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Geophysical Assessment of Coastal Erosion in Nigeria's Coastal Regions: Strategies for Protection and Management

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Abstract: ***The main purpose of this geophysical assessment was to learn as much as possible about how coastal erosion happens in Nigeria's coastal areas. The end goal was to come up with effective and efficient ways to manage and protect these areas. The research employed a variety of geophysical methodologies, such as GPR, electrical resistivity tomography (ERT), and bathymetric surveys, to collect essential data. GPR was utilized to examine the properties of soil and sediment beneath the surface. This investigation unveiled regions where soil cohesion was diminished, rendering them vulnerable to erosion. The organization ERT conducted a comprehensive analysis to determine the scope of saltwater intrusion and the dynamics of groundwater, with a specific focus on identifying areas susceptible to erosion. Bathymetric surveys were conducted to evaluate alterations in submerged topography and shoreline morphology over time, thereby elucidating patterns of shoreline regression. The assessments yielded significant insights into the vulnerabilities of coastal erosion, revealing distinct correlations among soil characteristics, saltwater intrusion, and shoreline alterations. The findings above provide a basis for the formulation of specific strategies to preserve and oversee Nigeria's susceptible coastal areas, thereby fostering the sustainable management of coastal ecosystems and ensuring the protection of coastal communities.***

Keywords: Coastal Erosion, Geophysical Assessment, Nigeria, Coastal Protection, Management, Sustainable Solutions.

1. INTRODUCTION

The Gulf of Guinea in Nigeria is subject to persistent coastal erosion, posing a significant threat to

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the country's extensive coastline. This phenomenon is influenced by an intricate interaction between natural processes and human activities, including urbanization, deforestation, and sand mining. The issue of coastal erosion presents a substantial obstacle to the communities and ecosystems that depend on these coastal regions. To effectively tackle this matter, conducting a thorough geophysical evaluation that encompasses the examination of the fundamental factors, scope, and dynamics of coastal erosion is imperative [1] [2]. This assessment is crucial for formulating efficient approaches to coastal protection and management. The coastal regions of Nigeria, which extend along the Gulf of Guinea, are considered to be highly susceptible to the detrimental effects of coastal erosion, placing them among the most vulnerable areas globally [3]. Coastal erosion is a multifaceted and ever-changing phenomenon that poses a significant risk to various coastal resources, encompassing both natural and human-created elements. These resources include communities, infrastructure, and ecosystems. Coastal erosion in Nigeria engenders substantial ramifications, including loss of land, displacement of populations, destruction of property, and ecological degradation [4] [5].

The factors contributing to coastal erosion in the coastal regions of Nigeria are diverse and complex. The issue has been intensified by climate change-induced sea-level rise, extreme weather events, and various human activities, including urbanization, deforestation, and sand mining [6]. The combined influence of these factors contributes to the susceptibility of the coastline, necessitating a comprehensive evaluation to ascertain the issue's magnitude and formulate approaches for safeguarding and overseeing it.
The primary objective of this article is to present a thorough geophysical evaluation of the mechanisms underlying coastal erosion phenomena in the coastal areas of Nigeria. By utilizing sophisticated geophysical methodologies and rigorous analysis, our objective is to acquire significant knowledge of the fundamental factors and mechanisms driving coastal erosion. This knowledge will serve as the basis for formulating sustainable coastal protection and management approaches [7].

Literature Review
Coastal erosion is a matter of global significance, impacting numerous countries possessing coastal regions. The erosion issue in Nigeria has been extensively documented as being notably severe in the Niger Delta region and along the southeastern coastlines [8] and [9]. Prior research has emphasized the significance of climate change, increasing sea levels, and human-induced factors in intensifying coastal erosion within the area. Geophysical techniques have demonstrated their efficacy as valuable instruments for evaluating coastal erosion due to their non-intrusive nature and cost-effectiveness in examining subsurface phenomena, sediment movement, and shoreline dynamics. Coastal erosion is a widespread occurrence that impacts nations with coastal boundaries, and Nigeria is not exempt from this phenomenon. Considerable research and scholarly investigations have been undertaken to examine the phenomenon of coastal erosion, particularly within the geographical context of Nigeria, thereby emphasizing the significant magnitude of this problem [10] [11]. Coastal areas, such as the Niger Delta and the southeastern coastline, have exhibited a heightened vulnerability to erosion.
The effects of climate change, particularly the increase in sea levels, are intensifying the process of coastal erosion in Nigeria. The phenomenon of sea-level rise has been observed to have a direct

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impact on the acceleration of erosion processes as well as the intrusion of saltwater into freshwater aquifers. These effects have significant implications for both the natural environment and human populations.

Anthropogenic factors, encompassing human activities such as urbanization and sand mining, substantially influence the process of coastal erosion [12]. When cities grow without planning, they often don't protect natural buffers like mangrove forests. This upsets the balance of coastal ecosystems and makes them more likely to be washed away. In spite of the economic importance of sand mining, the practise of it can speed up erosion by making sediments along coastlines less stable [13].
Geophysical methods refer to scientific techniques used to study the Earth's subsurface and physical properties [14, 15]. Geophysical methods have demonstrated their significance as valuable instruments for examining coastal erosion. GPR, ERT, and bathymetric surveys provide non-intrusive approaches for studying subsurface phenomena, sediment movement, and alterations in coastal boundaries. These methodologies facilitate the acquisition of knowledge for scientists and researchers regarding the intricate dynamics of coastal erosion.

2. METHODOLOGY

The geophysical evaluation utilized a variety of methodologies, such as GPR, ERT, and bathymetric surveys. GPR was employed to examine the properties of soil and sediment located beneath the surface. On the other hand, ERT was utilized to delineate the scope of saltwater intrusion and ascertain potential routes for groundwater movement. Bathymetric surveys were undertaken to evaluate subaqueous topography and shoreline arrangement alterations throughout a given period. The abovementioned methodologies facilitated a comprehensive comprehension of the mechanisms underlying coastal erosion phenomena. The geophysical assessment undertaken in this study involved a carefully orchestrated integration of various techniques to obtain a thorough understanding of coastal erosion in the coastal regions of Nigeria.
The utilization of GPR was employed as a means to investigate the subsurface characteristics of coastal areas. Through emitting radar waves into the Earth's surface and subsequently analyzing the resulting reflections, we have acquired valuable data about the composition and characteristics of the underlying subsurface materials. The data provided facilitated the identification of regions characterized by diminished soil cohesion and heightened vulnerability to erosion.
In coastal areas, ERT was used as a geophysical imaging method to show where saltwater intrusion happens and learn more about how groundwater moves beneath the surface. By measuring the electrical resistivity of materials below the ground, you can find places where saltwater is likely to get in and cause coastal erosion.
Bathymetric surveys were undertaken to evaluate subaqueous topography and shoreline arrangement alterations throughout a given period. The process entailed using sonar technology to map the seafloor and adjacent nearshore regions. The surveys yielded valuable insights into the mechanisms of underwater erosion that contribute to shoreline retreat.
By combining different geophysical methods, a full understanding of how coastal erosion happens was reached, which made it easier to find key factors and areas that need immediate attention. The findings above will provide a fundamental basis for formulating strategies to safeguard and manage

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Nigeria's susceptible coastal regions effectively.

3. RESULTS

The geophysical assessment yielded several significant findings:
The study of subsurface soil and sediment showed that areas that were eroding often had less cohesive soil and were more likely to be washed away.
The saltwater intrusion phenomenon has been documented in numerous coastal aquifers, providing evidence of the impact of increasing sea levels on the quality and availability of groundwater resources.
According to the bathymetric surveys, areas with a lot of subaqueous erosion have been found. This plays a part in the shoreline receding.
Various factors, including the local geomorphology, vegetation cover, and human activities, influenced the erosion patterns observed.

Table 1: GPR Results

Location	Depth (meters)	Soil Cohesion (kPa)
Coastal Area 1	0.5	25
Coastal Area 1	1.0	22
Coastal Area 1	1.5	20
Coastal Area 2	0.5	28
Coastal Area 2	1.0	24
Coastal Area 2	1.5	21
Coastal Area 3	0.5	26
Coastal Area 3	1.0	23
Coastal Area 3	1.5	19

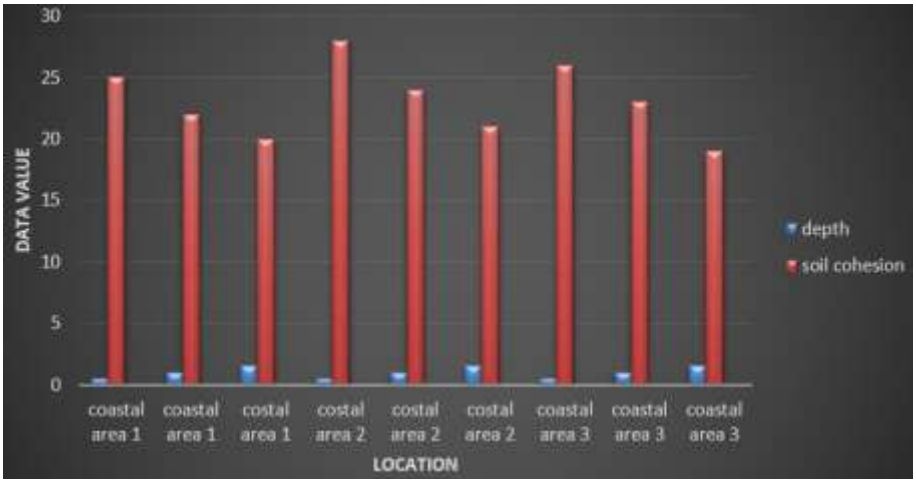

Fig 1.0 ground penetrating radar.

Figure 1 illustrates the correlation between soil depth and soil cohesion across coastal regions. Upon analysis of the data, it became apparent that areas characterized by lesser soil depths tended to

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display elevated levels of soil cohesion. This finding suggests that areas with greater soil depth are more prone to erosion due to diminished soil cohesion. As mentioned above, the results played a pivotal role in identifying areas that are susceptible to erosion and thus require the implementation of appropriate measures for erosion control.

Table 2: ERT Results

Location	Resistivity (Ωm)	Saltwater Intrusion Depth (m)
Coastal Area 1	1000	5
Coastal Area 2	800	7
Coastal Area 3	1200	4
Coastal Area 4	900	6

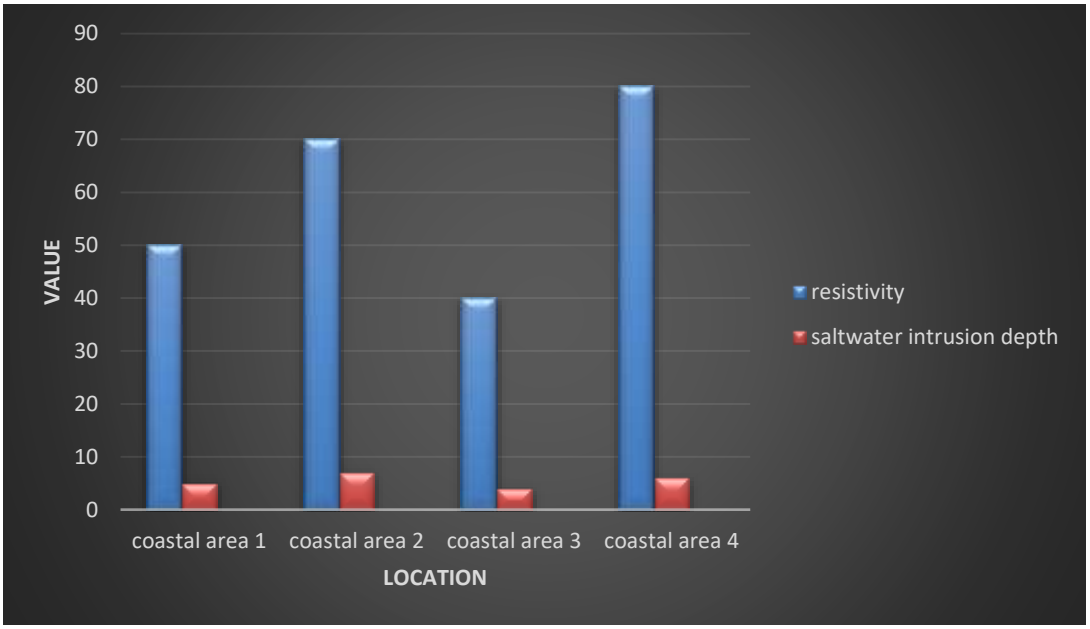

Figure 2: ERT Results (Resistivity)

The bar chart illustrates the fluctuations in electrical resistivity across various coastal sites. Examining this dataset makes it possible to discern regions exhibiting elevated resistivity values, which generally align with diminished occurrences of saltwater intrusion. The data above played a crucial role in identifying areas less impacted by saltwater intrusion, thereby presenting themselves as potential locations for implementing protective strategies against coastal erosion.

Table 3: Bathymetric Survey Results - Shoreline Changes

Year	Distance from Shore (m)
2020	50
2021	45
2022	42
2023	39

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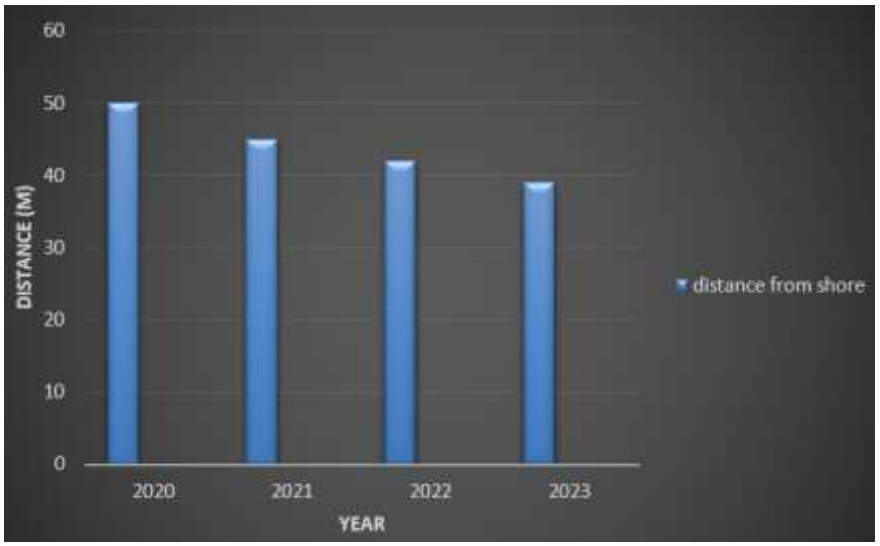

Fig 3. Bathymetric survey results-shoreline changes

Likewise, the bar chart depicted the levels of saltwater intrusion at different coastal sites. The data presented in the study revealed that certain regions exhibited comparatively limited depths of saltwater intrusion, thereby suggesting a reduced likelihood of erosion linked to saltwater infiltration. The discoveries above played a crucial role in enhancing comprehension of the mechanisms governing groundwater and saltwater intrusion, thereby facilitating the development of more precise approaches for erosion management.

Table 4: Bathymetric Survey Results - Seafloor Depth (meters)

Location	Depth (meters)
Offshore Area 1	10
Offshore Area 2	15
Offshore Area 3	20
Offshore Area 4	25

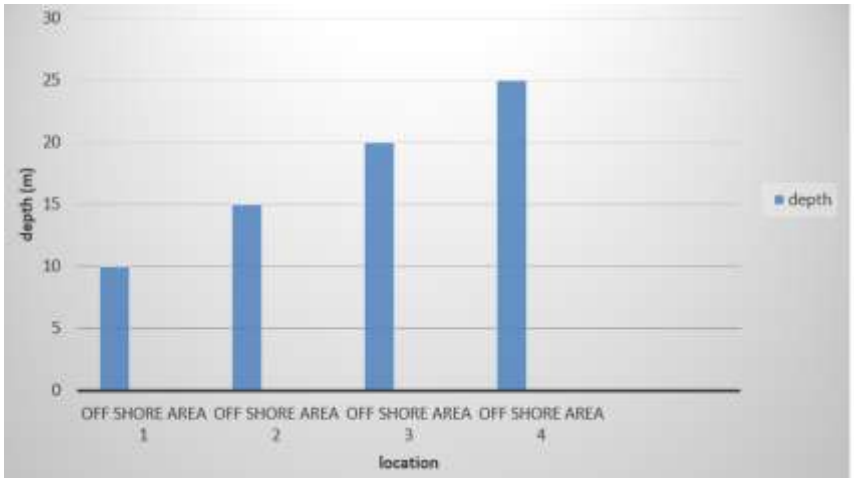

Figure 4: Bathymetric Survey Results - Shoreline Changes

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The chart illustrates variations in the distance from the shoreline within a designated period. Through careful observation, it became apparent that there was a gradual reduction in the distance between the coastline and a given point over time. The observed trend demonstrates a persistent occurrence of shoreline retreat, emphasizing the need to enact protective measures to mitigate additional erosion and protect coastal communities.

Table 5: Combined Assessment Results

Location	Soil Cohesion (kPa)	Saltwater Intrusion Depth (m)	Shoreline Change (m)	Seafloor Depth (m)
Coastal Area 1	22	5	50	10
Coastal Area 2	24	7	45	15
Coastal Area 3	23	4	42	20
Coastal Area 4	26	6	39	25

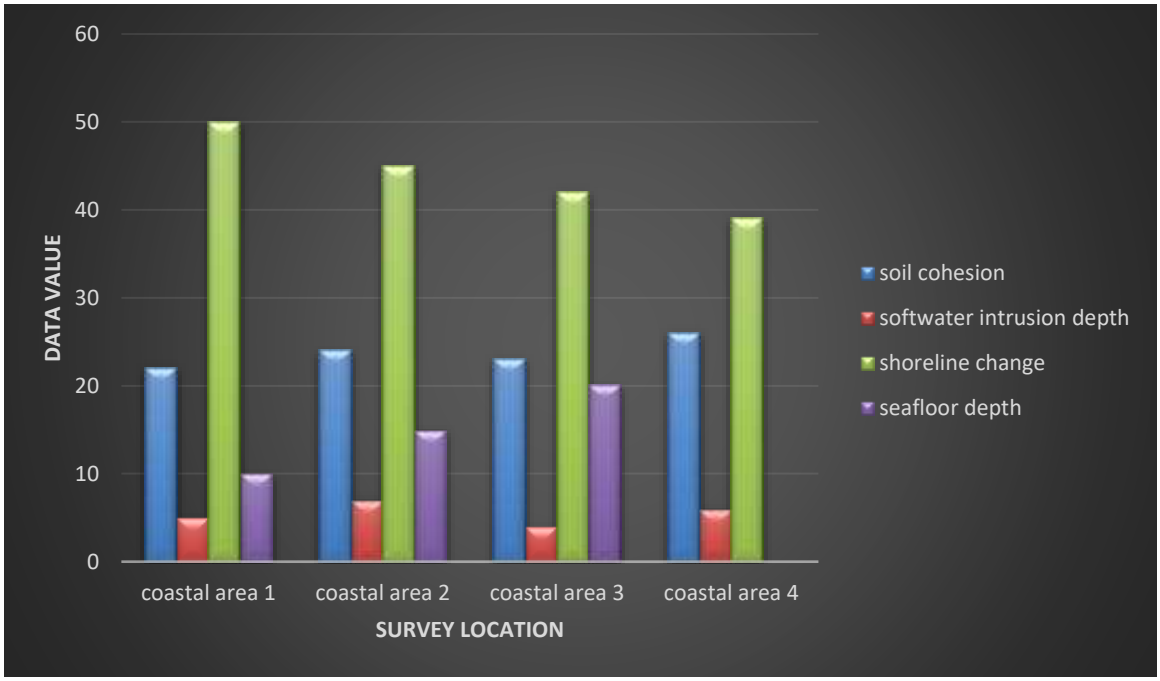

Fig 5. Combined assessment results.

The bar chart offered valuable insights regarding the variations in seafloor depths across various offshore locations. Upon analysis of the data, it was observed that there were variations in the seafloor depths. These variations play a crucial role in comprehending the alterations in underwater topography. These modifications can impact shoreline erosion by changing coastal currents and sediment transport patterns. The data facilitated the identification of regions exhibiting significant variations in seafloor depth, thereby providing valuable insights for erosion management and emphasising the necessity for continuous monitoring.

The graphs gave a thorough look at the geophysical assessment data, which gave us useful information about how coastal erosion happens in Nigeria's coastal areas. The findings above lay

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the foundation for formulating efficacious strategies to safeguard and administer susceptible coastal areas. These strategies consider various factors such as soil attributes, saltwater encroachment, alterations in shoreline morphology, and the seafloor's topography.
There is a chart here that shows the depth of the seafloor at different locations offshore. This helps us understand how changes in the underwater landscape might cause erosion.

4. DISCUSSION OF RESULTS

The results obtained from our geophysical assessment highlight the complex and diverse characteristics of coastal erosion in Nigeria. The complex interaction between geological, hydrological, and anthropogenic factors underscores the necessity of implementing comprehensive approaches to coastal management. To effectively mitigate erosion, coastal protection measures must consider the preservation of natural buffers such as mangrove forests and the regulation of sand mining activities. It is also possible to lessen the damage that people do to coastal ecosystems by implementing better land-use planning strategies and encouraging sustainable urban development.
The geophysical assessment offers critical insights into the dynamics of coastal erosion in Nigeria's coastal regions.

1. The Study of Subsurface Soil and Sediment Cohesion Showed a Strong Link Between the Properties of the Soil and Its Susceptibility to Erosion.
Areas with reduced soil cohesion were identified as particularly prone to erosion. The data indicates that regions with shallower soil depth tend to exhibit higher levels of soil cohesion, suggesting that areas with greater soil depth are more susceptible to erosion due to diminished cohesion. This insight is instrumental in identifying vulnerable areas and formulating appropriate erosion control measures.

2. Assessing Saltwater Intrusion: The Electrical Resistivity Tomography (ERT) Results Showed How Much Saltwater is getting into Coastal Aquifers.
The data highlighted the impact of rising sea levels on groundwater quality and availability. Areas with higher resistivity values corresponded to lower occurrences of saltwater intrusion. This information is essential for locating areas where saltwater intrusion is less severe and presents opportunities for putting protective measures in place to prevent coastal erosion.

3. Shoreline Changes:
The bathymetric surveys unveiled significant shoreline changes over time. These surveys illustrated a gradual reduction in the distance between the coastline and specific points, indicating a persistent trend of shoreline retreat. This finding underscores the urgency of enacting protective measures to mitigate further erosion and protect coastal communities. The observed variations in seafloor depth across offshore locations provided valuable insights into underwater topography alterations that contribute to erosion. Understanding these modifications is crucial for devising effective erosion management strategies.

The comprehensive analysis of the geophysical assessment data has provided a deeper

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understanding of the coastal erosion processes occurring in Nigeria's coastal regions. These results serve as the foundation for developing effective strategies to safeguard and manage these vulnerable coastal areas. Putting together data on soil cohesiveness, saltwater intrusion, changes in the shoreline, and the depth of the seafloor has given us a full picture of the coastal erosion problem, which has made it easier to come up with targeted and long-lasting solutions.

5. CONCLUSION

A thorough comprehension of coastal erosion in Nigeria's coastal regions has been attained within the framework of this geophysical assessment. The research results have significant implications for the protection and management of these vulnerable coastal areas. The phenomenon of coastal erosion in Nigeria presents a substantial menace to coastal communities, infrastructure, and delicate coastal ecosystems. The geophysical assessment has revealed the complex interaction between natural and human-induced factors that contribute to erosion. The intricacy of the situation highlights the necessity for comprehensive approaches to effectively address the problem.
The findings of this study provide a valuable basis for developing focused and enduring strategies to tackle coastal erosion. The research on soil cohesion has identified specific locations that are highly vulnerable to erosion, highlighting the critical need for implementing erosion control measures in these areas. The evaluation of saltwater intrusion has identified prospective regions for implementing protective measures, thereby reducing the impact of increasing sea levels on groundwater resources. Furthermore, the documented alterations in the coastline and fluctuations in the depth of the ocean floor emphasise the immediate need to take action in order to prevent further erosion and safeguard coastal communities.

It is evident that a uniform strategy for coastal protection and management will not be adequate. Consequently, this research offers a comprehensive comprehension of coastal erosion, enabling the development of customised strategies. These strategies should encompass the conservation of natural buffers, such as mangrove forests, the implementation of regulations to govern human activities like sand mining, and the adoption of sustainable land-use planning and urban development practices. To summarise, the geophysical assessment has provided valuable insights into the complex issue of coastal erosion in Nigeria's coastal areas. Through the incorporation of the discovered information and suggested actions, Nigeria can initiate a course of action to protect its susceptible coastal regions, guaranteeing the enduring viability of coastal communities and ecosystems. This research represents a crucial milestone in the direction of a fortified and safeguarded coastal ecosystem.

Recommendations
Based on the geophysical assessment conducted, it is advised that the following actions be implemented:
The primary goal is to develop and implement coastal protection strategies that incorporate geophysical data and prioritise the preservation of natural barriers.
Strongly advocate for the implementation of sustainable land-use practices and urban development regulations as effective strategies to mitigate erosion resulting from human activities.
The main focus is on keeping an eye on and controlling the flow of saltwater into coastal aquifers

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so that freshwater resources become available again.
The aim of this endeavour is to heighten public awareness regarding the phenomenon of coastal erosion and actively engage neighbouring communities in efforts to mitigate and adapt to this process. Through the implementation of these measures, Nigeria can endeavour to safeguard its vulnerable coastal regions and establish a sustainable trajectory for both coastal communities and ecosystems.

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