch, and 2012 – 2022 as epoch.

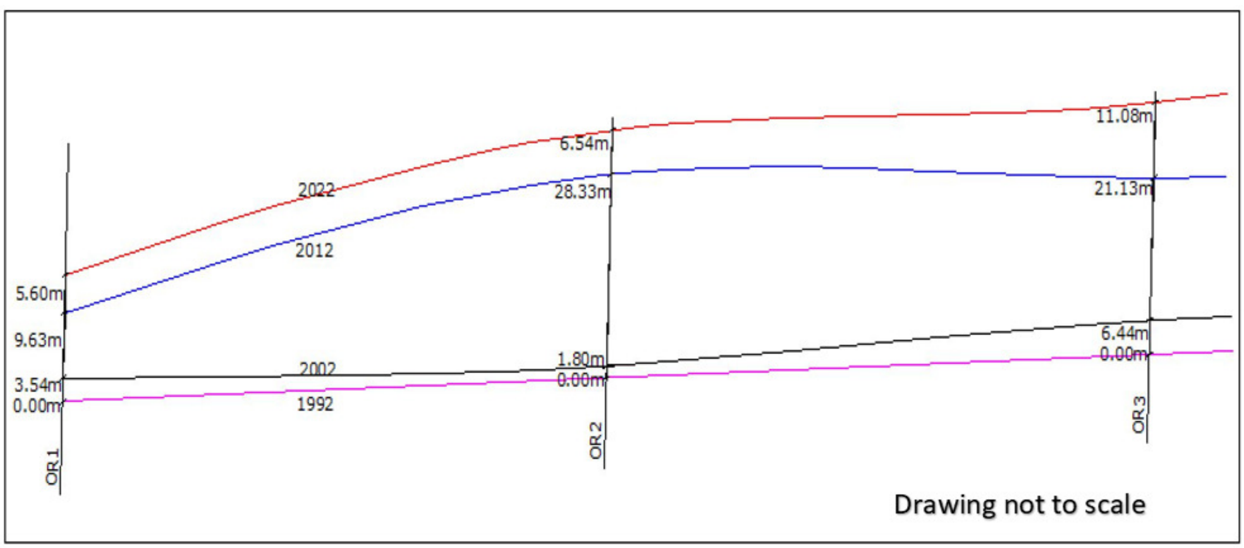


Figure 2.2:A Section of Right-Hand Side Transects for 1992 - 2022.
Source: Authors Field Data, 2022

The shoreline extraction/analysis was done for the both sides of the river channel to portray the entire change in geometry, considering the two wings of the river as Left and Right sides of the Orashi River Catchment for the purposes of analysis and to show the change in one epoch to the other using a horizontal distance of 200-meters interval to define the rate of change that has occurred and this was calculated with the help of the DSAS/HTA a GIS enabled computer software program considering all the indicator as a uniform agent.

Shoreline Erosion Based Models

The erosion-based models depend on sediment mass conservation and attempt to balance volume of sediment with in the littoral zone in order to determine shoreline change. A typical model was proposed by United States Army Corps of Engineers (USACE, 1992).

The equation is as follows:

$$\frac{\Delta x}{\Delta t} + \frac{1}{D_B + D_C} * \left(\frac{\Delta Q}{\Delta Y} + q\right) = \qquad eqn. 1$$

Where,Δx is the change in shoreline perpendicular to the shore;
Δt the time interval of the analysis;
ΔQ the rate of sediment transport;
Δy is the length of the shoreline under consideration;
DB and DC are offshore closure depth and berm crest elevation respectively.
Sand mining is considered through the term q in the equation.

End Point Rates (EPR) Method

End Point Rates method derives a linear equation from two shoreline points available, the slope of which gives the recession rate.

$$\text{EPR} = \frac{\text{Distance in meters}}{\text{Time between oldest and most recent shoreline}} \qquad eqn. 2$$

Average of Rates (AoR) of change Method

The minimum time criteria define a time T min which represents the minimum time that must elapse between measured shorelines in order to ensure that the average rates calculation produces result that exceed measurement error.
The time T min require the end point rates for all the pairs of shorelines available as input (Dolan et al., 1991)

$$T_{min} = \frac{\sqrt{E_1 + E_2}}{R_1} \qquad \text{eqn. 3}$$

Where E1=measurement error in the first shoreline point
E2=measurement error in the second shoreline point, and
R1=end point rate of the longest times pans from the transect

Shoreline Change Analysis

DSAS is an add-on tool in Arc MAP created by USGS to determine the rate of shoreline change. DSAS requires all input data to be stored in a personal geo database. At least two digitized shorelines and a user defined baseline are required to calculate shoreline change statistics. DSAS uses the baseline to create perpendicular transect lines that are used in the shoreline change calculations. The shoreline for each epoch was extracted using the GIS enabled DSAS/HTA for every March of the epoch were the researcher presumed less influence of other factors/indicators that contribute to the shoreline change. Each epoch was made of 10 years and thus the analysis was for the year 1992 – 2002, 2002 – 2012, 2012 – 2022, and 30 years was the duration of the of the study using 1992 as the study baseline.

The shoreline extraction was carried out for the Right Hand and Left Hand sides of the Orashi River Catchment to show the transects change from one epoch to the other which horizontal distance are then measured in 200-meter interval to define the rate of change that has occurred and this was calculated with the help of the DSAS-HTA. There are many indicators that causes shoreline change but the GIS Tools considered it as a unit for carrying out the analysis.

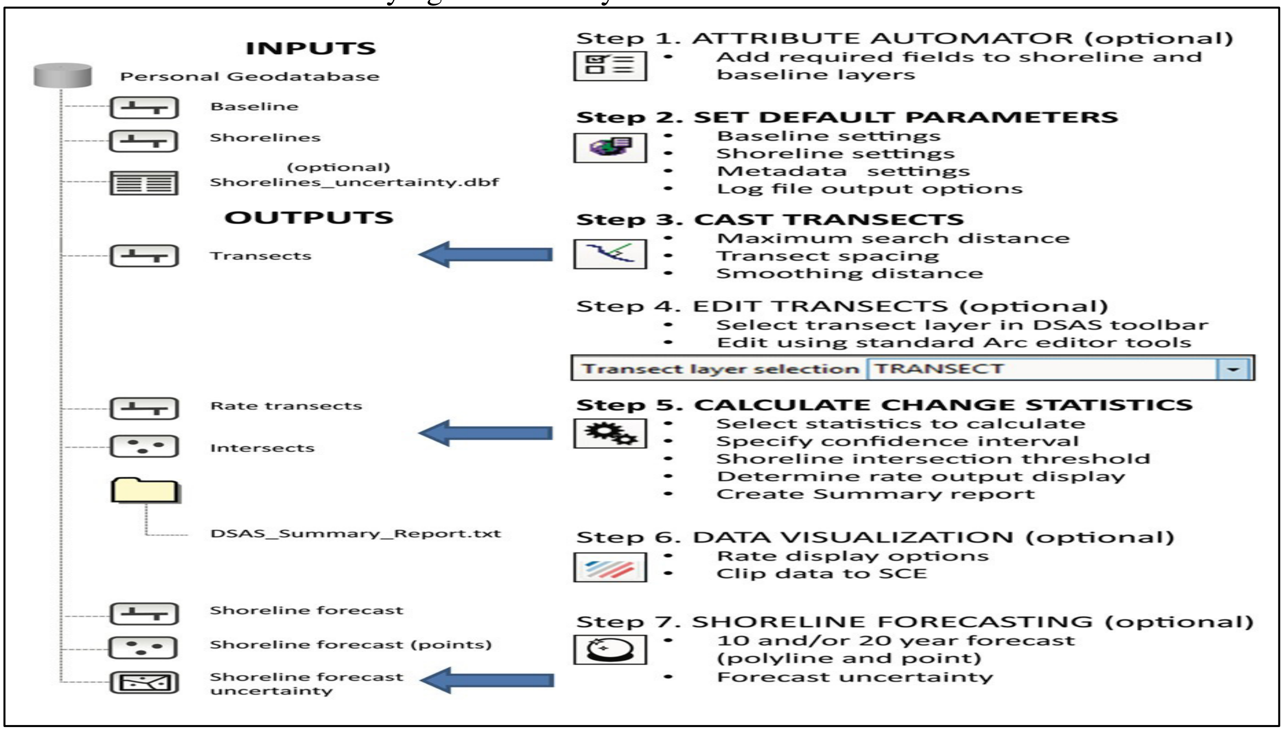


Figure 2.3. DSAS workflow from the DSAS User Guide (Himmelstoss et al. 2018).

Table 3.5: DSAS shoreline geo database field requirements (Himmelstoss et al. 2018).

Field Name	Data Type	Attribute Addition	DSAS Requirement
OBJECTID	Object identifier	Auto-generated	Required
SHAPE	Geometry	Auto-generated	Required
SHAPE Length	Double	Auto-generated	Required
DATE_ (DSAS date)	Text (Length=10 OR Length20)	User-Created	Required
UNCERTAINTY (DSAS_uncy)	Any numeric field	User-Created	Required
SHORELINE_TYPE	Text	User-Created	Optional

(DSAS_Type)			

Transects are automatically drawn by DSAS perpendicular to the baseline. Transect spacing and length can be specified by the user. A transect spacing of 200m was specified with the option to clip transects at the furthest shoreline extent for this project. After transects were cast, they were manually inspected and edited to make sure they crossed all the shorelines only once.

Land use/ Land cover (LULC)

The study analyzed the LULC changes as one of the contributors of shoreline changes in the study are a using satellite imageries. For this purpose, three classes of land use land cover changes such as vegetation, water bodies, and build-up are as were examined

Adopted LULC classes and description adopted from Elemuwa, Hart and Eze, (2021)

LU/LC Types	Description
Vegetation	forest, farm, palm, crops etc
Water bodies	lakes, pond, reservoirs, river etc
Built-up	residents, commercial, roads, Industrial, urban.

Image pre-processing and processing were performed using ERDAS 9.2 and Arcmap10.5.Landsat

3. RESULTS AND DISCUSSIONS

Table 3.1: Transects measurements of the Orashi River Shoreline Left Shore.

Transects	1992-2002 Left Shore (m)	2002-2012 Left Shore (m)	2012-2022 Left Shore(m)	Eastings (m)	Northings (m)
OL 0+000	0.19	1.88	2.05	217429.78	560043.14
OL 1+000	2.45	3.53	2.17	218428.54	560186.43
OL 2+000	3.41	1.39	1.98	218981.47	560940.65
OL 3+000	2.61	11.26	4.84	218822.72	562061.25
OL 4+000	0.59	36.24	20.45	219682.47	562817.94
OL 5+000	1.82	18.05	12.25	221093.05	563367.61
OL 6+000	1.08	26.96	10.45	220682.73	564579.08
OL 7+000	1.08	20.94	4.34	220804.76	565598.25
OL 8+000	2.50	23.21	4.45	221136.25	566541.74
OL 9+000	2.423	17.69	1.88	221308.62	567542.72
OL 10+000	0.181	1.81	1.38	222771.56	568077.51

Table 3.2: Transects Measurements along the Orashi River Shoreline at Right Shore

Transects	1992-2002 Right Shore (m)	2002-2012 Right Shore (m)	2012-2022 Right Shore (m)	Eastings (m)	Northings (m)
OR 0+000	2.45	4.65	3.38	217473.13	559911.96

OR 1+000	3.54	9.63	5.60	218467.80	560089.02
OR 2+000	1.80	28.33	6.54	219093.45	560687.55
OR 3+000	6.44	21.13	11.08	218913.19	561815.92
OR 4+000	5.05	14.01	7.32	219578.62	562638.78
OR 5+000	2.53	2.92	5.03	221144.57	563136.35
OR 6+000	1.43	31.39	17.36	220927.08	564278.16
OR 7+000	3.8	33.96	8.34	220844.18	565371.36
OR 8+000	2.97	25.37	12.62	221236.41	566292.92
OR 9+000	1.88	19.41	18.45	221265.25	567345.74
OR10+000	1.72	10.29	1.66	222674.90	567899.77

Table 3.3: Rate of Change in shoreline position (1992 - 2022)

Left	**Right**
23.734m	33.102m

Table 3.4: Area Computation Results for Each Epoch in Hectares

Year (1992-2022)	Area (ha)
1992 – 2002	116.774
2002-2012	147.363
2012-2022	152.594

Source: Authors field result, 2022.

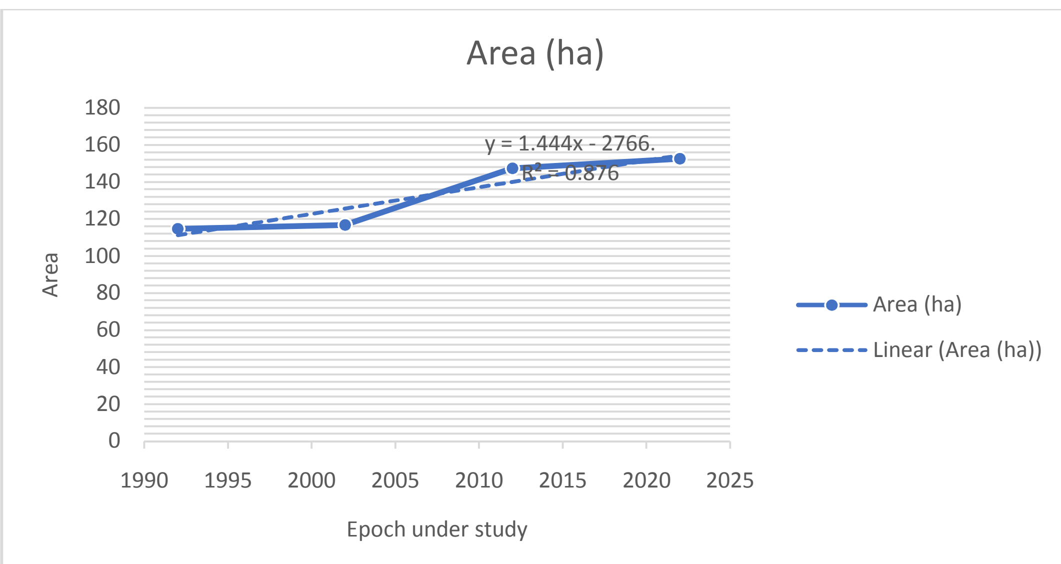
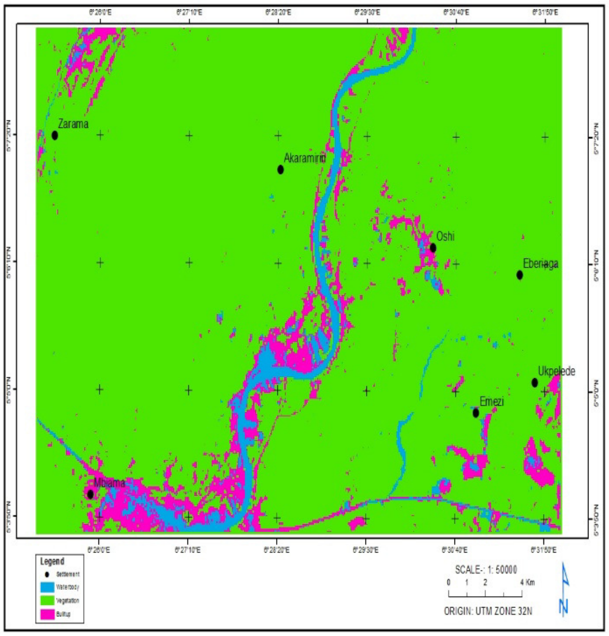


Figure 3.1: Graphical Representation of Change in Area of Shoreline under Study



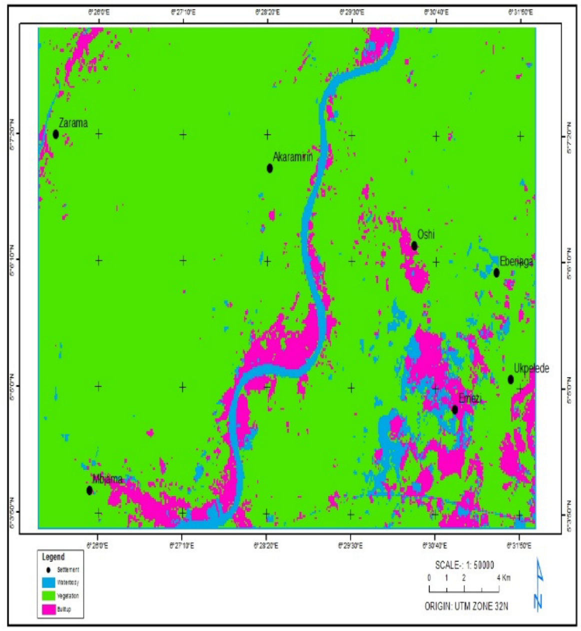
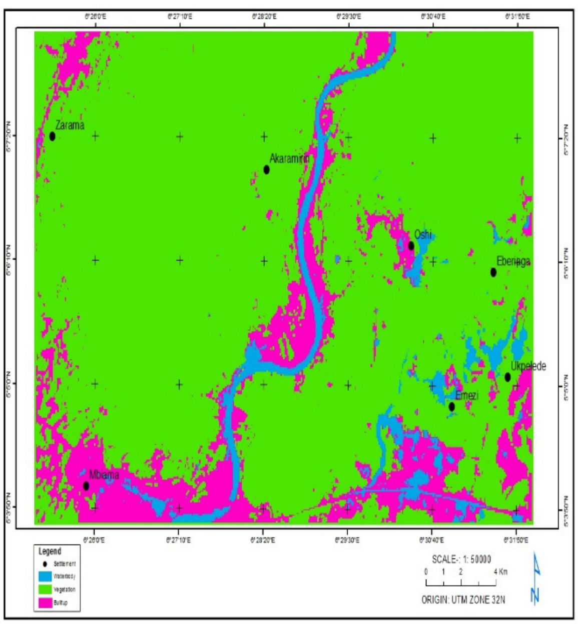


Figure 3.2: classified Map, 1992 **Figure 3.3: Classified Map, 2002**



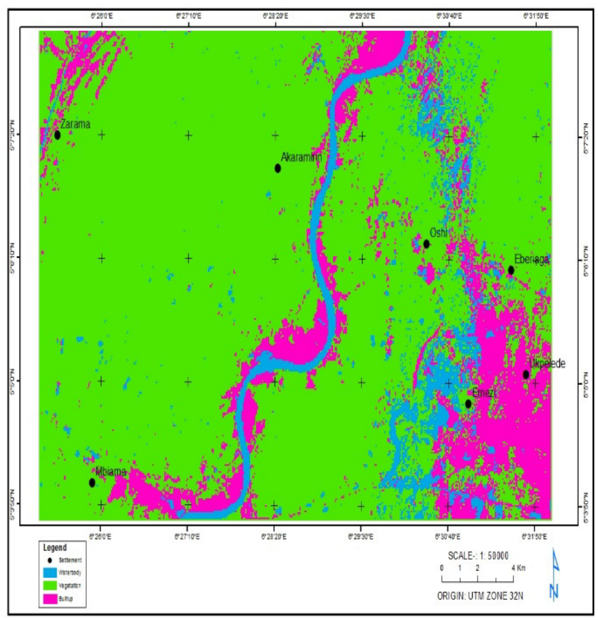


Figure 3.4: Classified Map, 2012.Figure 3.5: Classified Map, 2022.

Table 3.5: LULC Percentage Change of the Study Area

LULC Clas	1992 Area (ha	% Change	2002 Area (ha	% Change	2012 Area (ha	% Change	2022 Area(ha)	% Change
Built-up	990.63	18.35	1,103.75	20.44	1,204.81	22.31	1,310.11	24.26
Vegetation	4,207.29	77.91	4,077.70	75.51	3,805.42	70.47	3,822.39	70.79
Water Body	202.08	3.74	218.55	4.05	389.77	7.22	267,50	4.95
Total	5400.00	100.00	5400.00	100.00	5400.00	100.00	5400.00	5400.00

Table 3.6: LULC Change Detection of the Study Area

LULC Cla	1992 Area (ha	Change detection	2002 Area (ha	Change detection	2012 Area (ha	Change detection	2022 Area(ha)
Built-up	990.63	+113.12	1,103.75	+214.18	1,204.81	+319.48	1,310.11
Vegetation	4,207.29	-162.59	4,077.70	-401.87	3,805.42	-384.90	3,822.39
Water Bod	202.08	+16.47	218.55	+187.69	389.77	+65.42	267,50
Total	5400.00	0.00	5400.00	0.00	5400.00	0.00	5400.00

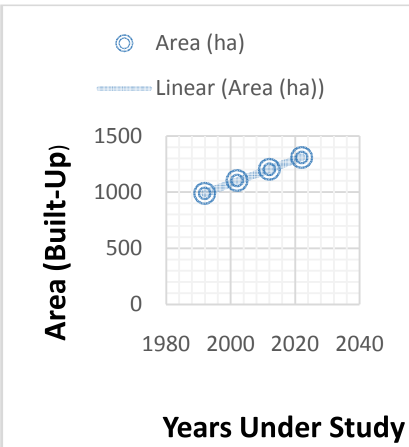


Figure 3.6: Built-up

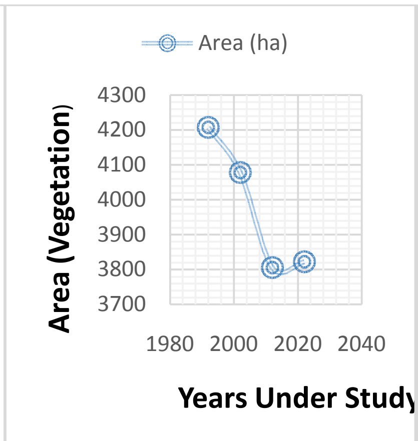


Figure 3.7: Vegetation

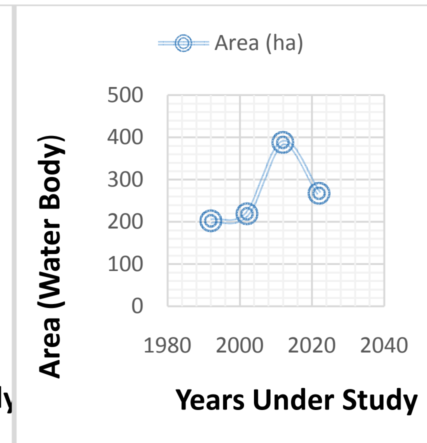


Figure 3.8: Water Body

Discussions

Table 3.2 Shows shoreline transect measurement value of the Right-hand side of the river and the shoreline change, the changes between the shoreline of 1992 – 2002 = 3.54m, 2002 – 2012 = 9.63m and 2012 – 2022 = 5.60m. As described in the table below with Ch. 1+000, OR is used as point description of the chainage along the shoreline transects of each epoch

Table 3.1: Shows shoreline transect measurement value of the Left-hand side of the river and the shoreline change, and the changes between the shoreline of 1992 – 2002 = 2.45m, 2002 – 2012 = 3.53m and 2012 – 2022 = 2.17m with Ch. 1+000, OL used as point description of the chainage along the shoreline transects of each epoch.

As shown in figures 3.2, 3.3, 3.4, and 3.5, the above table represents the changes in land use and land cover as image classification are done into three classes considering those features which contributes as indicator to change. This includes built-up areas, vegetation and water body which shows a strong spatiotemporal change dynamic in land use and land cover along the section of the Orashi river catchment and its environment. Table 3.5 and 3.6 shows the extent of change and percentage change as well as change detectors for each feature classified.

The classification map obtained from Maximum Likelihood Classifier (MLC) for each image is shown in figure 3.2 - 3.5 below. Image classification was carried out in order to establish vegetation lines adopted as shoreline boundaries.

The area of LULU classified covers a total of 5400 hectares of land which is made up of three features such as vegetation, built up and water body.

The time series graphs in figure 3.6, 3.7 and 3.8 indicates an increase in built-up, a continuous decrease in vegetation, whereas area covered by water body has a significant upward and downward changes. The high increase in water body in year (2012) may be attributed to the flood that occurred in the study area which resulted to loss of lives, food products and properties.

4. Conclusion

The combination of the Image processing techniques of Remote Sensing and GIS enabled DSAS-HTA software provided a unique and vital tool extracting, analyzing the changes of the shoreline over the time.The changes identified in the shoreline under study has justified the necessity of this study. The available data were properly utilized to achieve the study aim and objectives.

5. Recommendations

Shoreline is dynamic in nature. Hence there is need for the relevant Government, its Agencies and the Coastline users to pay proper attention to factors that causes shoreline change. Periodic mapping and monitoring of the shorelines using geospatial techniques to identify the position of the shoreline is required to forestall possible shoreline total collapse.

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