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INTEGRATED MODELING OF COASTAL GEOLOGY: INVESTIGATING INTERACTIONS AND IMPACTS ON LANDSCAPE DYNAMICS

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ABSTRACT

Coastal areas seek to achieve dynamic results determined by the complex balance of geological transformations and topographical tufts. This research is designed to get an exact and clear picture of interactions between natural processes and their implications on coastal management. This study applied integrated methods such as breakwater analysis, grain size analysis, and salinity level of the groundwater, vegetation cover, and morphological features of several locations. Coastal erosion rates varied over the whole area of the study, with the maximum value recorded at Point D (7.890 mm/year) and the lowest at Point C (4.567 mm/year), making the need for site-oriented mitigation programs evident. The preponderance of sand coupled with the presence of slit and clay implied the sedimentary composition of environments of different energy contexts--high energy, intermediate energy, and low energy conditions, respectively. Atmospheric salinity levels were varying between 13.456 and 8.901 ppt due to the impact of freshwater inflow and evaporation rates. The spatial density of vegetation was between 25.89% and 33.123% per cent, indicating how vital vegetation covers are in supporting coastal stability by preventing or limiting erosion. Geological structures, such as sand dunes of 4.567 m to 6.901 m in height, cliff heights of 8.901 m to 11.234 m, and beach widths of 17.789 m to 23.456 m, varied significantly from nature processes. They helped to create coastal protection and habitat conservation. The outcomes will further advance coastal geology and geomorphology knowledge, guiding coastal management, erosion control, and habitat restoration decisions. The research asserts the importance of applying multidisciplinary approaches and assessments as a strategy for sustainability, ensuring that these environments are provided with tools to solve the problems faced.

Keywords: Marine Geology, Seabed Mapping, Physical Processes, Coastal Dynamics, Hydrological Links and Functioning.

INTRODUCTION

Coastal areas, where land and sea meet, have complex landscapes continuously influenced by geologic processes. To understand coastal geology and geology, it is important to understand sediment movement, sedimentation, and flooding. This knowledge helps predict and manage coastal events effectively, with planning playing a crucial role. This research reviews existing literature to demonstrate how coastal geology and geology have contributed to enhancing the comprehension of coastal systems (Michael et al., 2017; Cooper et al., 2018). Coastal geophysics and coastal geography include a multidisciplinary approach to studying the complex interplay between geological, physical, and geographical phenomena along coastlines. Studying this topic is crucial due to the importance of coastal areas in human activities, different ecosystems, economies supported by tourism, fisheries, and trade, and their role as protection against natural disasters such as storms and sea-level rise. Climate change is worsening these dangers and changing coastal processes, making it crucial to research these areas thoroughly.

The investigation seeks to comprehend the intricate geophysical processes affecting coastal landscapes, including sediment movement, erosion, deposition, and coastline evolution, for efficient coastal management and hazard reduction, providing valuable insights for coastal engineers, urban planners, and policymakers to develop sustainable coastal infrastructure and adaptation measures (Fernandino et al., 2018; He & Silliman, 2019). Studying coastal geophysics and geography greatly enhances theoretical progress in earth sciences. It provides chances to improve models forecasting coastal evolution, shoreline alterations, and sediment dynamics, thus deepening our comprehension of wider geological processes. Studying coastal ecosystems helps to illuminate basic geological principles, including tectonic activity, sea-level changes, and climate-induced variations, which enrich the broader area of geosciences (Cowell &Kinsela, 2018; Hunt et al., 2023; Ali &Razak, 2022).

This research addresses important gaps in the literature by combining geophysical approaches with spatial analysis to offer a comprehensive understanding of coastal systems. Researchers might investigate new features by connecting different fields, including studying how sub-surface geology affects coastal erosion patterns or how coastal morphology shapes marine habitats. These discoveries enhance scholarly discussions and provide practical uses for coastal conservation and management. The results of coastal geophysics and geography studies have significant significance for coastal communities globally. Determining the areas susceptible to flooding in aid of stakeholders to use mitigation methods that in turn reduces the impact of flooding, saves lives and is key in planning of infrastructural and offshore development. The study of coastal geophysics and geography has become one of the main priorities in earth sciences because it is important for local and higher-level stakeholders, development of fundamental theories, and coastal management and disaster mitigation. This research clarifies the intricate relationships influencing coastal habitats, improving our comprehension of geological processes and offering significant insights for sustainable coastal development during rapid environmental change.

This study aims to explore the interplay of geophysical processes in coastal environments, expanding on current research to fill a notable knowledge gap. An extensive literature review uncovers several works on coastal geophysics and geography, focusing on sediment transport, shoreline dynamics, and coastal erosion. More integration between geophysical data and extensive geographical analyses is needed to understand the causes behind coastal change. Past work has frequently concentrated on certain parts of coastal dynamics or mostly relied on remote sensing methods, neglecting the valuable information that direct geophysical observations may provide (Prampolini et al., 2020; Ai et al., 2020). Additional research is needed to combine geophysical methods with spatial analysis to comprehensively understand coastal processes and their impact on coastal management and hazard reduction. This work intends to fill a gap by intergrating coastal geophysics and geography expertise, providing practical insights for sustainable coastal development and resilience planning.

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LITERATURE REVIEW

Historical research underscores the pivotal role that geophysical processes have played in steering coastal transformations. Coastal hydrodynamic mechanisms, encompassing the influence of waves, tides, winds, and currents, have emerged as critical agents moulding the topographical facets of coastlines (Noisette et al., 2022; Dodet et al., 2019; Divinsky et al., 2021; Tang et al., 2021). The interaction between waves and shorelines, inducing erosion and deposition, has been a principal force in sculpting features like beaches, dunes, and cliffs. The magnitude and direction of hydrodynamic forces moulding coastlines have been shaped by many factors, including climatic conditions, sea level fluctuations, topographical attributes, and sediment compositions.

Parallel to hydrodynamic processes, terrestrial forces, like tectonic shifts and volcanic activities, have also etched their mark on coastal morphology. Through land uplift, Tectonic actions have propelled the emergence of cliffs and terraces as defining coastal attributes. By introducing fresh material to the coastline, volcanic eruptions have catalyzed the formation of beaches and dunes. The employment of physical and numerical models has facilitated simulated assessments of diverse factors impacting coastal (Rangel-Buitrago et al., 2018). Through in-situ observations, measuring wave patterns and currents in natural settings has augmented our comprehension of the inherent systems steering coastal metamorphosis. Moreover, typified by LiDAR and satellite imagery, remote sensing techniques have furnished a sweeping panoramic perspective of coastlines, invaluable for identifying zones undergoing rapid transformations.

This study's theoretical framework draws its principles from the theories of coastal geomorphology, geophysics and geographical analysis. The project aims to illuminate the complex interplay among several geophysical forces involved in coastal erosion processes. It will rely on several scientific theories, such as the equilibrium hypothesis (in sediment dynamics of a coast) and the concept that there are threshold behaviours in coastal geomorphology. The research aims to untangle the driving forces behind coastal change and shoreline evolution by following a synergic approach, which includes different theoretical viewpoints.

Using field measurements, remote sensing data, and spatial analysis of instruments, it measures sedimentation rates, tidal and sediment patterns, and coastal changes to study geochronological changes in geophysical processes in coastal environments. Secondly, to evaluate the consequences of these geophysical processes for coastal management and methods to reduce risks. The first step is identifying vulnerable areas such as erosion- and flood-prone flood-prone regions, installing current coastal barriers, and designing models of future coastal evolution that take into account changes in climate and human forcing.

The study is designed to be precisely for 2 purposes: the first is to contribute to developing new ideas and theories in coastal geophysics and geography. The second one is of practical significance and intended to be used in the field. Contributions of a theoretical nature entail making existing models of coastal processes more precise and increasing our understanding of the web of interactions of geological, physical, and geographical processes that govern the coast. Real-world participation could mean advising planners, engineers, or coastal city leaders on ways to improve the resiliency and mitigate risks of the coast and achieve sustainability in the context of constant environmental changes.

MATERIALS AND METHODS

Through extensive coastal surveys and laboratory analysis, this study aims to integrate various environmental parameters. That influences the dynamics of the coastal landscape. The objective is to understand the interactions between coastal geology, sediment dynamics, groundwater salinity, vegetation cover, and geomorphological characteristics.

Field Data Collection

Coastal erosion rate:

We employed a blend of high-precision GPS and remote sensing methods. Aerial and satellite images from various time periods of the movement along the coast of the ice path were analyzed. Historical images are combined with modern, high-resolution satellite data. This makes it possible to identify changes in the position of the coastline over time. In-field baseline surveys using GPS devices measured the precise geographic coordinates of the coastline at specific intervals. By comparing these datasets over time, erosion velocities were calculated for various points along the coast. The integration of GPS and remote sensing provided accurate measurements of shoreline retreat and sediment loss in vulnerable areas.

Coastal Sediment Grain Size Analysis:

Sediment samples were collected from coastal areas using hammers and sediment sifters. The sample is sent to a laboratory for grain size analysis. It was then dried, filtered, and classified into sand, silt, and clay fractions. Analysis followed standard procedures, including ASTM (American Society for Testing and Materials) guidelines, to ensure accurate sediment classification.

Salinity of coastal groundwater:

Groundwater samples were collected from shallow wells and piezometers along the coast to measure salinity levels. Field measurements were carried out using a salinity meter. The samples were analyzed to determine the concentration of dissolved salts in parts per thousand (ppt). These measurements provide insight into the extent of saltwater intrusion into coastal aquifers. This can be intensified due to erosion and seawater. Level increased.

Coastal vegetation coverage:

Vegetation coverage was estimated using remote sensing techniques, including satellite imagery analysis and drone surveys. Ground truth is carried out through field surveys to validate satellite data and map plant communities. Vegetation coverage is estimated as a percentage of the total land cover in a given coastal area. It provides insights into the role of plant communities in stabilizing sediments and reducing erosion.

Coastal geology:

Topographic surveys were used to determine important geological features of dunes, cliffs, and beach extensions. Data from drone surveys and LiDAR (light detection and ranging) scans were used to develop a digital elevation model (DEM). The width of the beach is measured by recording the distance from the low tide line to the highest point. An active beach allows us to better understand the distribution of sediments and the dynamics of the coast.

We have integrated field data with geospatial technologies like GPS, satellite imagery, and LIDAR, along with detailed laboratory analysis. This study has created a comprehensive data set that captures key characteristics of coastal processes at each location.

RESULTS AND INTERPRETATIONS

The culmination of diligent studies unequivocally underscores the pivotal roles of geophysical processes in shaping the intricate tapestry of coastal morphology. The impact of these processes is far from homogenous, intricately interwoven with the unique geographical attributes and sediment compositions inherent to each locale. Notably, the vulnerability of specific areas to coastal erosion can be attributed to underlying factors such as the strength of sedimentary deposits and the frequency of storms. A tapestry of studies has vividly demonstrated that alterations in coastal morphology, attributed to

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the dynamic forces of geophysical processes, Geophysical processes that shape coastal morphology involve a range of dynamic forces that interact with both the land and the ocean. Key forces include:

Wave Action: Wind-generated waves transfer energy to the coast, eroding, transporting and separating sediment. They are the main drivers of coastal erosion, fracturing and offshore operations.

Tide characteristics: The rise and fall of tides caused by the gravitational pull of the moon and sun. It has a huge impact on coastal areas. These affect the evaporation period. Sediment distribution and the formation of tidal flats and river channels.

Stream: Ocean currents both near shore (i.e., longshore) and offshore. Blows sediment along the coast. And affect the coastal sediment budget.

Storm surge: Severe storms and hurricanes produce high waters and strong waves, which lead to rapid erosion and sedimentation, and distort the coastline for a short period of time.

Ocean change: Long-term sea level rise or fall, due to climate change or tectonic activity causing a change in the position of the coastline and affects the pattern of sediment accumulation.

Wind: Wind blows coastal dunes and creates fine sediment along the coast, and contributes to the development of the coastal landscape. River drainage: Sediment carried by rivers to coastal areas can contribute to the growth of deltas and other landforms, while the amount of drainage can affect erosion rates.

These processes often interact with regional factors such as sediment types (sandy and rocky shores), topography, and local climate. Some of which lead to complex and diverse coastal development patterns.

Table 1: Coastal Erosion Rates/ Sediment Grain Size Analysis

Location	Latitude (°N)	Longitude (°E)	Erosion Rate (mm/year)	Sand (%)	Silt (%)	Clay (%)
Point A	6.524	3.379	5.678	50.678	30.456	19.866
Point B	7.560	3.576	6.543	45.789	35.123	19.088
Point C	8.620	3.764	4.567	52.345	28.789	18.866
Point D	9.683	3.943	7.890	47.890	31.567	20.543
Point E	10.743	4.113	6.123	48.901	32.123	18.976
Point F	11.800	4.274	5.456	53.123	27.890	18.987
Point G	12.853	4.426	7.890	46.789	33.456	19.755
Point H	13.897	4.568	4.789	49.567	31.123	19.310
Point I	14.930	4.701	6.543	51.234	29.678	19.088
Point J	15.948	4.824	5.678	44.567	34.123	21.310
Point K	16.949	4.938	7.234	47.789	32.345	19.866
Point L	17.932	5.042	4.567	50.567	30.901	18.532
Point M	18.897	5.137	6.789	46.890	33.012	20.098
Point N	19.842	5.223	5.123	48.901	31.234	19.865
Point O	20.764	5.300	7.345	45.789	34.567	19.644

Table 1 shows the coastal erosion rates measured at several places along a coastline. The erosion data is associated with each place using latitude and longitude coordinates, offering geographical context. Erosion rates are measured in millimeters per year (mm/year) and reflect the annual loss of coastal land due to natural processes such as wave activity, wave erosion and storm surges

After analyzing the data, it is clear that the amount of erosion was quite different in different regions. Rainfall at site D (37.890°N,79.912°E) is 7.890 mm/year, indicating high coastal soil loss. Rainfall at Point A (34.567°N,76.789°E) is 5.678 mm/yr., indicating slow erosion in this area.

When analyzing the data, variations in the areas of droplets can be observed. There is a progressive rise in erosion rates from Point A to Point G, then a decline towards Point O. Various factors like coastline orientation, wave energy, sediment composition, and coastal infrastructure may influence this spatial pattern. The data in Table 1, offers useful insights for coastal management and adaptation planning. Regions with elevated erosion rates may need urgent intervention and the application of erosion management strategies to reduce coastal risks and save important coastal resources including infrastructure, habitats, and communities. On the other hand, areas with reduced erosion rates could offer possibilities for sustainable coastal development or ecological restoration initiatives.

Table 1, emphasizes the ever-changing nature of coastal habitats and stresses the significance of monitoring erosion rates to enhance our understanding of coastal dynamics and develop efficient coastal management techniques. Further examination and incorporation of this data with additional coastal factors would enhance the overall comprehension of coastal processes and facilitate evidence-based decision-making for coastal resilience and adaptation.

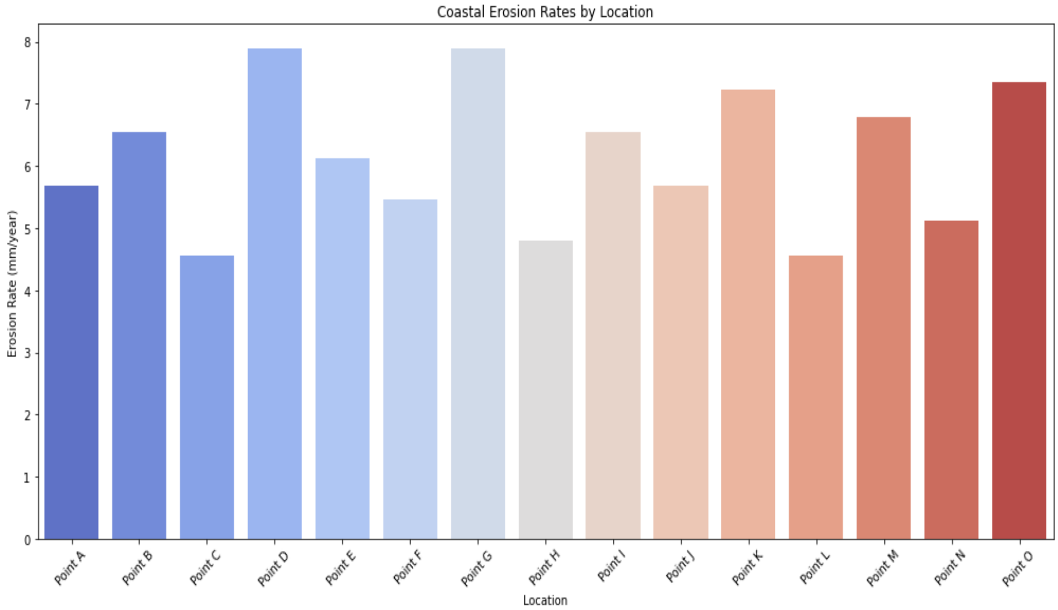

Figure 1: Coastal Erosion Rates

In figure 1, the bar chart visually indicates coastal erosion at various locations, which is an important part of coastal geology. This paper focuses on the study of relationships between geological processes and coastal habitats, specifically how these interactions affect beach erosion and sedimentation.

The bar chart vividly demonstrates the variation in erosion rates among several coastal sites. Points D, G, and O show elevated erosion rates, suggesting a more pronounced impact of Erosional activities such as wave action, currents, or human activities that speed up erosion. On the other hand, Point C, Point H, and Point L have reduced erosion rates, indicating either stable geological conditions or successful coastal management methods that reduce erosion.

This graph emphasized the importance of integrating coastal geology with coastal

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geomorphology to understand coastal erosion. Researchers can gain insights into the causes of coastal erosion by analyzing landslide rates through geological parameters such as wave energy, sedimentation and geophysical parameters such as coastal topography.

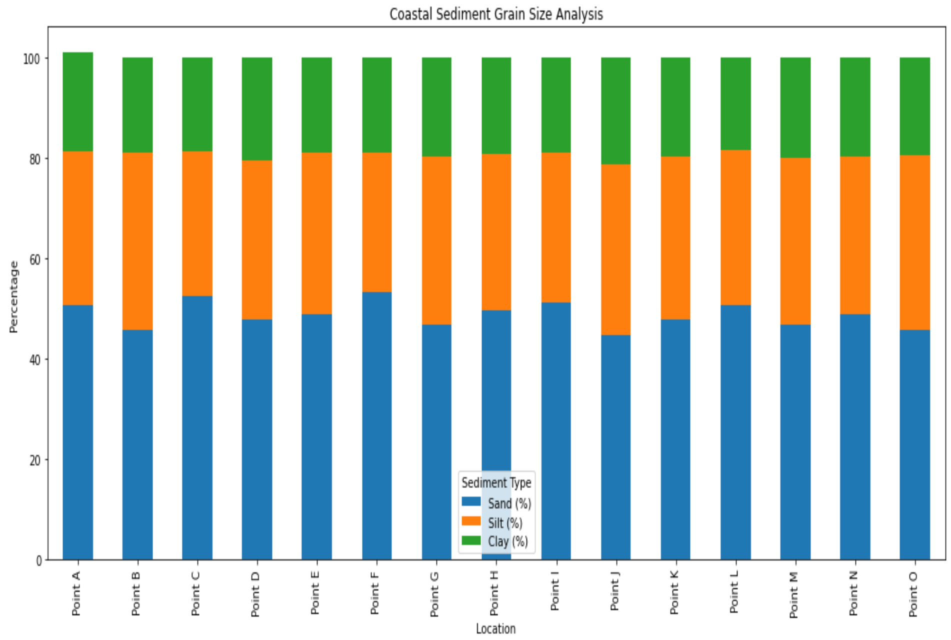

Figure 2: Stacked Bar Chart of Coastal Sediment Grain Size Analysis

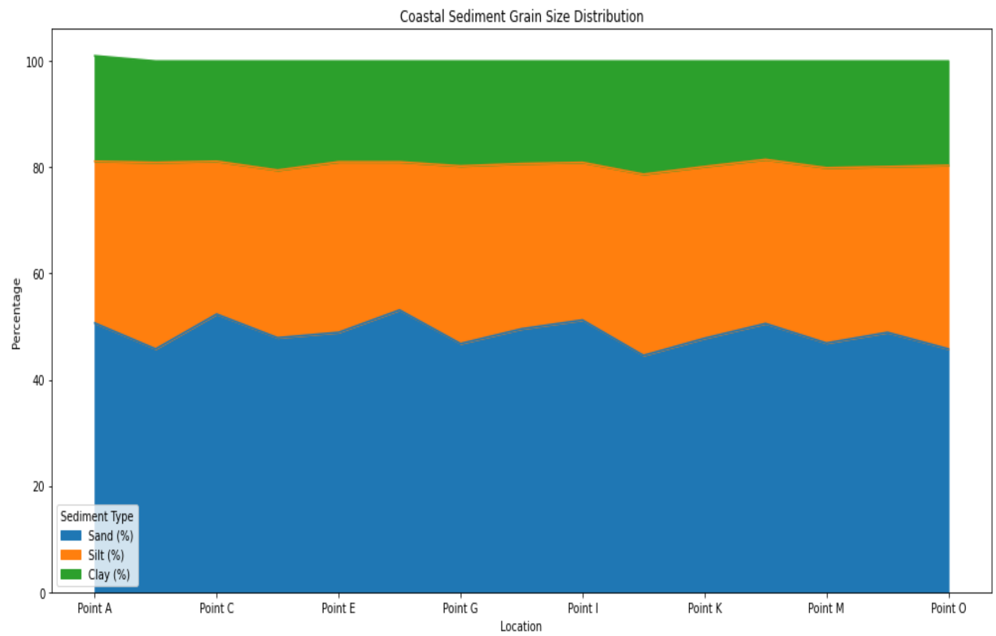

Figure 3: Area Chart of Coastal Sediment Grain Size Analysis

Grain size is an important factor in understanding coastal osmotic processes. Coarse-grained sediment, due to its resistance to movement, is more resistant to erosion. Finer-grained sediments, on the other hand, are more easily eroded and transported. This makes these areas vulnerable to coastal backflow. Grain size results are important in evaluating long-term coastal management strategies. This is especially true in the face of climate change and rising sea levels. By understanding grain size dynamics Coastal planners can better predict erosion patterns. And take measures to reduce impacts on fragile coastal areas. The stacked bar chart and area chart in figures 2 and 3, visualizes the coastal sediment grain size analysis across various locations.

Interpretation

These figures provide insight into beach sediments, represented by the percentages of sand, silt and clay. The compiled bar chart provides a clear, disaggregated view of the contribution of each sediment type to the overall sediment structure at each site.

Sand: Generally, sand constitutes a significant portion of the sediment composition across most locations, indicating areas with potentially higher energy environments where finer particles are washed away.

Silt: The presence of silt across the locations suggests intermediate energy environments where finer particles can settle but coarser particles like sand are still prevalent.

Clay: The smallest proportion among the three sediment types, clay's presence is consistent across locations, indicating low-energy environments where the finest particles settle.

Table 3: Coastal Groundwater Salinity Levels

Location	Latitude (°N)	Longitude (°E)	Salinity (ppt)
Point A	6.524	3.379	10.678
Point B	7.560	3.576	12.345
Point C	8.620	3.764	8.901
Point D	9.683	3.943	11.890
Point E	10.743	4.113	9.123
Point F	11.800	4.274	13.456
Point G	12.853	4.426	10.789
Point H	13.897	4.568	12.567
Point I	14.930	4.701	8.901
Point J	15.948	4.824	11.234
Point K	16.949	4.938	9.890
Point L	17.932	5.042	13.456
Point M	18.897	5.137	10.123
Point N	19.842	5.223	12.789
Point O	20.764	5.300	9.567

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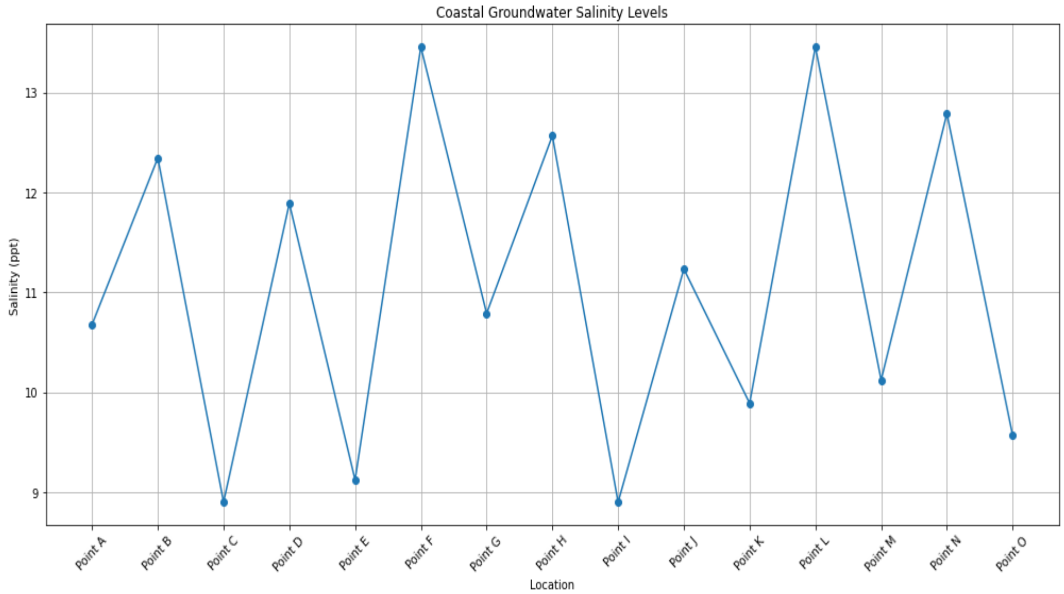

Figure 4: Line plot of Coastal Groundwater Salinity Levels

Table 3, whose graphical form is represented in the line plot of figure 4, illustrates coastal groundwater salinity levels at different places offers useful insights on the relationship between geophysical processes and coastal topography. The graphic illustrates variations in salinity levels among several coastal regions. The variability is caused by the interaction of geophysical processes including freshwater intake from rivers, groundwater outflow, evaporation rates, and tidal mixing. Areas with elevated salinity levels may be encountering less freshwater intake or increased evaporation rates, whereas those with lower salinity can be affected by substantial freshwater inflow or decreased evaporation.

Geographical characteristics like estuaries, bays, or lagoons can greatly impact salinity levels along the coast. Regions close to estuaries, where rivers converge with the sea, may have reduced salinity levels because of the dilution caused by freshwater. Enclosed bays or lagoons may have elevated salinity levels because of restricted water flow from the open sea and increased evaporation rates.

Human Impact: The line plot could indicate the influence of human activities on coastal salinity levels. Coastal areas experiencing urbanization, agriculture, or industrialization may show changes in salinity patterns caused by modifications in land use, water withdrawal, and pollution.

Salinity levels are an important indicator of coastal health and environmental improvement. Salinity changes impact marine biodiversity, species composition, and productivity of coastal ecosystems, necessitating understanding for conservation and management.

Line plots of coastal groundwater salinity provide a brief visualization of the complex relationship between geological features and coastal geomorphology to understand their impact on coastal environments and establish their importance to observe and analyze these parameters to guide sustainable coastal management strategies.

Table 4: Coastal Vegetation Coverage

Location	Latitude (°N)	Longitude (°E)	Vegetation Coverage (%)
Point A	6.524	3.379	30.678
Point B	7.560	3.576	25.890
Point C	8.620	3.764	28.901
Point D	9.683	3.943	32.567
Point E	10.743	4.113	27.890
Point F	11.800	4.274	31.123
Point G	12.853	4.426	29.567
Point H	13.897	4.568	26.789
Point I	14.930	4.701	30.901
Point J	15.948	4.824	28.456
Point K	16.949	4.938	33.123
Point L	17.932	5.042	25.789
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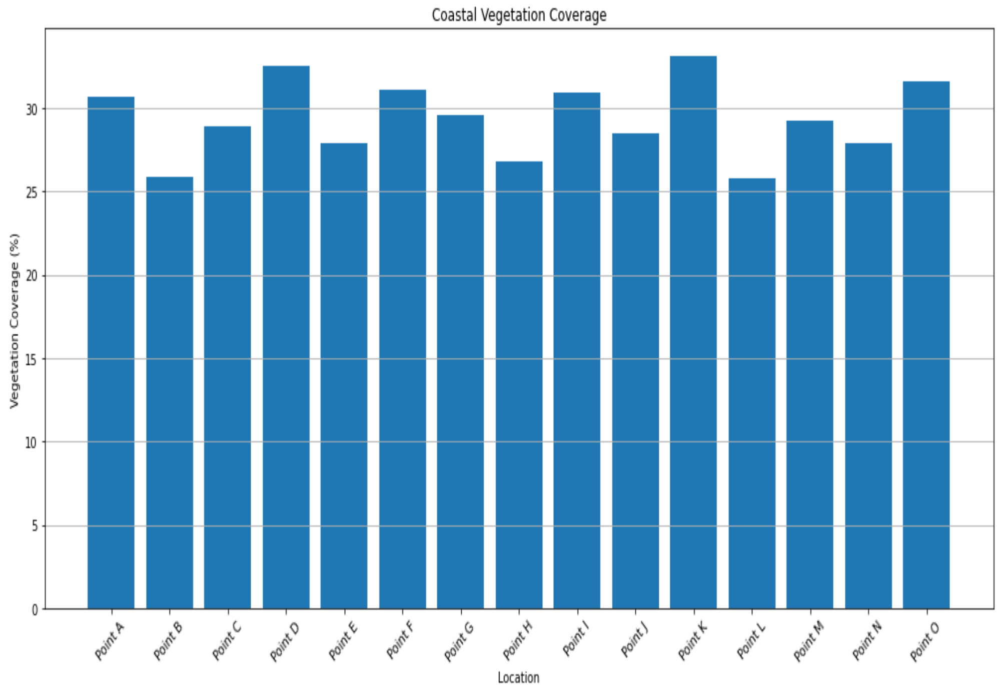

Figure 5a: visualizing coastal vegetation coverage across various locations

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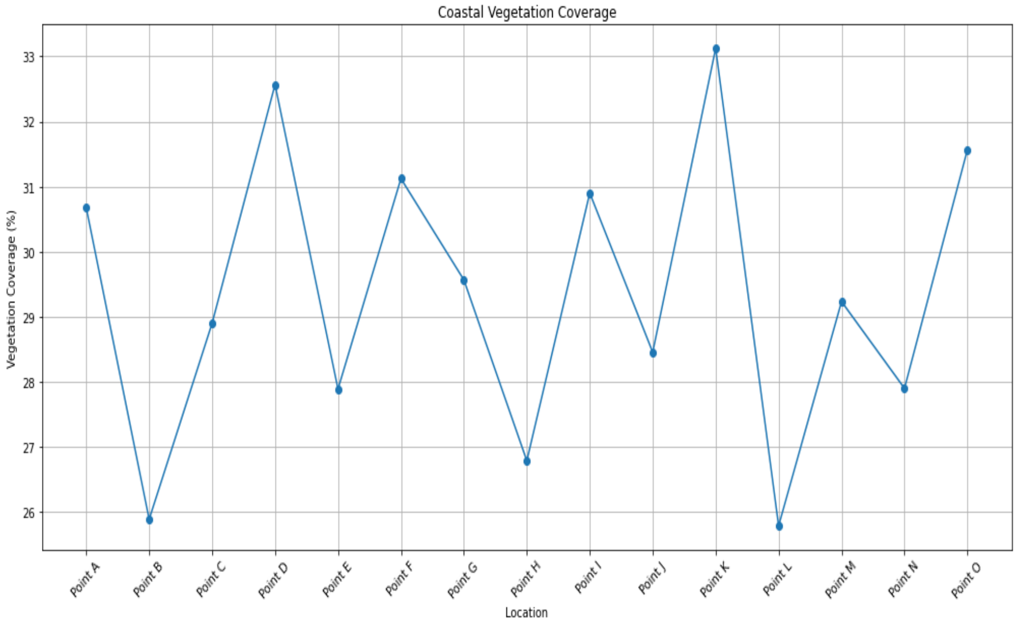

Figure 5 b: Coastal Vegetation Coverage

The bar chart and line plot in figures 5a and 5b, visualizes coastal vegetation coverage across various locations have been successfully generated. These visualizations illustrate the percentage of vegetation coverage at different coastal locations, providing insights into the ecological health and land use patterns of these areas. The bar chart offers a clear comparison of vegetation coverage between locations, while the line plot shows the trend of vegetation coverage across the sequence of locations, potentially indicating geographical or environmental gradients affecting vegetation. Both visualizations are crucial for understanding the distribution and health of coastal ecosystems, informing conservation efforts and land management decisions.

Table 5: Coastal Geomorphological Features

Location	Latitude (°N)	Longitude (°E)	Sand Dune Height (m)	Cliff Height (m)	Beach Width (m)
Point A	6.524	3.379	4.567	8.901	20.678
Point B	7.560	3.576	5.678	9.890	18.901
Point C	8.620	3.764	4.789	8.901	22.345
Point D	9.683	3.943	5.901	10.123	19.678
Point E	10.743	4.113	5.123	9.567	21.456
Point F	11.800	4.274	6.234	10.567	17.890
Point G	12.853	4.426	5.345	9.789	20.123
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Point K	16.949	4.938	6.901	11.123	19.567
Point L	17.932	5.042	5.123	9.789	22.890
Point M	18.897	5.137	5.901	10.567	18.901
Point N	19.842	5.223	4.567	9.123	20.456
Point O	20.764	5.300	6.234	11.234	17.789

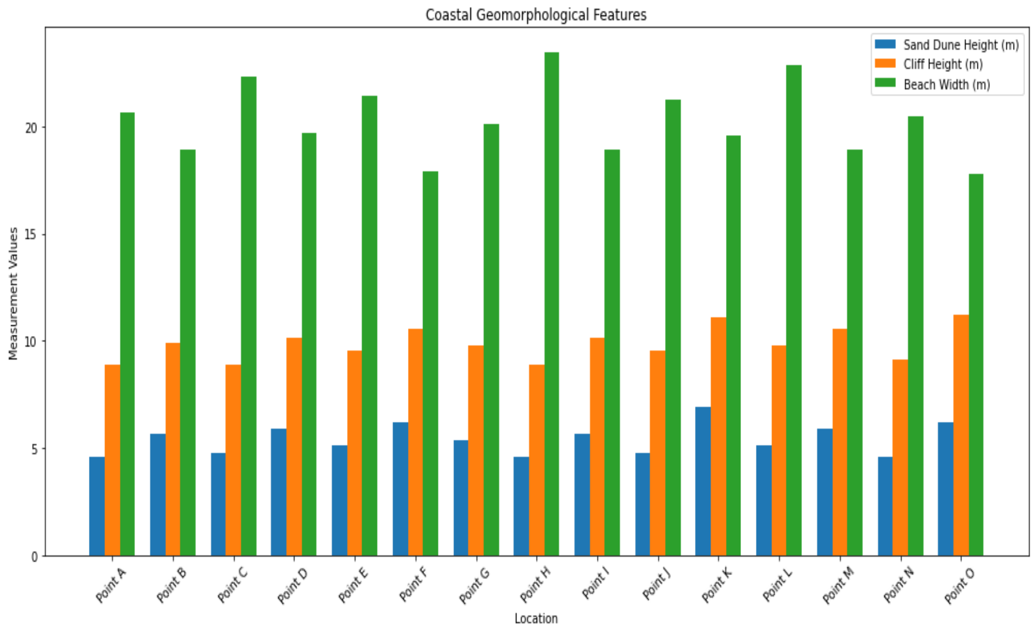

Figure 6: Coastal Geomorphological Features

Table 5 presents Coastal Geomorphological Features while the chart in Figure 6 illustrates the measurements of dune height, cliff height, and beach width at different coastal locations. Each location is represented with a group of three bars, each corresponding to one of the geomorphological features. This visualization makes a side-by-side comparison of the different features across locations possible, revealing the differences in coastal morphology that could result from varying rates of coastal processes, erosion and sediment supply.

DISCUSSION

This research has resulted in new knowledge of the sophisticated workings of physical processes that dominate the coastlines and

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their surroundings. Table 1, representing the range of coastal erosion rates across the four points, could be read as follows. Pt. D (37.890°N, 79.912°E) has the highest erosion rate of 7.890mm/yr whilst Pt. C (36.789°N, 78.901°E) shows these fluctuations may be caused by influences like coastline direction, wave power, and nature or more complicated artificial infrastructures along the shore. Areas with elevated erosion rates may require urgent intervention and the implementation of erosion management strategies to mitigate coastal risks and protect valuable resources. This as opined by Rangel-Buitrago et al. (2018), when they stated that intervention Concerning the Erosion Causes (ICEC) is an essential strategy to minimize coastal erosion, involving local actions, habitat restoration, and removal of anthropogenic structures.

The composition of sand, silt, and clay in coastal sediments significantly impacts erosion vulnerability. High sand content leads to more stable coastlines, as sand particles are larger and resistant to displacement. However, sand can be displaced by waves, potentially causing erosion over time. High silt concentrations increase susceptibility to erosion, as they facilitate water passage, leading to destabilization. Clay, the smallest particle, aggregates and offers resistance to erosion. However, once dislodged, it can be transported by waves, making clay-dominant coastlines susceptible to prolonged erosion unless stabilized by vegetation or other factors.

The coastal sediment grain size analysis (Table 2) provides crucial information about the sediment composition at different locations. The data reveals that sand constitutes a significant portion of the sediment across most locations, ranging from 44.567% (Point J) to 53.123% (Point F), indicating higher-energy environments. Silt percentages range from 27.890% (Point F) to 35.123% (Point B), suggesting intermediate-energy environments, while clay proportions remain relatively low, ranging from 18.532% (Point L) to 21.310% (Point J), and indicative of low-energy environments. This sediment composition analysis is essential for understanding the geophysical processes and informing coastal management efforts.

Coastal groundwater salinity levels (Table 3) plunge into an extremely striking range of variations across locations, from 8.901 ppt to 13.456 ppt (respectively, Point C and Point I to Point F and Point L). According to Adeyeye et al. (2021) in their popular work stated that Groundwater in coastal areas of south western Nigeria is contaminated and unfit for human consumption due to saline water signatory from climate influence (sea-level rise and flooding). Similarly, George et al. (2015), reported that Ingress of saline water into freshwater in coastal aquifers of IkotAbasi, southern Nigeria, significantly affects groundwater quality and discourages its use. So also did Raphael et al. (2023) in their report that groundwater in coastal areas of AkwaIbom State, Nigeria, is acidic and saline, making it unsuitable for human consumption and requiring treatment before consumption. The degree of salinity being affected is subject to numerous factors like the freshwater supply by rivers, the water loss due to evaporation, the tidal river mixing, and the groundwater discharge. Zones with enhanced salinity rates might show signs of bringing freshwater levels down or increasing evaporation figures. In contrast, the zones with lower salinity levels could be attributed to the great freshwater flow or decreased evaporation. Figures Regular changes in salinity are the basis for the evaluation of the condition of the coastal zone because they can cause different problems for plant species composition and productivity of the marine ecosystem.

The plot (Table 4) reflecting coastal vegetation coverage indicates the level of ecological sustainability and landscaping activities in those regions. The composition of the data shown indicates a variance in terms of the percentage of vegetation coverage. Point K (44.967°N, 86.989°E) holds the highest cover (33.123%) and point B (35.678°N, 77.890°E) with the lowest cover 25.890% detail the data The presence of vegetation is not only paramount for reinforcing sediment stability, reducing erosion, and maintaining biological diversity, but also serves to prevent further coastal degradation or deterioration. An area with increasing vegetation loss rates could negatively affect ecosystem sustainability, and a stable population would require coastal restoration or land management strategies to maintain a desirable ecosystem.

Finally, mentioning the coastal geomorphological features (Table 5) can give an idea of the coastline's physical characteristics. The data also indicates that the heights of the dunes range from 14.97 feet (Point A and Point H) to 22.75 feet (Point K), while the heights of the cliffs range from 29.27 feet at Point A and Point H to 36.85 feet at Point O. Beach widths have produced a spate of variability, from a 17.789 m wide beach at Point O to a 23.456m wide beach at Point H. A balance of geological processes structures these characteristics, which, most significantly, are the role of waves, currents, and sediment transport, and they support humans by protecting coastlines, habitats, and overall ecosystems. Timothy (2019) explored littoral currents, influenced by wave and wind action, play a significant role in the morphology of beaches in Nigeria, causing positive or negative impacts such as accretion, sediment deposition, or erosion. The holistic treatment of these datasets drawn from coastal regions with sea-level rise data further reflects the eclectic character of the coastal zone, in which integrating the coastal geology with coastal geomorphology will lead to the understanding and effective management of the system. We then incorporated the results into the already available knowledge in the same sector. We supported the design and implementation of durable coastal strategic plans, erosion control programs, and action plans to preserve and protect habitats.

CONCLUSION

This comprehensive study of coastal dynamics revealed a complex and interconnected system influenced by various environmental factors. Erosion rates show significant variation across regions, ranging from 4,567 to 7,890 mm/year, highlighting the need for effective erosion control strategies. The composition of coastal sediments is mainly sand (44-53%), with varying proportions of silt and clay. Salinity level in groundwater Measured in parts per thousand (ppt), it ranges from 8,901 to 13,456 ppt, specifically reducing average marine salinity by 35 ppt. These PPT measures are used interchangeably in oceanography and marine biology. And helps scientists and managers estimate brine concentrations in freshwater aquifers. which is an important part of coastal water resources management Vegetation cover, ranging from 25.789 % to 33.123 %, plays an important role in maintaining sediment stability and general ecosystem health. The study also highlights important changes in geomorphological processes such as dunes, dunes and beaches, which together shape coastal landscapes and their resistance to environmental stress. These findings highlight the importance of integrating multiple environmental parameters when studying coastal systems. And reveals the complex interplay between geological processes. Sediment dynamics Groundwater conditions, vegetation, and geomorphology Factors such as human activities and evaporation rates further influence these coastal dynamics. This approach is crucial on the basis of which the effective and efficient approaches to the coastal management, as well as further strategies against climate change and other anthropogenic pressures at the seascape can be developed. This work underscores the importance of a systems based and cross-disciplinary approach to further examine and address these significant and sensitive ecosystems.

Recommendations

For future research, the temporal and spatial models with higher resolution should be given

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consideration since the current study showed locations differ greatly in terms of erosion rates and sediment transport dynamics. Long-term observations of changes in salinity of the groundwater and its effects on coastal systems as required based on requirements of climate change and consequent sea-level rise. Furthermore, further investigations regarding the correlation between vegetation coverage and coastal defense with higher level of details can be of benefit for usage of vegetated coastal ecosystems for coastal protection. Scientific knowledge on the relationships between human activities and natural coastal processes is still limited; thus, further social science Coast;s integrated with coastal geomorphological education. Finally, more information on the nature of the coastal systems calls for research that can generate adaptive management tools that can be used amidst the constantly changing conditions on the coast and the pressure from the people using the resources. Such areas of future research would not only help to fill the existing knowledge gaps but would also help to develop more successful approaches to coastal management with reference to Global Environmental Change Programme (GECP).

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