International Journal on Engineering Technologies and Informatics

Investigation of Coastline Changes in Sagbama, LGA Bayelsa State, Nigeria Using Remote Sensing

Research Article

Volume 4 Issue 4- 2023

Author Details

Oborie Ebiegberi[1], Fatunmibi Ibukun Emmanuel[2] and Onwuka Echezona Lawrence[3]*

[1]*Department of Geology, Niger Delta University, Nigeria*

[2]*Department of Marine Science, University of Lagos, Nigeria*

[3]*Department of Mechanical Engineering and Production Technology, Nnamdi Azikwe University, Nigeria*

*Corresponding author

Oborie Ebiegberi, Department of Geology, Niger Delta University, Wilberforce Island, Bayelsa State, Nigeria

Article History

Received: December 05, 2023 Accepted: December 14, 2023 Published: December 15, 2023

Abstract

Coastal erosion and accretion have emerged as a significant geological and environmental concern to numerous coastal communities of the Niger Delta. To investigate these phenomena, this study utilized Landsat imagery data from the United States Geological Survey (USGS) and geospatial technique (ArcGIS 10.6) for the data analysis. This research is particularly focused on the coastline dynamics in Sagbama communities over a span of 30 years (from 1991 to 2021). The results show that during the 1991-2001 period, approximately 8.88km^2 of the coastal area experienced erosion, while 12.01km^2 underwent accretion. Moving to 2001-2011, the erosion rate was 8.18km^2, with 16.47km^2 of accretion observed during the same time frame. Subsequently, from 2011 to 2021, the erosion-affected area decreased to 7.71km^2, accompanied by 8.29km^2 of accretion. The study's findings bear significant implications for policymakers and environmentalists, offering vital insights to devise effective strategies for mitigating erosion and fostering sustainable land use practices. Understanding the patterns of erosion and accretion is crucial for developing measures to safeguard coastal communities and their ecosystems in the face of ongoing environmental changes.

Keywords: Landsat Imagery, Accretion, Erosion, Coastline, Geospatial Technique

Introduction

The coastal areas of Bayelsa State in Nigeria have experienced substantial transformations in their coastline over the years, with both erosion and accretion processes at play. These changes have far-reaching implications, both positive and negative, for local communities [1]. The understanding of these dynamic trends in coastline alterations is crucial for effective coastal management and strategic planning [2]. Coastline change encompasses the fluctuation in land area along the marine boundary, which includes erosion (leading to land loss) and accretion (resulting in land gain) [3]. It serves as a vital indicator of environmental challenges in coastal regions, particularly in areas facing sea level rise, coastal erosion, and other coastal hazards [4]. The issue of coastline change is multifaceted and carries considerable implications. As coastlines shift, the natural habitats of various flora and fauna are significantly impacted. Furthermore, these alterations may jeopardize cultural resources, facilities, and critical infrastructure, thereby posing a substantial challenge for local communities and authorities [5].

To effectively tackle this issue, it is imperative to detect and understand coastline changes early on and establish a baseline understanding of normal coastline behavior. Continuous monitoring of coastline changes over an extended period is essential to gain insights into their multifaceted effects. According to Cozannet et al. [5], studies on geographic information have shown that global sea levels have risen by approximately 20 centimeters since the mid-19th century. The precise role of this process in contemporary and historical coastline mobility remains a subject of ongoing debate. Nevertheless, it is widely acknowledged that rising sea levels are a contributing factor to coastline alterations (Courtillot et al., 2022). Coastline changes are primarily driven by factors such as erosion and flooding. Erosion, which leads to the gradual loss of land to the sea, is often exacerbated by human activities such as deforestation, sand mining, and the construction of poorly planned infrastructure [6]. Flooding, on the other hand, can be triggered by factors like heavy rainfall, storm surges, and tidal changes. Both of these phenomena interact with each other, making it essential to comprehensively study and monitor their impact on Sagbama's coastline [7]. Remote sensing technologies have emerged as powerful tools for tracking and analyzing coastline changes. Satellite imagery, aerial photography, and other remote sensing techniques allow researchers and policymakers to observe these alterations with precision and consistency over time [8,9]. These technologies enable the creation of accurate coastal maps, the identification of erosion hotspots, and the assessment of accretion areas [10]. Additionally, remote sensing aids in predicting potential threats and formulating strategies for mitigating the adverse effects of coastline changes [11]. Therefore, the coastline changes in Sagbama, LGA Bayelsa State, Nigeria, are a critical concern that demands systematic monitoring and proactive management. The impacts of these changes extend beyond mere land loss and can disrupt ecosystems, culture, and infrastructure. By leveraging remote sensing technologies and interdisciplinary research, we can gain a deeper understanding of the forces driving these changes and develop sustainable solutions to protect and preserve this vital coastal region for future generations. Addressing these challenges requires collaboration among scientists, policymakers, and local communities to ensure the resilience and sustainability of Sagbama coastline.

Location of Study Area

The study area is located in the southern flank of the Niger Delta Region of Nigeria. It is located in Sagbama Local Government Area of Bayelsa State, Nigeria. It lies between Latitude 60831011E and Longitude 50271011N. It is accessible by road. The Topography of the study area is a flat, low-lying sedimentary basin sloping gently seaward and is within the range of 0-20m above sea level. The Niger Delta Region of Nigeria consists of approbatively 70,000km^2, it is the largest Wetland in Africa [12] and the third largest in the world [13, 14] 75% of Niger Delta Region is wetland with an annual rainfall of 2000-3000m, flooding may occur as a result of excessive rainfall, flood plains and excessive release of water from Niger and Benue Rivers. According to Igu & Rob [12], the study area is drained by the Niger River that is link to Forcados, Nun river, streams creeks, creek lets which are emptied into the Atlantic Ocean through the estuaries.

Geology of the Study Area

Geologically, the study area lies within the South-Western flank of the Niger Delta region, which formed due to a failed rift junction between the South American and African plates during the late Jurassic to mid-Cretaceous period [15]. The Niger Delta Basin covers an extensive land area of over 105,000km^2 [16]. The geological formations present in the study area include the Akata Formation, Agbada Formation, and Benin Formation. The Akata Formation, ranging from the Paleocene to the Holocene age, is the basal lithostratigraphic unit in the Niger Delta region [17]. It consists of thick shales, turbidite sands, and smaller amounts of silt and clay. The formation represents deep marine deposits with plant remains near the contact with the overlying Agbada Formation. It contains a diverse microfauna, including planktonic foraminifera, indicating a shallow marine shelf depositional environment. The Akata Formation ranges in thickness from 0 to 6,000 meters and is primarily subsea, [Figure 1] not visible at the shoreline [18].

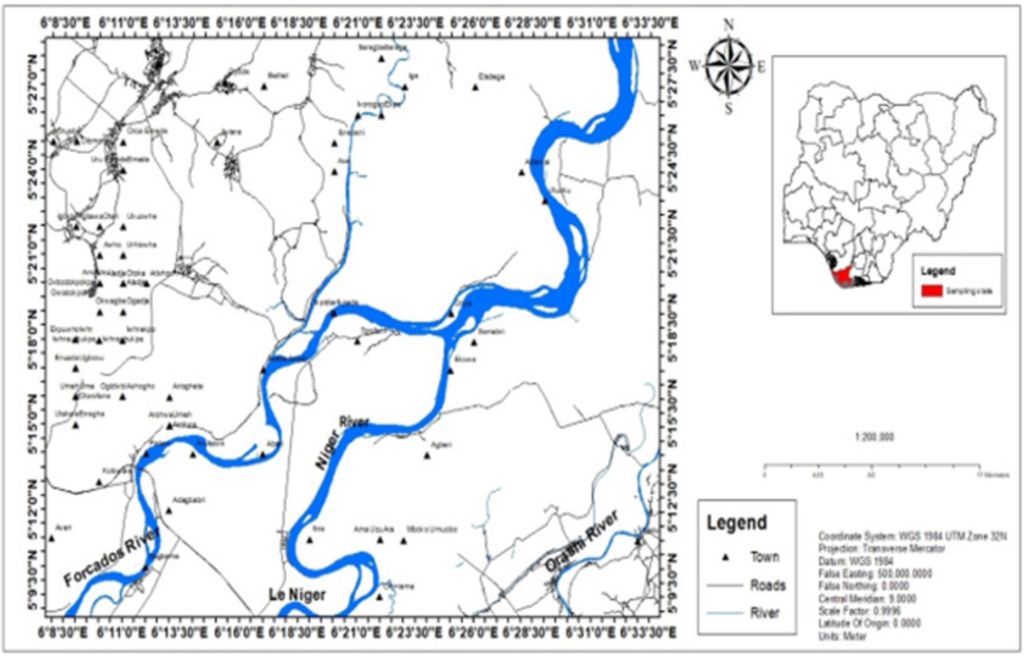


Figure 1: Study area map.

Materials and Methods

Data collection

Data acquisition involved the compilation of materials and information derived from Landsat 5, Landsat 7, and Landsat 8, acquired through the official platform of the United States Geological Survey (USGS) at https://earthexplorer.usgs.gov/. The selection of data sources was aimed at providing a comprehensive understanding of the landscape over time. Specifically, Landsat 5 data was procured for the temporal spans of 1991 and 2001, capturing the evolution of the landscape during these years. Furthermore, Landsat 7 data was sourced for the singular year of 2011, offering a detailed snapshot of the environmental conditions at that specific point in time. Lastly, Landsat 8 data was meticulously collected to represent the landscape in the year 2021, focusing on a specific geographical location identified by Path: 189, Row: 57. The utilization of data from these three Landsat satellites ensures a multi-temporal perspective, enabling a comprehensive analysis of land cover changes and environmental dynamics. This diverse dataset serves as a valuable resource for evaluating the transformation of the study area across different decades and enhancing the accuracy and reliability of the research outcomes.

Data Processing

Data processing steps for analyzing coastline changes using Landsat imagery in ArcGIS 10.5 software:

i. Set Project Coordinate System: To establish a standardized framework, Launch ArcGIS 10.5 is initiated, and within the "Table of Contents," project properties are accessed by right-clicking. In the "Coordinates" section, the project coordinate system is defined, ensuring spatial consistency.

ii. Import Landsat Imagery: Obtain pertinent Landsat data from 1991 and 2001 using Landsat 5, from 2011 using Landsat 7, and from 2021 using Landsat 8. Import the bands for visible blue, green, red, and near-infrared into ArcGIS 10.5, establishing the primary dataset for evaluating coastlines.

iii. Image Analysis and Classification: Leveraging the "Image Analysis" tool, bands for each year are highlighted. Subsequently, a composite is generated through the "Processing" menu, leading to the application of "Unsupervised Classification" for each year's imagery.

iv. Raster to Polygon Conversion: Using "Conversion Tools," raster data is transformed into polygon format by selecting the "Raster to Polygon" option, facilitating further spatial analyses.

v. River Layer Processing: The "Selection Tools" are utilized to process the river layer. Through the "Process Raster" option, a new layer is created from selected features, ensuring a focused assessment of river-related changes.

vi. Calculate Erosion and Accretion: Employing a specified formula, erosion and accretion are quantified: Erosion is determined by subtracting the unchanged area from the previous year's area, while accretion involves subtracting the unchanged area from the next year's area. Use the provided formula:

- Erosion = Area from the previous year - Unchanged area
- Accretion = Area from the next year - Unchanged area

vii. Statistical Analysis: To enhance interpretability, statistical analyses are performed, generating bar charts and pie charts for visualizing the coastal changes over time.

viii. Export Data to Microsoft Excel: Upon completion of all analyses, the processed data is exported to Microsoft Excel, enabling further manipulation and presentation, thereby providing a comprehensive overview of the coastline dynamics and facilitating deeper insights through adjustments and additional analyses in Excel.

These steps outline the sequence of processing tasks in ArcGIS 10.5 for analyzing coastline changes using Landsat imagery. Adjustments and further analysis in Excel can provide additional insights based on the processed data.

Results and Discussion

Coastline Analysis

The coastline is the boundary that separates the land from the water bodies, and it undergoes continuous transformations due to various coastal processes, including waves, currents, tides, nearshore circulation, storm surges, and human-induced activities such as dredging, mining, water extraction, and construction. These coastal processes contribute to both accretion (land gain) and erosion (land loss) of the coastline, resulting in dynamic changes over time as seen in Figure 2.

In this analysis, we focus on the coastline changes in Sagbama over three consecutive periods: 1991-2001, 2001-2011, and 2011-2021 as seen in Figure 3. Table 1 provides crucial data for each period, presenting the areas of the coastline for the previous 10 years, the next 10 years, the unchanged area, the erosion area, and the accretion area. By examining these values, we can discern trends and patterns in the geological evolution of the coastline.

From Figure 4 during the first period, from 1991 to 2001 (a), the Sagbama communities witnessed a slight increase in the next 10-year area compared to the previous 10-year area [Table 1]. However, a significant portion of the coastline remained unchanged, indicating relative stability during this period. It implies that the coastal processes causing both accretion and erosion were relatively balanced, leading to minimal net changes in the coastal area. Although there were areas experiencing erosion and accretion, the overall impact was limited.

Moving forward to the second period, from 2001 to 2011 (b) in Figure 4, the next 10-year area exhibited a substantial increase, surpassing the previous 10-year area by a considerable margin as seen in Table 1. This suggests a more rapid expansion of the coastline during this timeframe, indicating that accretion processes were dominant, resulting in a net gain of land. On the other hand, the unchanged area decreased, pointing to a higher level of dynamic changes during this period. This indicates that the coastal processes were more active and pronounced, causing significant changes in the coastal area.

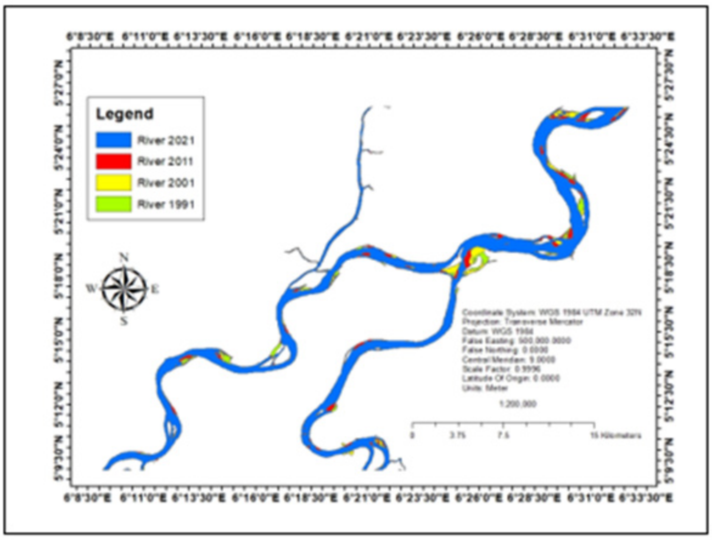


Figure 2: Sagbama River from 1991 to 2021.

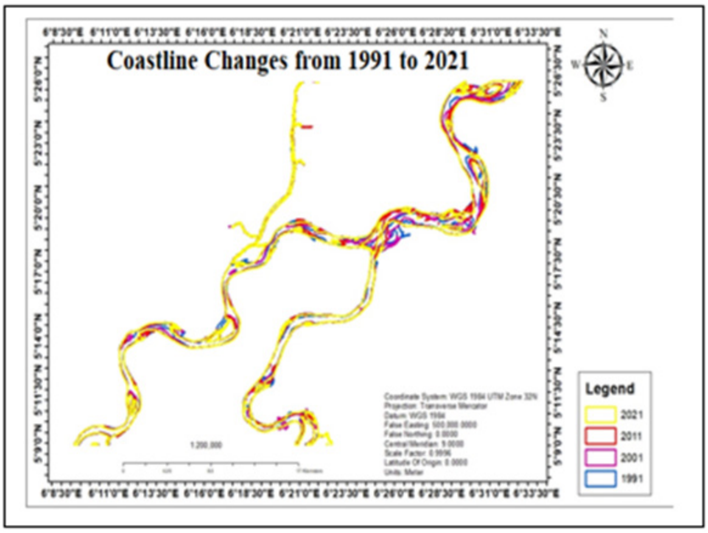
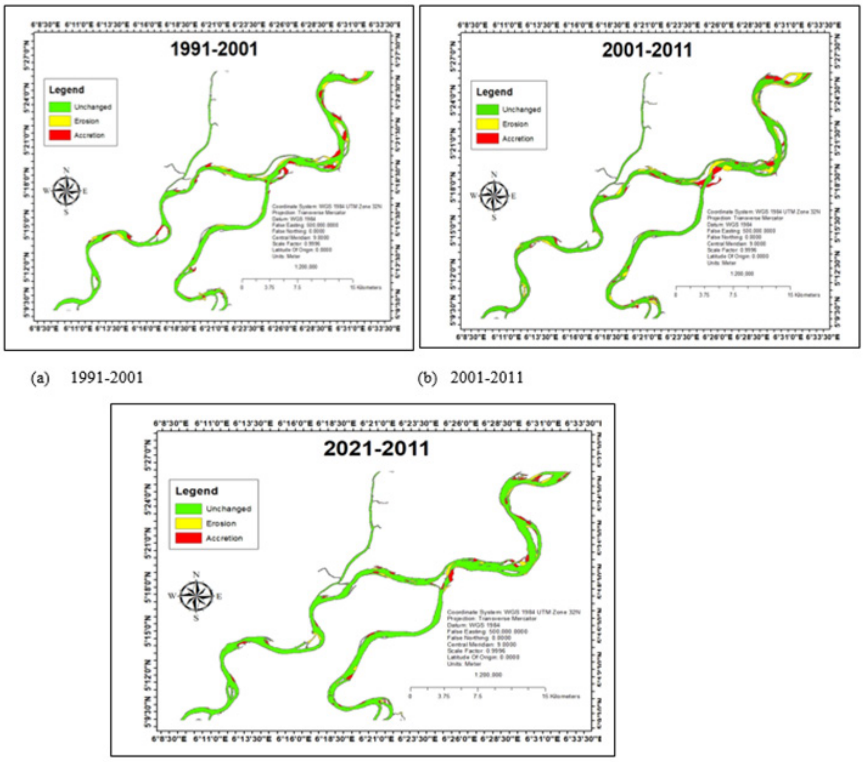


Figure 3: Coastline Changes from1991 to 2021.



(a) 1991-2001 (b) 2001-2011

(C) 2021-2011

Figure 4: Map describing erosion, accretion and unchanged region in Sagbama from (a), (b) and (c).

Table 1 displays Sagbama's coastline changes over two consecutive 10-year periods, from 2011 to 2021(c) in Figure 5. The data presents alterations in coastal areas in square kilometers (km²). Over the first decade (2011-2021), the coastal area measured 82.56km². In the following 10 years (2021-2021), it slightly increased to 83.14km². Importantly, 74.85km² of the coastal landscape remained stable without discernible changes. This data underscores coastal environments' dynamic nature, influenced by geological and hydrological processes like erosion, sediment deposition, and sea-level fluctuations. Changes impact local ecosystems, communities, and infrastructure.

Furthermore, the areas affected by erosion and accretion both increased during this second period [Table 2]. However, it is notable that accretion showed a substantial rise compared to the previous period. This suggests that during this time, coastal environments were experiencing an increase in deposition and sedimentation, leading to the creation of new land areas along the coastline. The data from these three periods reveals intriguing trends in Sagbama coastline changes. The region experienced continuous alterations in its coastal area over the years, with both expansion and reduction observed. The areas that remained unchanged indicate parts of the coastline that exhibit stability despite the dynamic forces acting upon them.

Changes in Erosion and Accretioni the Study Area

The study area of Sagbama has experienced significant changes in its coastline over the years, with both erosion and accretion playing crucial roles in shaping the coastal landscape. Erosion, caused by factors such as constant rainfall, flooding, and the action of flowing rivers and streams, has resulted in the gradual removal of sediments and rock materials from the coastline. On the other hand, accretion has led to the deposition of new sediments, contributing to the growth and expansion of the sedimentary terrain.

Erosion

Erosion due to constant rainfall, flooding, flowing rivers and streams has caused changes in the coastline of sagbama over the years. When erosion occurs in coastlines, there is a long-term removal of sediments and rock materials along coastline due to the action of wave, current, tides and wind driven water. Between the periods of 1991 and 2001 as seen in Table 2, the study area witnessed a notable increase in erosion, with an area of approximately 8.88 km^2 [Figure 5] being eroded, representing a percentage change of 36% Figure 6. This significant rise in erosion was attributed to the powerful forces of waves, currents, tides, and wind-driven water, which relentlessly acted on the coastal region, causing the removal of sediments and earth materials. The impacts of this erosion were profound, altering the physical structure of the coastline and leading to the loss of land.

Table 1: Coastline Changes in Sagbama.

Period	Previous 10-year Area (km^2)	Next 10-year Area (km^2)	Unchanged Area (km^2)
1991-2001	71.14	74.27	62.26
2001-2011	74.27	82.56	66.09
2011-2021	82.56	83.14	74.85

Table 2: Showing records of erosion and accretion in the study area.

Period	Erosion Area (km^2)	Erosion Percentage (%)	Accretion Area (km^2)	Accretion Percentage (%)
1991-2001	8.88	36	12.01	33
2001-2011	8.18	33	16.47	45
2011-2021	7.71	32	8.29	22

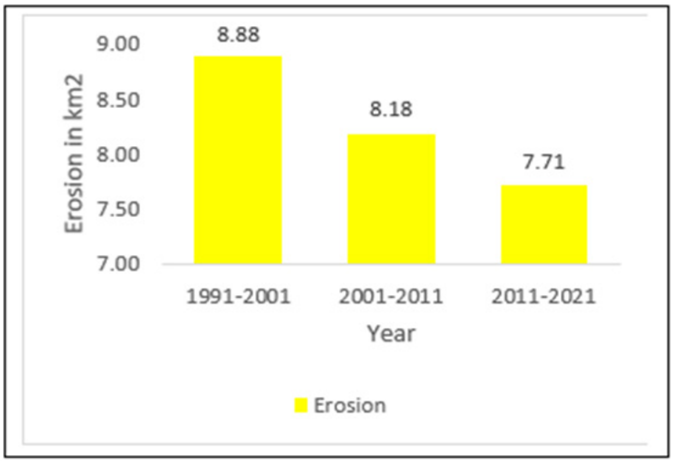


Figure 5: Rate of erosion over the last thirty years in Sagbama.

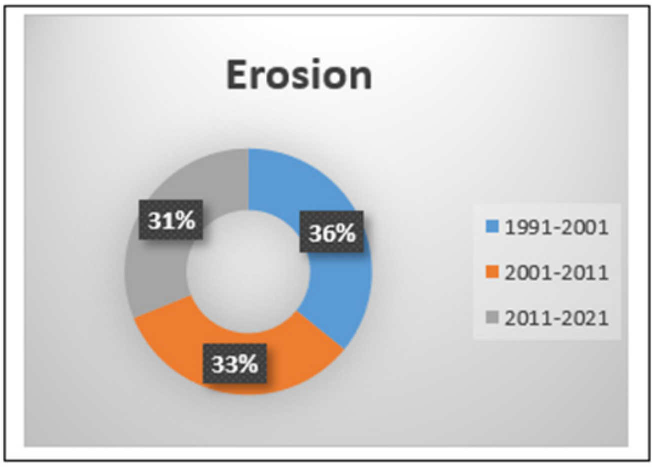


Figure 6: A pie chart on erosion over the last thirty years in Sagbama.

Citation: Ebiegberi O, Emmanuel FI, Lawrence OE. Investigation of Coastline Changes in Sagbama, LGA Bayelsa State, Nigeria Using Remote Sensing. *Int J Eng Tech & Inf.* 2023;4(4):1-8. DOI: 10.51626/ijeti.2023.04.00067

In the subsequent decade, from 2001 to 2011, the rate of erosion remained high, with an area of 8.18km² in Figure 5 being eroded, accounting for a percentage change of 33% [Figure 6]. While the rate of change was slightly lower compared to the previous decade, it still indicated a significant ongoing erosion process that continued to affect the coastal area of Sagbama. Erosion events during this period might have been influenced by various factors such as climate patterns, human activities, and changes in sediment supply. From 2011 to 2021, the rate of erosion further decreased, with an area of 7.71 km² in Figure 5 being eroded, reflecting a percentage change of 31% [Figure 6]. The reduction in the erosion rate during this period could be attributed to a combination of natural processes and potential human interventions, such as coastal management strategies or changes in land use practices. However, it is essential to note that even though the rate of erosion slowed down during this decade, it still had a considerable impact on the coastal morphology.

When sediments are eroded from the coastline, they are often transported and deposited in other regions, forming floodplains or contributing to sedimentary deposition in adjacent areas. This process of sediment transport and deposition is vital for understanding the dynamics of coastal environments and the redistribution of materials within the marine ecosystem.

Accretion

Accretion has played a crucial role in shaping the coastal landscape of Sagbama as well. This natural process involves the deposition of sediments and materials along the coastline, leading to the expansion and growth of the sedimentary terrain. The data presented in Table 2 highlights the records of accretion in the study area over different time periods. Between 1991 and 2001, accretion resulted in a deposition of approximately 12.01km² of sediments as seen in Figure 7, representing a percentage change of 32% [Figure 8]. During this decade, the coastal region experienced a significant influx of new sediments, contributing to the expansion of the land area.

The subsequent decade, from 2001 to 2011, witnessed the highest recorded value of accretion, with a deposition of 16.47km² of sediments, accounting for a percentage change of 45% in Figure 8. This substantial increase in sedimentary deposition indicated a period of significant growth and expansion of the coastal landscape. Various factors, such as sediment supply from adjacent areas, changes in coastal currents, and the presence of suitable depositional environments, could have contributed to this remarkable accretion event.

However, from 2011 to 2021, the rate of accretion decreased significantly, with an area of only 8.29km² [Figure 7] being deposited, representing a percentage change of 22% [Figure 8]. This decline in accretion could have been influenced by several factors, including changes in sediment availability, alterations in coastal currents, or the effects of ongoing erosion processes that might have counteracted sediment deposition.

The interplay between erosion and accretion in the study area of Sagbama has led to dynamic changes in the coastal landscape. Erosion has resulted in the loss of land and alterations to the shoreline, while accretion has contributed to the growth and expansion of the sedimentary terrain. Understanding the balance between these two opposing processes is essential for effective coastal management and the preservation of valuable coastal ecosystems.

Comparative Analysis of Coastline Erosion and Accretion

Comparing the trends of coastline erosion and accretion in Sagbama over three distinct time intervals: 1991-2001, 2001-2011, and 2011-2021, this analysis will delve into the driving forces behind these phenomena, their implications for the local environment, and potential strategies to alleviate their impacts.

The data presented in Table 2 enables a comprehensive examination of erosion and accretion along Sagbama's coastline across three well-defined periods. Between 1991 and 2001, as depicted in Figure 9, the extent of the eroded area (8.88km²) surpassed the area experiencing accretion (12.01km²). This suggests that Sagbama's coastline predominantly encountered erosion, potentially due to insufficient sediment influx or heightened wave energy. From 2001 to 2011: Over this timeframe, the region undergoing erosion slightly diminished to 8.18km², while the accretion area notably expanded to 16.47km². This pattern implies a possible transition towards a more balanced sediment equilibrium, facilitating increased deposition along the coastline. Between 2011 and 2021, the eroded area continued its decline, reaching 7.71km², accompanied by a reduction in the accretion area to 8.29km². The concurrent decrease in erosion and accretion areas during this phase could signify a period characterized by relatively stable coastal conditions.

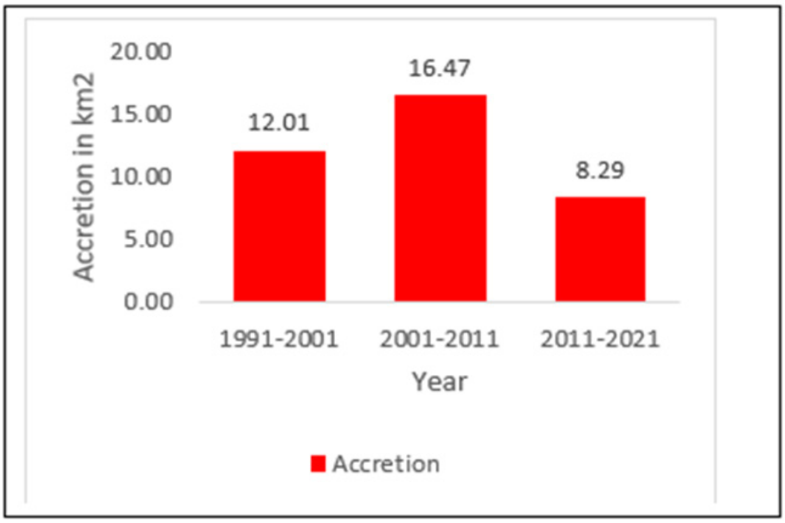


Figure 7: Rate of accretion over the last thirty years in Sagbama.

Citation: Ebiegberi O, Emmanuel FI, Lawrence OE. Investigation of Coastline Changes in Sagbama, LGA Bayelsa State, Nigeria Using Remote Sensing. *Int J Eng Tech & Inf.* 2023;4(4):1-8. DOI: 10.51626/ijeti.2023.04.00067

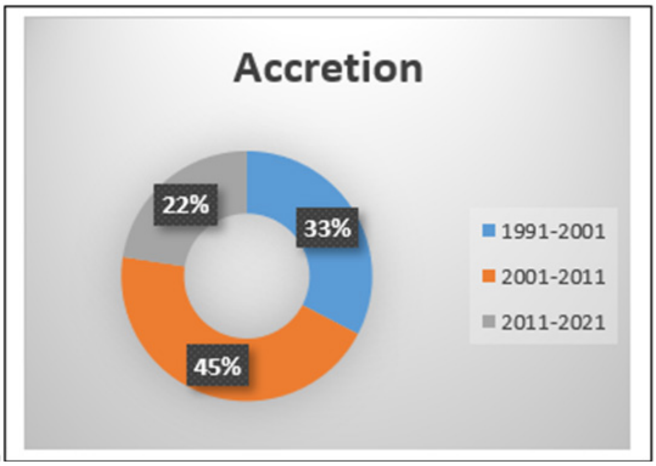


Figure 8: A pie chart on accretion over the last thirty years in Sagbama.

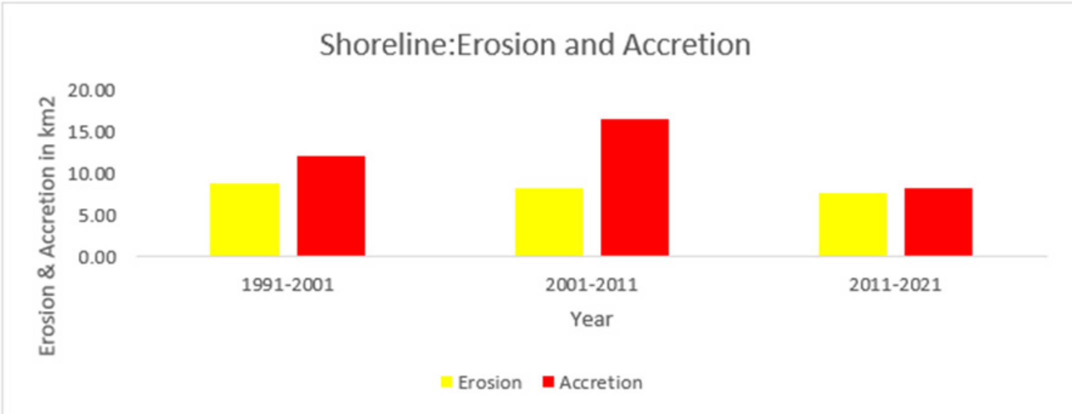


Figure 9: Above shows the level of erosion and accretion in sagbama over the last thirty years.

Implications and Potential Causes

The observed coastline changes in Sagbama communities have important implications for the local population and the surrounding environment. Erosion can lead to the loss of valuable land, infrastructure damage, and displacement of communities. Accretion, on the other hand, can provide opportunities for land reclamation and potential economic benefits. However, excessive accretion can also disrupt natural habitats and ecological processes. Several factors may contribute to the observed coastline changes. One potential cause is sea-level rise, which can lead to increased erosion and flooding in coastal areas. Another factor is sediment transport, influenced by factors such as wave energy, currents, and human activities. Coastal engineering projects, including the construction of jetties and seawalls, can also impact sediment dynamics and coastline stability.

Conclusion

The coastline records of erosion and accretion in Sagbama communities in Bayelsa State, Nigeria, provide valuable insights into the changing coastal landscape. The analysis of the data reveals varying trends and magnitudes of coastline changes over the three time periods. While erosion and accretion are natural processes, they can have significant implications for the local communities and the environment. Understanding the causes and implications of coastline changes is crucial for effective coastal management and planning. Strategies such as coastline protection measures, sustainable land use practices, and ecosystem-based approaches can help mitigate the negative impacts of erosion while harnessing the potential benefits of accretion. Continued monitoring and research efforts are essential to further our understanding of the dynamics of Sagbama's coastline and to develop informed strategies for coastal resilience and sustainable development.

Recommendation

Geospatial technology should be use to monitoring of coastline changes for effective coastal management and planning.

References

1. Eteh DR, Lolade AA, Nicholas DO, Opukumo AW, Omonefe F (2022) The Environmental Impact of Shoreline Changes and Land Use/Land Cover Change Detection in the Niger Delta Region using Geospatial Technology. Journal of Asian Scientific Research 12(4): 237-248.
2. Alves F, Sousa L, Esteves TCJ, Oliveira Eduardo, Antunes Inês, et al. (2014) Trend Change(s) in Coastal Management Plans: The integration of short and medium term perspectives in the spatial planning process. Journal of Coastal Research 70(spl): 437-442.
3. National Park Service (2019) Coastal Shoreline Change.
4. Griggs Gary, Borja G Reguero (2021) Coastal Adaptation to Climate Change and Sea-Level Rise. Water 13(16): 2151.
5. Cazenave Anny, Le Cozannet Goneri (2013) Sea level rise and its coastal impacts. Earth's Future 2(2): 15-34.
6. Almar Rafael, Stieglitz Thomas, Appeaning Addo Kwasi, Ba Kader, Abessolo Grégoire, et al. (2022) Coastal Zone Changes in West Africa: Challenges and Opportunities for Satellite Earth Observations. Surveys in Geophysics 44: 249-275.

7. Liang Huidi, Xudong Zhou (2022) Impact of Tides and Surges on Fluvial Floods in Coastal Regions. Remote Sensing 14(22): 5779.

8. Zhu Yuandong, Li Zhenjin, Zhao Zheng, Lu Li Jun, Yang Shucheng, et al. (2023) Spatio-temporal changes of coastline in Jiaozhou Bay from 1987 to 2022 based on optical and SAR data. Frontiers in Marine Science 10.

9. Yasir Muhammad, Hui Sheng, Binghu Huang, Ur Rahman Sami (2020) Coastline extraction and land use change analysis using remote sensing (RS) and geographic information system (GIS) technology- A review of the literature. Rev Environ Health 35(4): 453-460.

10. Zoysa Sanjana, Vindhya Basnayake, Jayanga T Samarasinghe, Miyuru B Gunathilake, Komali Kantamaneni, et al. (2023) Analysis of Multi-Temporal Shoreline Changes Due to a Harbor Using Remote Sensing Data and GIS Techniques. Sustainability 15(9): 7651.

11. Roy Sanjoy, Pandit Santa, Papia Mossammat, Rahman Md Masudur, Rehder Jan, et al. (2021) Coastal erosion risk assessment in the dynamic estuary: The Meghna estuary case of Bangladesh coast. International Journal of Disaster Risk Reduction 61: 102364.

12. Igu Nwabueze I, Rob Marchant (2017) Freshwater swamp forest use in the Niger Delta: perception and insights. Journal of forest Research 22(1): 44-52.

13. Ohimain EI (2012) Environmental impacts of petroleum exploration dredging and canalization in the Niger Delta. In Five decades of oil production in Nigeria: impact on the Niger Delta. Akpotoe AS, (Eds.) Centre for Environmental and Niger Delta Studies, Abraka, Nigeria 391- 405.

14. Spalding MD, F Blasco, CD Field (Eds.) (1997) World Mangrove Atlas. Okinawa: The International Society for Mangrove Ecosystems.

15. Rayment RE (1965) The Niger Delta: A major sedimentary province. Journal of the Geological Society 121(4): 497-508.

16. Reijers TJA (2011) Stratigraphy and Sedimentology of the Niger Delta. Geologos 17(3): 133-162.

17. Short KC, Stauble AJ (1967) Outline of Geology of Niger Delta. AAPG Bulletin 51: 761-779.

18. Etu Efeotor JO (1997) Depositional environment and sequence stratigraphy of the Akata Formation, Niger Delta. Journal of Petroleum Geology 20(1): 1-21.

Citation: Ebiegberi O, Emmanuel FI, Lawrence OE. Investigation of Coastline Changes in Sagbama, LGA Bayelsa State, Nigeria Using Remote Sensing. *Int J Eng Tech & Inf.* 2023;4(4):1-8. DOI: 10.51626/ijeti.2023.04.00067