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Coastal Erosion Mapping with Historical Data Using Google Earth Pro

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Abstract: Coastal erosion poses a significant threat to shoreline stability, impacting ecosystems, infrastructure, and local communities. This project aims to analyze and quantify shoreline changes over time at Manakudy Beach and Vaniyakudi Beach by utilizing historical imagery. Historical imagery from Google Earth Pro was extracted for multiple years 2010, 2016, 2020, and 2024 for Manakudy Beach and 2010, 2018, 2022, and 2025 for Vaniyakudi Beach and overlaid to visualize shoreline shifts. Distinct colors were assigned to each year to facilitate a clear visual comparison of shoreline movement, highlighting zones of erosion (landward shift) and accretion (seaward shift) over the selected time intervals. Polygons and markers were created to delineate these zones, ensuring the precise identification of areas experiencing land loss and land gain. For Manakudy Beach, data analysis revealed measurable shoreline displacement between 2010 to 2016, 2016 to 2020, and 2010 to 2024, while for Vaniyakudi Beach, significant erosion and accretion trends were observed between 2010 to 2018 and 2010 to 2025, capturing notable shoreline changes. Using Google Earth Pro's Ruler Tool, the distance of shoreline retreat and advance was accurately measured, followed by the calculation of erosion and accretion rates to quantify the magnitude of change over time. The analysis revealed that Manakudy Beach experienced moderate shoreline change initially, followed by accelerated erosion between 2016 and 2020, and minimal accretion between 2010 and 2024. Conversely, Vaniyakudi Beach exhibited high erosion between 2010 and 2018, with continued erosion and minor accretion between 2010 and 2025. These findings were visually represented through bar charts to provide a comparative assessment of shoreline dynamics for both locations, highlighting areas that demand immediate attention. The comprehensive results of this study offer valuable insights to coastal planners, policymakers, and environmental authorities in implementing informed and sustainable coastal protection measures.

I. Introduction

Coastal zones act as a buffer between land and sea, playing a crucial role in maintaining ecological balance and supporting diverse ecosystems. However, these zones are highly susceptible to erosion and accretion due to both natural and anthropogenic factors. Shoreline changes can have far-reaching consequences, affecting local livelihoods, infrastructure and buildings. To assess and mitigate these impacts, continuous monitoring and evaluation of shoreline variations are essential. Google Earth Pro, with its ability to provide historical satellite imagery over a wide temporal range, offers a powerful tool for visualizing and analyzing these changes with high precision. This project aims to utilize historical data available in Google Earth Pro to map shoreline dynamics over multiple years for Manakudy Beach and Vaniyakudi Beach, two regions known for their changing coastline patterns. Through systematic data extraction, visual comparison, and rate analysis of erosion and accretion, this study identifies critical zones that require intervention. The insights gained from this project contribute to a better understanding of coastal processes and aid in the formulation of effective coastal management strategies.

II. Literature Review

This provides an overview of the key concepts and previous studies related to shoreline changes and coastal dynamics. It highlights the

necessity of analyzing historical shoreline data to assess erosion and accretion trends. The discussion sets the foundation for understanding the significance of monitoring shoreline transformations for sustainable coastal management.

2.1 Analyzing coastal erosion and sedimentation using Sentinel-1 SAR change detection- An application on the Volta Delta, Ghana.

Di Biase and Hanssen (2024) explore the applicability of Sentinel-1 Synthetic Aperture Radar (SAR) data for analysing coastal erosion and sedimentation in Ghana's Volta Delta. The research addresses the pressing issue of coastal degradation, which poses a substantial threat to life and property in the region. The authors astutely utilize Sentinel-1 data, processed through the Google Earth Engine (GEE) platform, and a bespoke algorithm to pinpoint and quantify erosion and sedimentation processes between 2017 and 2021. This methodological framework provides a robust approach for monitoring coastal changes, offering insights into the type, intensity, and dimensions of erosion and sedimentation phenomena.

2.2 Detection of large-scale *Spartina alterniflora* removal in coastal wetlands based on Sentinel-2 and Landsat 8 imagery on Google Earth Engine.

Min et al. (2023) introduce a novel methodology for the automatic and rapid detection of large-scale *Spartina alterniflora* removal events in coastal wetlands, utilizing time-series Sentinel-2 and Landsat 8 imagery within the Google Earth Engine. The study meticulously addresses the challenge of monitoring *S. alterniflora* removal dynamics, which is crucial for evaluating the effectiveness of removal projects and for informed coastal wetland management. A key innovation of their method is the Tide Gap Filling algorithm, designed to reconstruct tidal-inundation-related Normalized Difference Vegetation Index (NDVI) and mitigate the impact of tidal inundation on removal detection. The research showcases the potential of their method to be applied at a national scale, providing essential baseline data for coastal wetland restoration and management.

2.3 Google Earth Engine and Sentinel 1/2 data-based forest degradation monitoring of Sundarban Biosphere Reserve.

Halder et al. (2024) present a study on forest degradation monitoring within the Sundarban Biosphere Reserve, employing Google Earth Engine (GEE) and Sentinel-1/2 data. The research meticulously examines the impact of tropical cyclones on biodiversity, environmental conditions, and mangrove deforestation, demonstrating the utility of remote sensing in assessing and monitoring these ecological changes. The authors leverage the cloud-computing capabilities of GEE and the Random Forest (RF) approach to analyse vegetation change and the effects of cyclones on landforms using Sentinel-1 Synthetic Aperture Radar (SAR) data. This study offers critical insights into mangrove dynamics and the imperative need for adaptive strategies and disaster management planning to mitigate the pernicious effects of climate change on these fragile ecosystems.

III. Methodology

The systematic approach used to analyse shoreline changes through historical imagery. It describes the techniques applied to extract shoreline data, overlay different time periods, and mark zones of erosion and accretion. The methodology ensures accurate measurement and visualization of shoreline dynamics for effective analysis.



IV. Methods and Application

4.1 Data collection and preparation

The research was carried out in the Manakudy and Vaniyakudi beach areas, both of which exhibit considerable shoreline variations due to natural processes and human-induced changes.

These regions are prone to coastal erosion and accretion, necessitating a detailed analysis to understand the ongoing transformations. Historical satellite imagery from Google Earth Pro was meticulously collected to facilitate this analysis, spanning multiple years to capture temporal changes.

For Manakudy Beach, images were obtained for the years 2010, 2016, 2020, and 2024, while for Vaniyakudi Beach, the imagery was collected for the years 2010, 2018, 2022, and 2025. These datasets provided a strong temporal framework for detecting variations in shoreline position. To extract the shoreline boundaries accurately, the Add Path tool in Google Earth Pro was employed, ensuring precise delineation of the shoreline for each selected year. The extracted shoreline data served as the baseline for analyzing changes in shoreline movement, enabling the identification of zones where erosion and accretion had occurred over time.

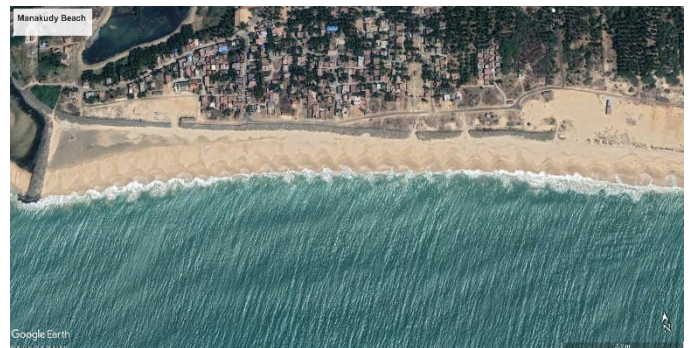


Figure 1: Manakudy Beach View

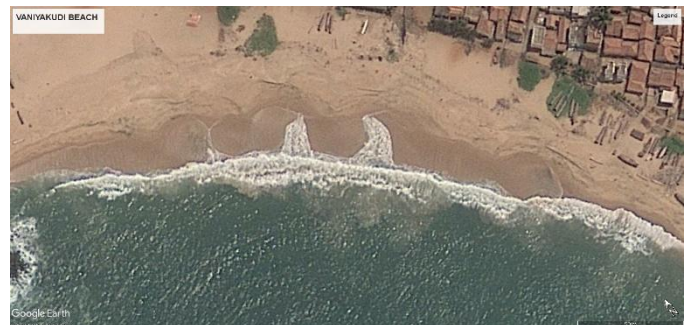


Figure 2: Vaniyakudi Beach View

4.2 Visual comparison and shoreline overlay

To facilitate an effective visual comparison for both Manakudy and Vaniyakudi beaches, the extracted shoreline data from different years were overlaid using distinct color codes to distinguish between the temporal variations in shoreline positions. This approach enabled a clearer understanding of shoreline displacement over time and provided a visual representation of erosion and accretion zones. For Manakudy Beach, the shorelines were color-coded as follows:

- Red for the year 2010
- Yellow for the year 2016
- Pink for the year 2020
- Blue for the year 2024



Figure 3: Shoreline image of Manakudy beach

Similarly, for Vaniyakudi Beach, the shoreline overlay included:

- Red for the year 2010
- Yellow for the year 2018
- Blue for the year 2022
- Pink for the year 2025



Figure 4: Shoreline image of Vaniyakudi beach

The visual overlay technique provided a clear depiction of shoreline shifts at these locations, enabling the identification of two primary types of changes:

- **Landward Shift:** This signifies erosion, where the shoreline moves inland, indicating a loss of land .
- **Seaward Shift:** This suggests accretion, where the shoreline extends outward, signifying the addition of new landmass.

4.3 Marking Zones of Erosion and Accretion

To identify and analyze the zones of erosion and accretion along two beaches , shoreline changes over the years were assessed, and distinct zones were marked using Google Earth Pro. The changes were categorized based on different time periods to determine the extent of land loss and land gain. Polygons and markers were created to delineate these zones effectively. The analysis involved marking and color-coding zones to visually represent areas of erosion (land loss) and accretion (land gain), providing a comprehensive understanding of shoreline transformations.

Marking Zones for 2010 to 2016

During this period, shoreline changes for Manakudy beach were assessed to identify the predominant trends. The identified zones were marked using distinct colors:

- **Orange Zone:** Represented areas of accretion where new land was gained due to sediment deposition or other coastal processes. This period showed moderate accretion along selected parts of the shoreline.

- **Blue Zone:** Indicated erosion where the shoreline retreated, leading to land loss caused by wave action and tidal forces. This highlighted the vulnerable zones where coastal erosion was prominent.



Figure 5: Erosion and Accretion Mapping_2010-2016

Marking Zones for 2016 to 2020

The analysis of this period revealed minimal accretion with dominant erosional activity along the shoreline.

- **Blue Zone:** Marked the regions affected by erosion during this period, where the shoreline experienced retreat. No significant accretion zones were observed, indicating continuous land loss without substantial land gain.



Figure 6: Erosion and Accretion Mapping_2016-2020

Marking Zones for 2010 to 2024

An extended analysis comparing shoreline positions from 2010 to 2024 provided a long-term view of shoreline dynamics.

- **Green Zone:** Represented erosion with significant land retreat over the years. This marked the areas where continuous land loss occurred due to sustained coastal processes.
- **No Major Accretion:** Unlike the previous periods, this extended timeline did not exhibit noticeable accretion, indicating a persistent trend of land loss without any substantial land recovery.



Figure 7: Erosion and Accretion Mapping_2016-2020

Similarly, shoreline changes at **Vaniyakudi Beach** were analyzed across different years, and zones were marked to highlight erosion and accretion patterns. Using Google Earth Pro, these zones were represented by different colors for distinct time periods.

Marking Zones for 2010 to 2018

- **Blue Zone:** Represented erosion where the shoreline retreated, indicating significant land loss during this period.
- **No Major Accretion:** No noticeable land gain was observed, reflecting a period dominated by erosional activity.



Figure 8: Erosion and Accretion Mapping_2010-2018

Marking Zones for 2010 to 2025

- **Blue Zone:** Denoted erosion with a retreat along the shoreline, signifying continued land loss over this extended period.
- **Yellow Zone:** Indicated accretion with a modest land gain, highlighting some areas where land was regained.



Figure 9: Erosion and Accretion Mapping_2010-2025

4.4 Measurement and rate calculation

This section presents the measured distances of erosion and accretion at Manakudy and Vaniyakudi beaches for the specified time periods. The analysis of shoreline changes is a critical part of understanding coastal dynamics, which helps in assessing the long-term impact of natural forces on the coastlines. The distances were determined by examining historical imagery in Google Earth Pro, measuring the shoreline positions at the beginning and end of each period. By comparing these measurements, we can calculate the rates of erosion and accretion, which are vital for understanding the changing coastal landscape.

Measured Distances and Changes for Manakudy Beach

- In 2010-2016, The erosion distance recorded was 8 meters, while the accretion distance was slightly higher at 19 meters.

- In 2016-2020, The shoreline at Manakudy underwent significant erosion during this time frame, with a total erosion distance of 64 meters with no significant accretion.
- In 2010-2024, Over this extended period, the erosion distance at Manakudy was 24 meters with no significant accretion was recorded, emphasizing the trend of shoreline retreat.

Measured Distances and Changes for Vaniyakudi Beach

- In 2010-2018 The erosion distance for Vaniyakudi beach during this period was 52 meters, with no significant accretion, indicates a rapid retreat of the shoreline
- In 2010-2025, In this more recent time frame, the erosion distance was recorded as 13 meters, with a slight accretion of 7 meters.

Rate Calculation

Formulas Used:

$$\text{Erosion Rate} : \frac{\text{Distance of retreat (in m)}}{\text{Time interval (in year)}}$$

$$\text{Accretion Rate} : \frac{\text{Distance of advance (in m)}}{\text{Time interval (in year)}}$$

Calculated Rates for Manakudy Beach:

2010 to 2016:

- Erosion Rate : $\frac{8 \text{ m}}{6 \text{ year}} = 1.33 \text{ m/year}$
- Accretion Rate : $\frac{19 \text{ m}}{6 \text{ year}} = 3.17 \text{ m/year}$

2016 to 2020:

- Erosion Rate : $\frac{64 \text{ m}}{4 \text{ year}} = 16 \text{ m/year}$

2010 to 2024:

- Erosion Rate: $\frac{24 \text{ m}}{14 \text{ year}} = 1.71 \text{ m/year}$

Calculated rates for Vaniyakudi Beach:

2010 to 2018:

- Erosion Rate : $\frac{52 \text{ m}}{8 \text{ year}} = 6.5 \text{ m/year}$

2010 to 2025:

- Erosion Rate: $\frac{13 \text{ m}}{15 \text{ year}} = 0.87 \text{ m/year}$
- Accretion Rate : $\frac{7 \text{ m}}{15 \text{ year}} = 0.47 \text{ m/year}$

These rates provide an essential understanding of the extent of coastal changes at both beaches and underline the need for continuous monitoring and management to address erosion and promote sustainable coastal protection.

V. Result Visualization and Presentation

The final phase of the study focuses on the visualization and presentation of the shoreline change data for Manakudy and Vaniyakudi beaches. This section provides a comprehensive analysis of the temporal variations in erosion and accretion rates, highlighting critical periods of shoreline retreat and advancement. Visual aids, such as charts and graphs, offer a clear understanding

of the observed trends, facilitating better interpretation of the findings.

- During this period of 2010-2016, Manakudy Beach exhibited moderate shoreline changes. Erosion occurred at a rate of 1.33 m/year, while accretion was recorded at 3.17 m/year, indicating a temporary balance between erosion and sediment deposition. The presence of accretion during this period suggests some natural or external factors contributed to the deposition of material along the shoreline.
- The period from 2016 to 2020 witnessed a significant increase in erosion at Manakudy Beach. The rate of erosion surged to 16 m/year, highlighting a period of aggressive shoreline retreat. No significant accretion was recorded during this period, suggesting that erosion processes dominated the coastal dynamics, leading to a substantial loss of land.
- Over this 14-year period from 2010-2024, Manakudy Beach experienced progressive erosion at a rate of 1.71 m/year, indicating a consistent trend of shoreline retreat. The cumulative effect of ongoing erosion over the years has led to a net loss of coastal land, emphasizing the need for long-term coastal management strategies.
- Vaniyakudi Beach experienced high erosion during the period of 2010-2018, with a recorded erosion rate of 6.5 m/year. No significant accretion was observed, indicating that shoreline retreat was the dominant trend. The absence of accretion during this period highlights the vulnerability of the beach to ongoing erosion processes.
- The analysis for the extended period from 2010 to 2025 indicates ongoing erosion at a rate of 0.87 m/year. Although the erosion rate significantly reduced compared to the 2010–2018 period, minor accretion of 0.47 m/year was recorded. This slight accretion suggests limited natural replenishment, although it was insufficient to counteract the ongoing land loss.

To enhance the understanding of these trends, graphical representations were generated to visualize the erosion and accretion rates over time. These graphs provide a clear depiction of the magnitude of shoreline changes and allow for easy comparison between different periods and locations.

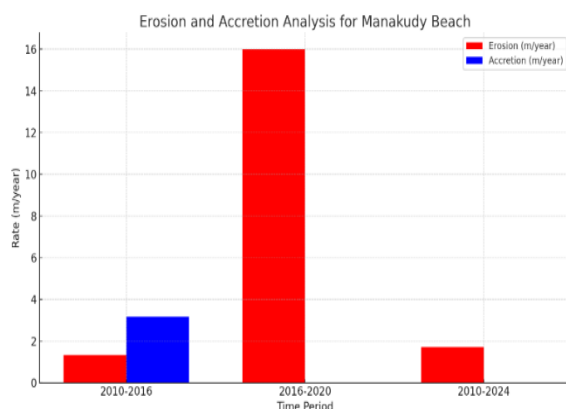


Figure 10: Comparison chart of Manakudy beach

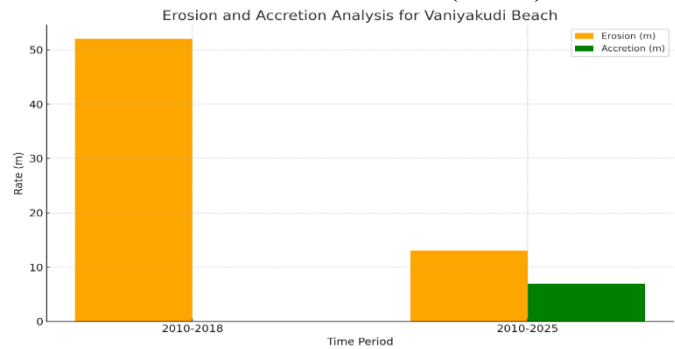


Figure 10: Comparison chart of Vaniyakudi beach

VI. Key Findings and Recommendations

Manakudy Beach recorded 16 m/year erosion, while Vaniyakudi Beach experienced erosion at 6.5 m/year emphasizing the vulnerability of these coastal areas. Accretion was observed only at Manakudy Beach between 2010 and 2016, with a rate of 3.17 m/year. Vaniyakudi Beach experienced minimal accretion at 0.47 m/year over 15 years, suggesting that natural replenishment has been insufficient to offset the ongoing erosion. Given the consistent trend of shoreline retreat, it is imperative to establish a long-term monitoring program to assess future changes and implement timely coastal management measures. Sustainable coastal management strategies should include construction of coastal protection structures to reduce erosion.

VII. Conclusion

The analysis of shoreline changes at Manakudy and Vaniyakudi beaches using historical imagery in Google Earth Pro has revealed consistent shoreline retreat over the years, with varying rates of erosion and minimal accretion. Manakudy Beach experienced moderate accretion between 2010 and 2016, followed by significant erosion, while Vaniyakudi Beach exhibited continuous erosion, with only slight accretion recorded from 2010 to 2025. The highest erosion rates were observed during the 2016–2020 period for Manakudy beach and during the 2010–2018 period for Vaniyakudi beach, indicating aggressive shoreline retreat at both locations. Despite minor accretion observed in isolated periods, the overall trend highlights a net loss of land, emphasizing the dominance of erosion processes. Bar charts used to visualize these trends provided clear insights into the temporal variations and comparative analysis of shoreline changes. The findings underscore the urgent need for sustainable coastal management interventions, including erosion control measures, artificial nourishment, and continuous monitoring to prevent further shoreline degradation. Proactive efforts to safeguard these vulnerable coastal areas are essential to mitigate the adverse impacts of erosion and ensure the long-term stability of the region.

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