



Assessment of Shoreline Changes of Kaiama Stretch of the Nun River, Bayelsa State, Nigeria

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ABSTRACT

Original Research Article

Shoreline is the transition between land and water body and it is susceptible to changes due to various coastal processes such as waves, tides, currents, storm surges, accretion, erosion, and anthropogenic activities such as dredging, mining, and various coastal Engineering constructions. The shoreline of the Nun River in Kaiama Town in Kolokuma/Opokuma Local Government Area (LGA) is affected by the processes of erosion and accretion and this phenomenon has constituted various natural hazards such as the annual river bank erosion that has led to the destruction of natural and artificial resources and also commercial activities. This research work aimed at assessing the shoreline changes in Kaiama stretch of the Nun River in Kolokuma/Opokuma LGA, to facilitate this, Remote Sensing (RS) and Geospatial Information System (GIS) were integrated to address the aim of the study. The shoreline for 1979 - 2019 were defined for each of the remotely sensed imagery for the four epochs, an overlay map was generated for the four sets of imageries obtained and a shoreline change map was produced on a scale of 1:20,000. The results revealed that the rate of changes on the left and right side of the Nun river for the following epochs were 1989 - 1999; 7.306m & 8.371m, 1999 - 2009; 14.246m & 16.263m, 2009 - 2019; 10.089m & 9.384m, 2019 - 2023; 13.211m & 24.724m respectively. These values represents the average distance change between shoreline vertices giving insights into the coastal erosion and accretion dynamics, the study revealed that coastal erosion and accretion simultaneously impacts both sides (left and right) of the Nun River.

Keywords: Accretion, Dynamics, Erosion, Shoreline, Transition.

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Introduction

Water covers approximately 71% of the Earth's surface; oceans, seas, and other water bodies, and the majority of the cities with larger populaces are situated near a coastline. According to Eke and Iyowuna (2022), 39 of the capital cities of the world with populations of more than 5 million people are within 100 kilometers of the coast. The Coastal zone is a dynamic area which connects terrestrial zone to the marine zone and it constitutes about 10% of the land area but it is a densely populated area sustaining as much as 60% of the world's population. Hart, Frank, and Eke (2020) say that the shoreline is the line that separates land from the sea or ocean. The shore has multi benefit as it provides riparian settlements

with food, potable water, transportation of oil and natural gas resources and job recreation, (Hart, Frank and Eke, 2020). It provides harbors, beaches and shorelines which attract residents for tourism, wetlands and estuaries that are critical for sustained fisheries (Addo, 2015 in Hart, Frank & Eke, 2020).

Shoreline represents the border between land and water body, which is prone to change resulting from the many coastal processes, example near shore circulation, waves, currents, tides, storm surges, accretion, erosion, and anthropogenic activities such as dredging, mining, water extraction, and construction (Eteh, Abiola, Digha, Alfred & Francis, 2022). The coastline displays how the shore changes and how the

shoreline moves over time. The significant alterations in the shoreline's morphology are mostly attributable to human activities and natural processes, resulting in either erosion or accretion (Hart, Frank, & Eke, 2020). Other processes include sedimentation, wind, wave, and sea level rise patterns also cause changes in the shoreline (Arunkumar, Dodamani, & Dwarakish, 2017).

Many beaches around the world have problems with erosion (wearing down the top surface) and accretion (building up loose materials in a place). Erosion takes away land and other natural and manmade resources along the shoreline, while accretion adds land area to the sea (Eteh et al., 2022). Geospatial Information Systems (GIS) is a digital framework that is used to analyse such data by measuring and comparing previous and current shoreline locations. The integration of satellite Remote Sensing and GIS techniques provides a formidable basis for the identification, mapping, and analysis of shoreline changes over time (Egai, Eteh, & Inko-Tariah, 2021).

The geospatial interface of the shoreline, which is the line between land and sea, as well as the different ways that land is used and the effects of geological and hydrodynamic phenomena, have made shoreline change one of the most common processes in coastal areas. These changes can happen in different ways over short and long periods of time. Understanding sediment erosion, transport, and deposition is one of the most critical and delicate marine processes that directly affects the design of ports and marine structures and coastal management as a whole. Coastal areas, estuaries, canals, and coasts have all seen changes in erosion and sedimentation because of more rain.

Consequently, discerning the predominant methodology for assessing volatility and positional shifts of the shoreline is the paramount criterion necessary for effective coastal management. (Tamassoki, Amiri, & Soleymani, 2014).

Erosion, accretion, and morphodynamics are the most important things to look for while trying to find changes along the shoreline. Shorelines are the places where land and sea meet. Because they are in a constantly changing environment, they are always changing due to natural causes such changes in shape, climate, or geology. The shoreline features are shaped by the ever-changing interplay between waves, tides, rivers, and physical processes.

Shoreline change over the years have become a significant concern in Yenagoa and other regions worldwide, leading to the loss of lives, property, and farmlands. In Kaiama Town, located in Kolokuma/Opokuma LGA Bayelsa State, Nigeria. The Nun River shoreline has undergone substantial transformations due to erosion and accretion processes. This phenomenon has resulted in various natural hazards, including annual riverbank erosion, which has led to the destruction of both natural and man-made resources, as well as commercial activities such as farming, housing, transportation, and electricity infrastructure. The impacts of River-bank erosion in the study area have significantly affected the livelihoods of residents and the environment over the years.

Some of the consequences include homelessness, financial instability, economic decline, disruptions to agricultural activities, and negative effects on health, education, and settlement patterns. Additionally, there is a growing risk of structural collapse, particularly affecting key infrastructure such as an Anglican Church Cathedral and the bridge connecting Kaiama Town to Sampou and Zarama via the East-West Road (Elele-Alimini-Patani Road), as depicted in Plate 1. Given these challenges, this study is essential for assessing the extent of shoreline changes and their implications. The findings will provide valuable insights for predicting potential future risks and formulating proactive solutions to mitigate the adverse effects of riverbank erosion in the region.



Plate 1: Shoreline Dynamics of a Section of the Nun River (a) and (b) in Kolokuma/Opokuma LGA, Bayelsa State.
Source: Author's field Study, 2023.

The study focus is to assess shoreline changes in Kaiama stretch of the Nun River in Kolokuma/Opokuma LGA, Bayelsa State by downloading satellite imageries and defining the shoreline for each of the remotely sensed imagery for five (5) epochs (1979 - 2023) and generate an overlay map for the four set of datasets acquired in order to provide shoreline change deliverable for the study area.

Study Area

The Nun River is a river that runs through Bayelsa State in Nigeria. When the Niger River splits into two at Toru-Abubou, near Agbere Town in the Sagbama Local Government Area, the Nun River is formed. The Nun River flows for almost 160 kilometres (100 mi) south to the Gulf of Guinea at Akassa (Uma, 1988). Its course runs mainly through thinly settled areas and swamps. In the 19th century,

the Nun was a hub for trade between the Igbo Kingdom, which was based at Aboh, and Europe. The river's trading history began with the trade of slaves but was later replaced by palm oil export. However, at the turn of the century, the river mouth silted heavily, blocking the passage. Subsequently, traders began using the more accessible waters of the Forcados River.

The Nun River is immortalised in the poetry of Gabriel Okara in his poem "The Call of the River Nun" it is a nostalgic ode to the river that passes through his home (Uma, 1988). The Nun River across Kaima Town, Kolokuma/Opokuma LGA is bounded by the following projected coordinates in Universal Transverse Mercator (UTM) Zone 32North, World Geodetic System (WGS) 84 shown.

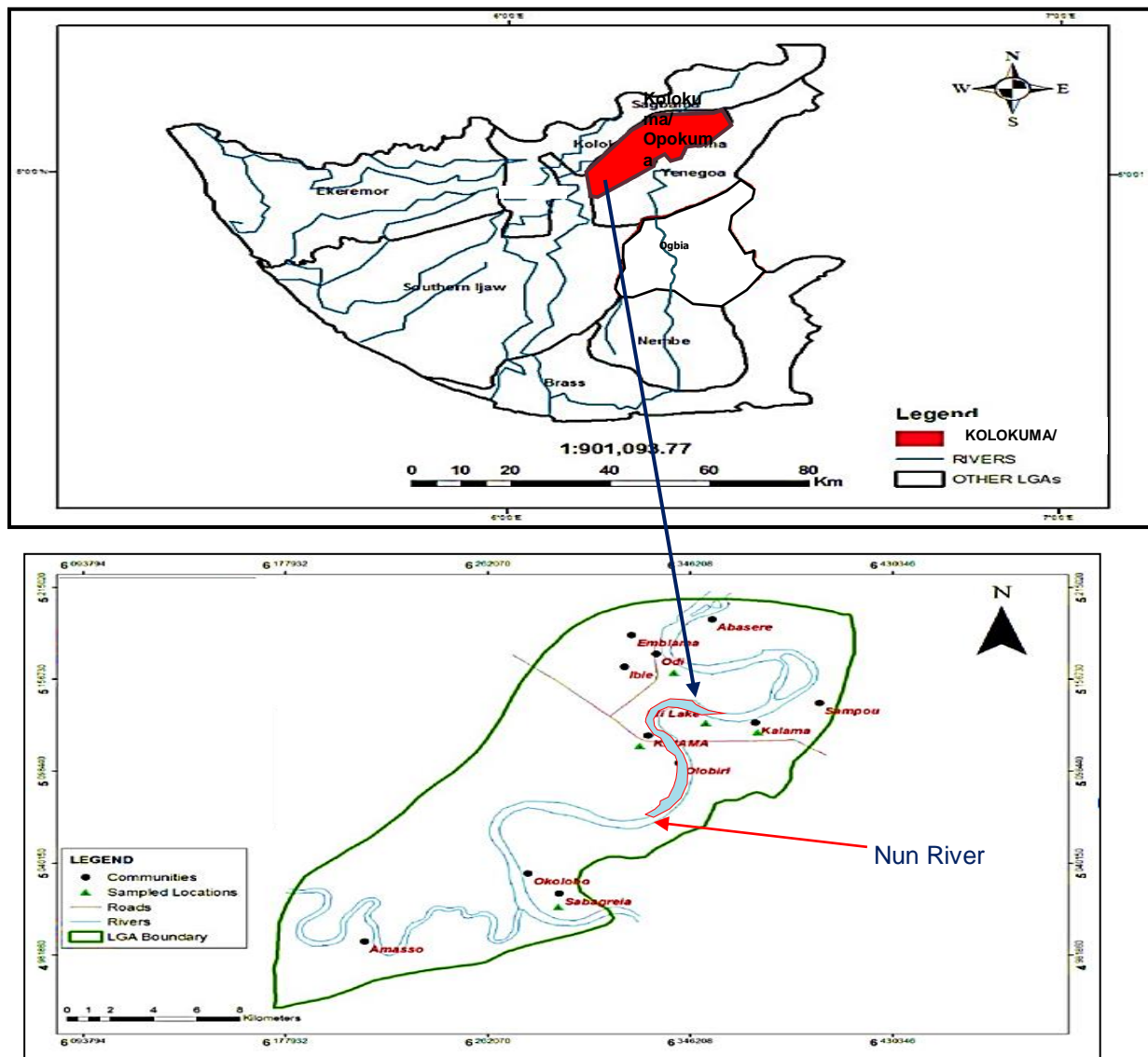


Figure 1: Map of Bayelsa State Showing the Study Area.

Source: Nwankwoala, Egesi and Agi, (2016); Abadom and Nwankwoala (2018).

Materials and Methods

For the purpose of the research work, the quantitative research approach was adopted as the study was based on observations and measurements in assessing and detecting changes that occurred on the shoreline in the study area.

Remote Sensing (RS) and GIS tools were integrated in addressing the aim and the objectives of the study. Instruments used in the course of this research work are; Garmin GPS Map 76Csx, Personal Computer, Field Book and Writing Materials as shown Table 1.

Table 1: Software and Hardware selection

S/N	Software	Hardware
1.	QGIS 3.28.7	Printer
2.	ArcGIS 10.7 plus Digital Shoreline Analysis System	Scanner
3.	Google Earth Pro 2023	Laptop
4.	Microsoft Office Suite (Word, Excel) 2013	Field book
5.		Camera
6.		Garmin GPS Map 76Csx (handheld GPS receiver)

Data Acquisition

Reconnaissance: This is the primary investigation or examination of an area that is to be surveyed; this enables the surveyor to prepare a framework for the survey. The end product of a reconnaissance survey is a reconnaissance diagram or index sketch. The reconnaissance survey was used to prepare a framework for execution of the research;

1. Acquisition of coordinates at various intervals of the shoreline using Handheld GPS receiver.
2. Information about the shoreline from secondary sources like Google Earth that aided the geo-referencing and digitizing of the river from existing topographic map.
3. The best possible approach for the shore delineation was ascertained.

4. Decision was made on choice of datasets.

Primary Data Sources: These are data that were acquired directly on the field or from field observation. These includes: coordinates of some points on the shoreline and photographs of the study area.

Secondary Data Sources: These are data that were extracted or gotten from an existing work. Secondary data needed for this research work are; topographic maps and academic articles were used to gather information on the study area; including historical shoreline changes, and environmental data, and other relevant information.

Table 2: Data, Sources and Year of acquisition

Data	Sources	Year
Topo Map Sheet 319	Office of the Surveyor General of the Federation (OSGOF)	1979
LANDSAT Datasets	US Geological Surveys	1989-2023
Shoreline Delineation	Primary Field Data	2022

Table 3: LANDSAT Dataset and Description

LANDSAT Data	Acquisition Date
LANDSAT LT04_L1TP (Baseline Data)	1989-12-26
LANDSAT LE07_L1TP	1999-12-06
LANDSAT LE07_L1TP	2009-06-08
LANDSAT LE07_L1TP	2019-12-29
LANDSAT LC09_L1TP	2023-04-28



Figure 2: Topo Map Sheet 319, 1979, Showing Kaiama Town.
Source: OSGOF, 1979.

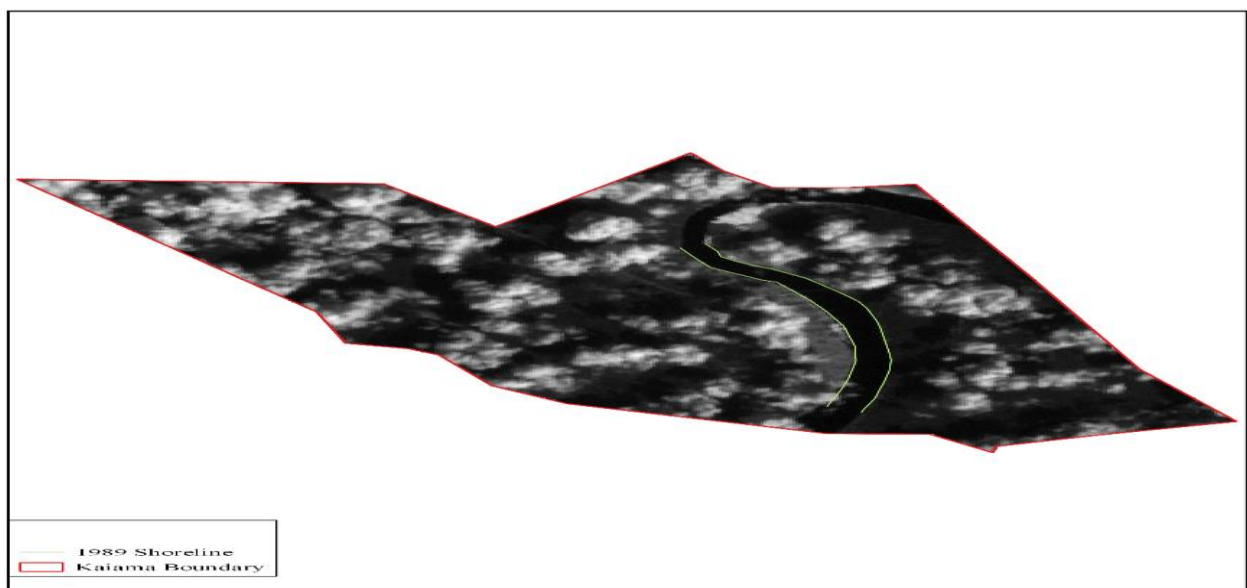


Figure 3: 1989 LANDSAT Imagery of Kaiama Town.
Source: US Geological Surveys, 1989.

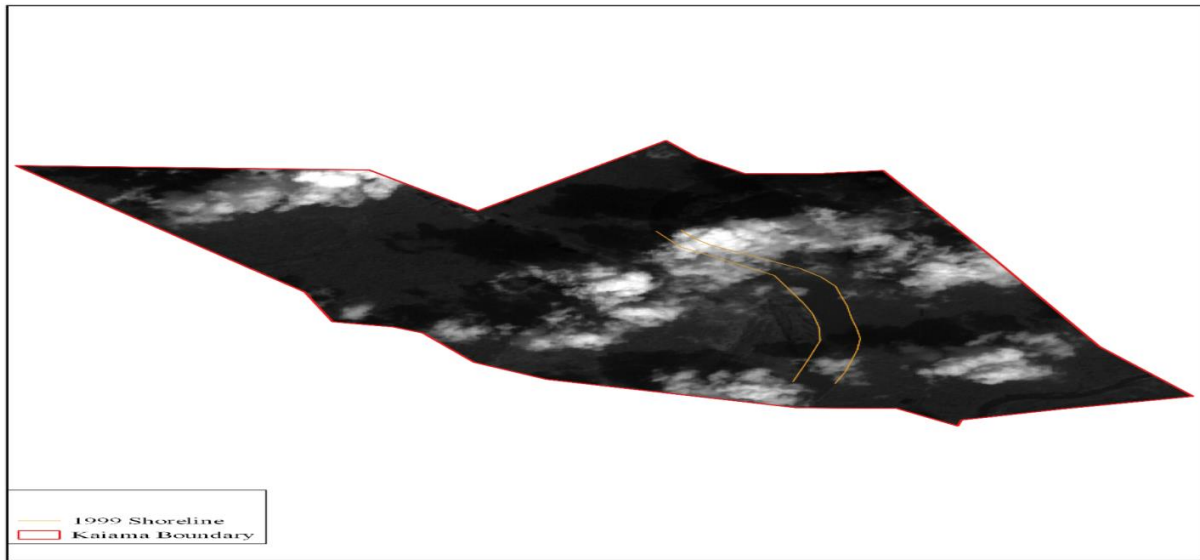


Figure 4: 1999 LANDSAT Imagery of Kaiama Town.
Source: US Geological Surveys, 1999.



Figure 5: 2009 LANDSAT Imagery of Kaiama Town.
Source: US Geological Surveys, 2009.

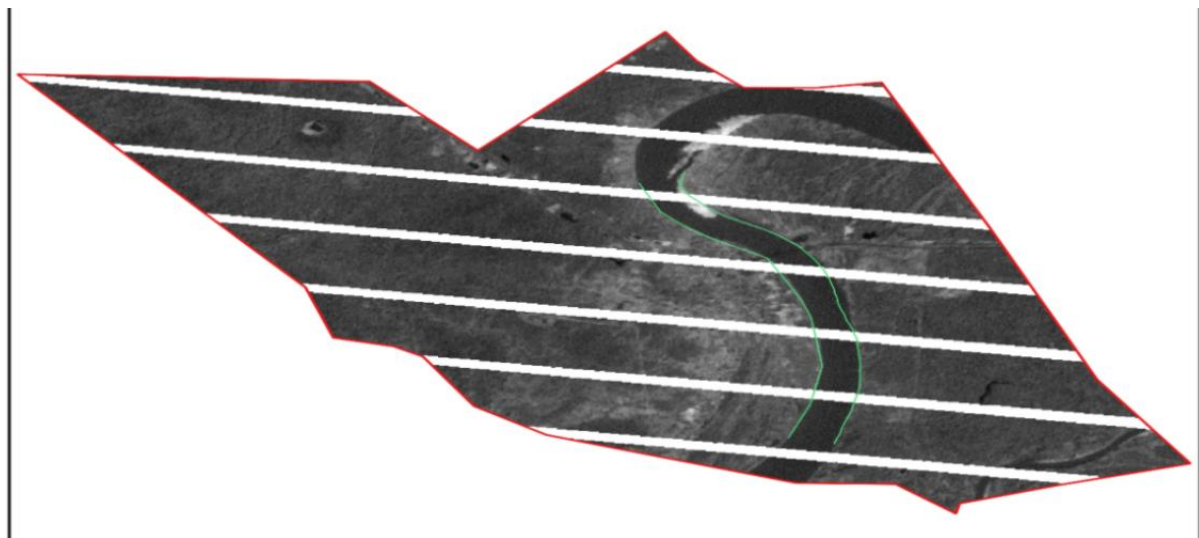


Figure 6: 2019 LANDSAT Imagery of Kaiama Town.
Source: US Geological Surveys, 2019.

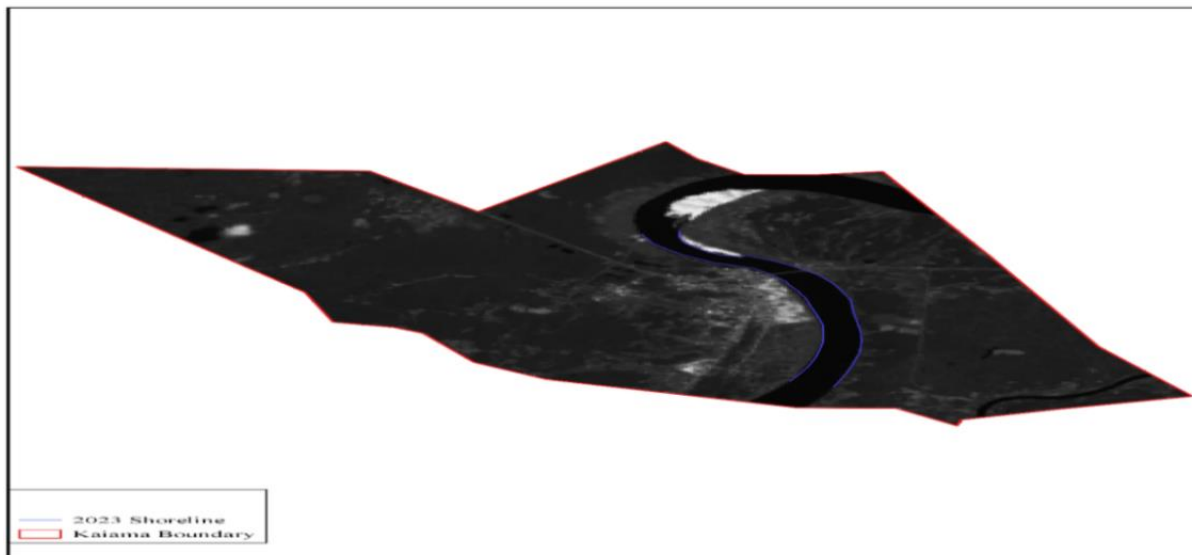


Figure 7: 2023 LANDSAT Imagery of Kaiama Town.
Source: US Geological Surveys, 2023.

Data Processing

Assessment Procedures using Satellite Datasets

After downloading the satellite datasets covering the project area for the different years of interest, they were imported to QGIS for the necessary preprocessing. A shape file of the Nun River was also imported to the GIS software to confirm an overlay of the study area on the images. The image processing procedure includes the following key steps for satellite datasets: Image Preprocessing, Water Separation and Spatial Filtering.

1. **Image Preprocessing:** This involves converting the raw satellite images into a format that can be used for analysis. The steps involved in preprocessing includes; Radiometric Correction and Geometric Correction.
 - a. **Radiometric Correction:** This involves correcting for variations in brightness and contrast caused by atmospheric conditions and sensor differences.
 - b. **Geometric Correction:** This involves correcting for distortions in the image caused by the sensor and the Earth's surface.
2. **Water Separation:** Dry land and most of the clouds are removed.
3. **Spatial Filtering:** Speckle noise in the LANDSAT imagery is removed using spatial filtering.

Data Analysis

Data analysis of shoreline changes was done utilizing Digital Shoreline Analysis System (DSAS), a widely used software

tool in coastal research and management that facilitates assessing shoreline movement over time. The analysis began with data preparation, where the selected dataset was preprocessed to ensure compatibility with DSAS. This involved geo-referencing the images, making necessary corrections (such as ortho-rectification), and digitizing shorelines and baselines into a personal geo-database for accurate shoreline positions. Next, DSAS was configured with appropriate settings and default parameters to suit the analysis. This included defining the reference baseline, specifying measurement transects, and selecting desired measurement intervals. DSAS was then used to predict future shoreline positions from the prepared dataset, employing various algorithms and techniques for accurate predictions.

Statistical analysis was conducted on the extracted shoreline positions to derive meaningful insights. This involved calculating rates of shoreline change, identifying erosion and accretion areas, and examining trends and patterns over the study period. To enhance understanding and communicate key findings effectively, the analyzed data and results were visualized using maps, illustrating the magnitude and spatial distribution of shoreline changes. The data analysis and interpretation provided valuable insights into the dynamics of shoreline changes in the study area, contributing to a better understanding of coastal processes and informing decision-making for coastal management and adaptation strategies. Below are the results of the shoreline for the years of study.

Results and Discussion

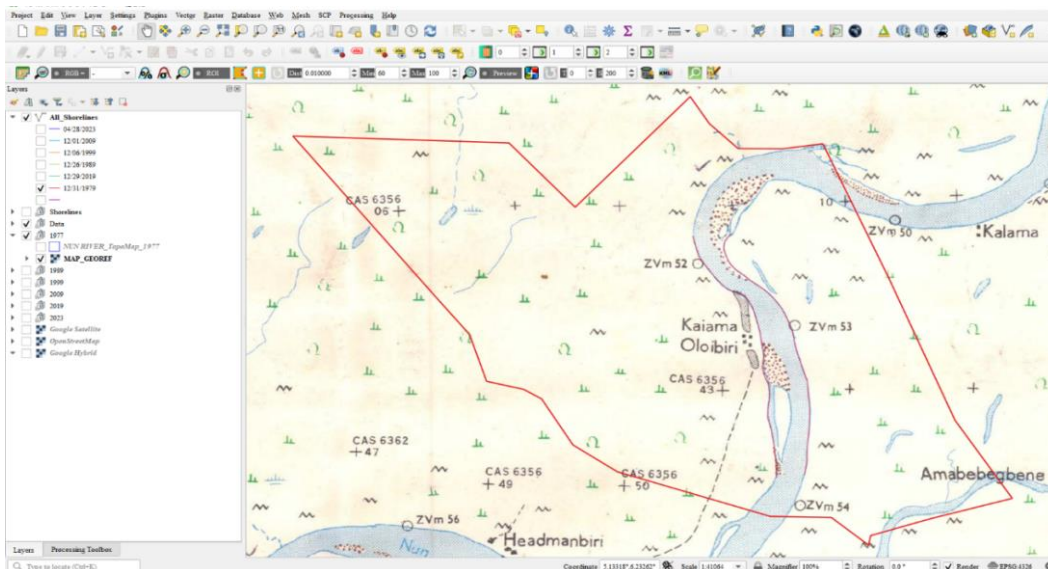


Figure 8: Shoreline of the Kaiama Stretch of the Nun River in 1979.

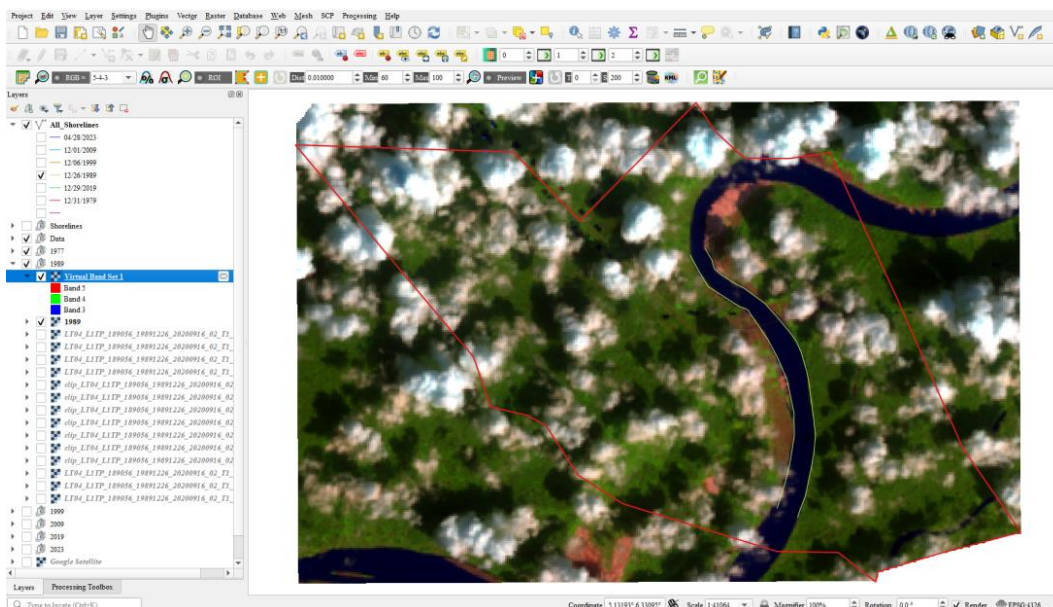


Figure 9: Shoreline of the Kaiama Stretch of the Nun River in 1989.

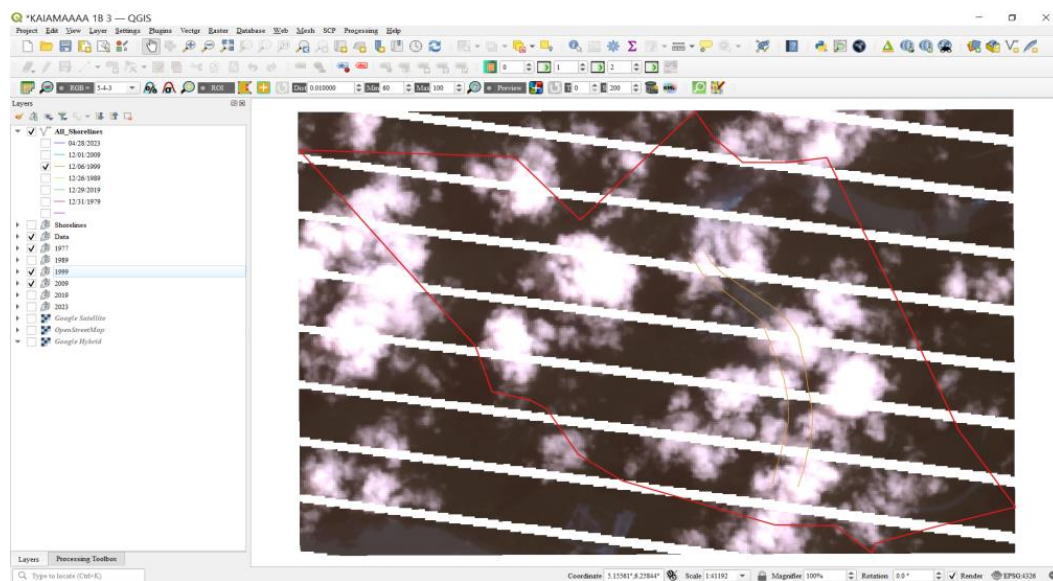


Figure 10: Shoreline Dynamics of the Kaiama Stretch of the Nun River in 1999.

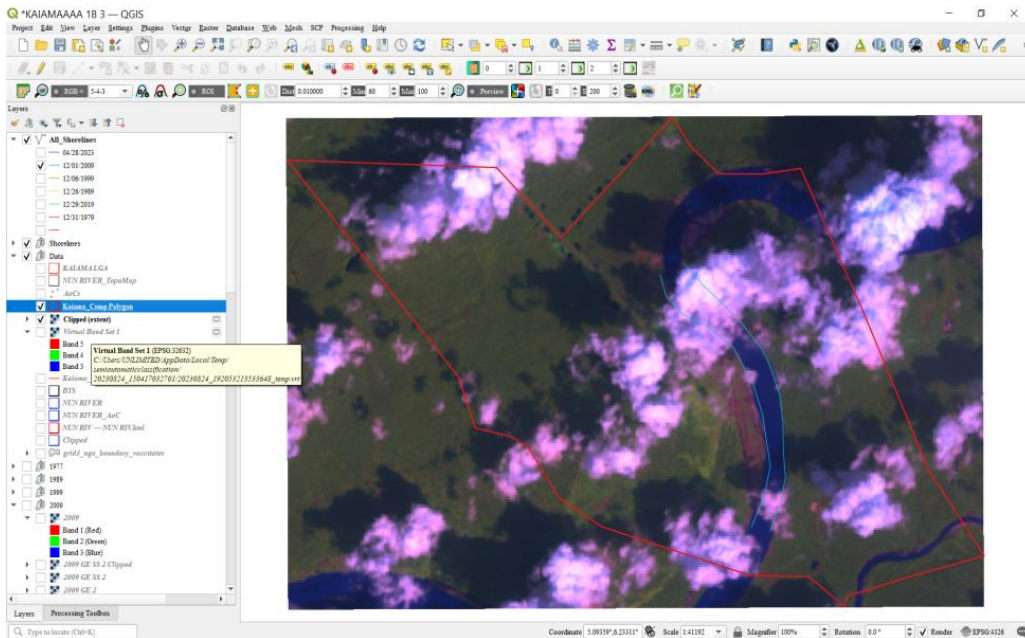


Figure 11: The Shoreline Dynamics of the Kaiama Stretch of the Nun River in 2009.

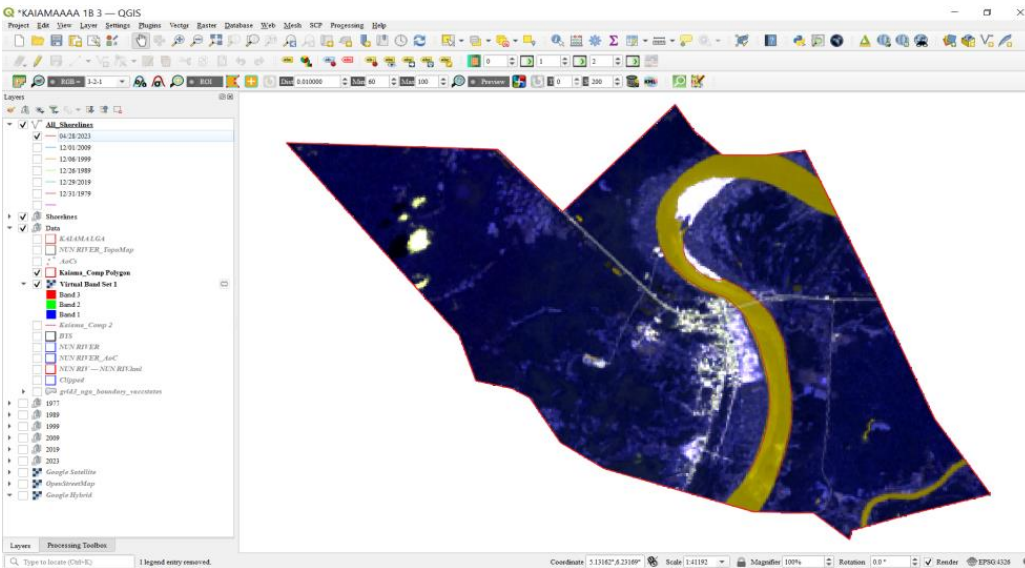


Figure 12: The Shoreline Dynamics of the Kaiama Stretch of the Nun River in 2023.

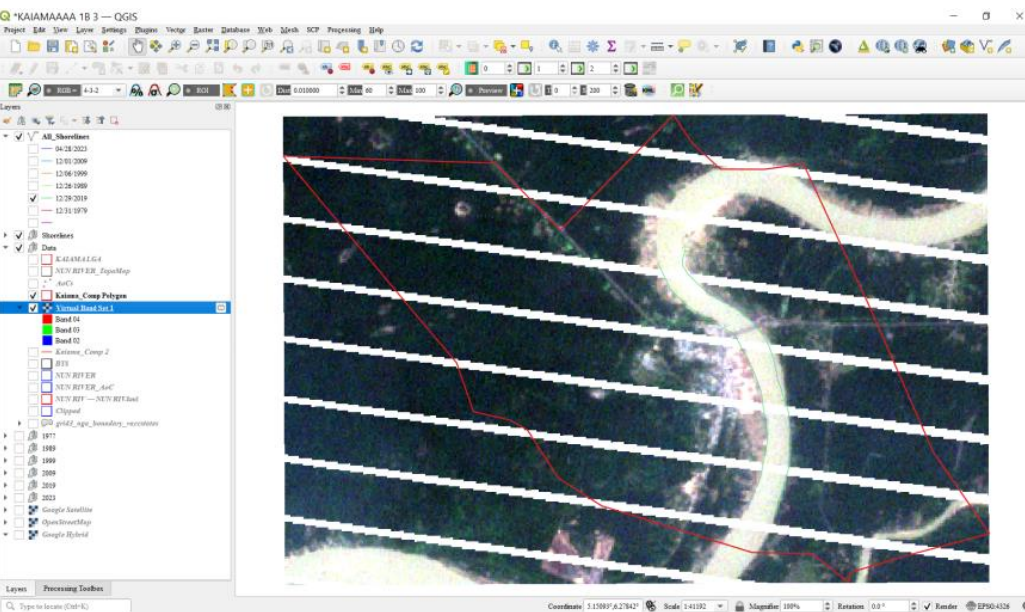
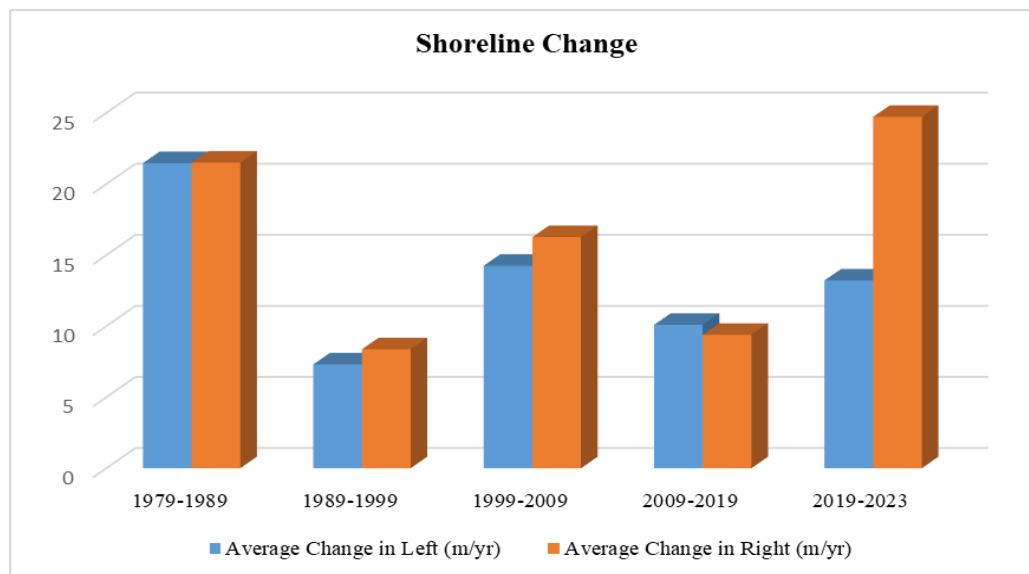
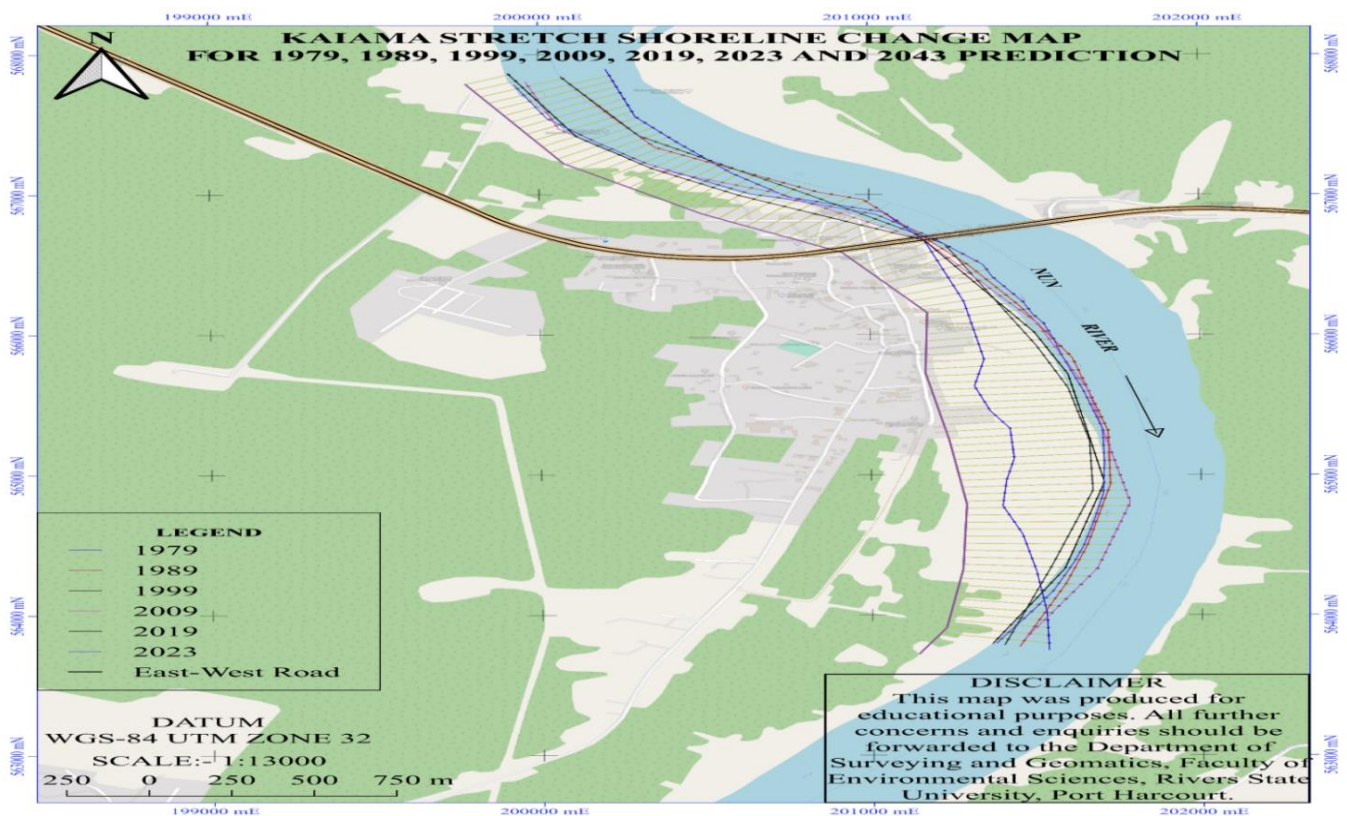


Figure 13: The Shoreline Dynamics of the Kaiama Stretch of the Nun River in 2019.

Table 4: Rate of Shoreline changes in Kaiama Stretch of the Nun River

Time Period	Left Average Change (m/yr.)	Average Change in Right (m/yr.)
1979 - 1989	21.465	21.504
1989 - 1999	7.306	8.371
1999 - 2009	14.246	16.263
2009 - 2019	10.089	9.384
2019 - 2023	13.211	24.724

**Figure 14:** Chart Illustrating the Shoreline Changes in the Left and Right of the Nun River.**Figure 15:** Map showing the Dynamics of the Shoreline in the Study Area.

Findings and Discussion

The analysis of shoreline change in Kaiama reveals significant alterations on both the left and right sides over the study period (1979 - 2023). The study utilized digitized shorelines from LANDSAT satellite dataset for five different years and compared them to determine the rate of shoreline

changes. The results are visually represented in Table 4 and Figures 14 to 16. Table 4 provides the average shoreline changes per year for both the left and right sides during various time periods. These values represent the average distance change between shoreline vertices, giving insights into the coastal erosion or accretion dynamics.

The study indicates that coastal erosion and accretion simultaneously impact both sides (left and right) of the shoreline at different epochs. The directions of flow on the shoreline change and prediction map, as shown in Figure 16, help identify the left and right sides. During the period 1979 - 1989, the left shoreline experienced an average annual change of approximately 21.465m between its vertices, suggesting a rapid coastal erosion or accretion process. Similarly, the right shoreline had an average annual change of about 21.504m. Moving to 1989 - 1999, the average annual change for the left shoreline reduced to approximately 7.306m, suggesting a slower rate of change and possible stabilization or a less significant erosion/accretion process.

The right shoreline also exhibited a slower average annual change of about 8.371m during this period. For the period 1999 - 2009, the left shoreline experienced an average annual change of approximately 14.246m, indicating an intensified erosion or accretion process compared to the previous decade. The right shoreline also had an increased average annual change of approximately 16.263m. Between 2009 and 2019, the left shoreline displayed a relatively steady average annual change of about 10.089m, suggesting a consistent erosion or accretion process during this time. Similarly, the right shoreline showed a consistent average annual change of approximately 9.384m during this period.

From 2019 to 2023, the left shoreline exhibited an increased average annual change of approximately 13.211m, possibly indicating an acceleration of the erosion or accretion process. The right shoreline, on the other hand, showed a significant increase in the average annual change, measuring approximately 24.724m, suggesting an intensified erosion or accretion process during this time. In summary, the analysis highlights the varying rates of shoreline changes in Kaiama Town over the study period, with both erosion and accretion processes impacting the left and right sides of the shoreline at different intensities throughout different epochs.

Conclusion

The purpose of this research was to investigate the dynamics of shoreline alteration along the River Nun, in Kaiama Town, Kolokuma/Opokuma LGA, Bayelsa State, Nigeria, using geospatial techniques and tools. The analysis of multiple imageries and topographic maps spanning several decades revealed significant alterations in the shoreline over time. The results demonstrated that Kaiama has experienced notable shoreline changes, with varying rates of erosion and accretion. The analysis of average shoreline changes reveals fluctuations in erosion or accretion processes over different time periods. The findings indicate significant average changes from 1979 to 1989, followed by a decrease in the rates of change from 1989 to 1999. Subsequently, there was an increase in average changes from 1999 to 2009, followed by relatively steady rates of change from 2009 to 2019.

Finally, there was an observed increase in rates of change from 2019 to 2023.

The integration of RS and GIS proved to be effective in capturing and analyzing the shoreline changes. By combining historical data with contemporary imagery, a comprehensive understanding of the coastal dynamics was achieved. The generated maps provided visual evidence of the evolving shoreline and highlighted areas of concern. The observed shoreline changes in Kaiama have important implications for coastal management and planning. These underscore the vulnerability of the area to coastal hazards and the need for sustainable development practices. The information obtained from this study can aid decision-makers in formulating strategies to mitigate the adverse impacts of shoreline changes and ensure the long-term resilience of the coastal community.

Further research is recommended to investigate the underlying factors driving the observed shoreline changes in Kaiama. This could involve studying sediment transport patterns, hydrodynamic processes, and human activities influencing the coastal environment. Such knowledge will contribute to more accurate predictions and informed decision making regarding coastal management and adaptation measures. Overall, this study enhances our understanding of the dynamics of shoreline changes in Kaiama Town and provides valuable insights for coastal planning and resilience-building efforts. It emphasizes the importance of employing remote sensing and GIS techniques to monitor and assess coastal environments, ultimately contributing to sustainable coastal development. Finally, decision makers will be able to identify susceptible locations and create more effective responses to coastal challenges with the aid of the current study of shoreline changes.

Recommendations

The shoreline is very dynamic due to anthropogenic and natural processes so there is a need to critically investigate the processes ongoing along our shorelines. Hence, the study recommends:

1. The rate of change along the shoreline must be monitored to detect eroding areas subsequently so as to avert further damage to infrastructures.
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. There should be a regulation of anthropogenic activities carried out within the shore.

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