

MULTI-DECADAL SHORELINE VARIABILITY ON THE EASTERN COAST OF SRI LANKA: CONTRASTING EROSION HOTSPOTS AND STABLE CONTROL SITES THROUGH QUANTITATIVE ASSESSMENT OF COASTAL INSTABILITY (2010-2025)

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Abstract

Coastal erosion has emerged as a critical global challenge, yet large-scale quantitative assessments of shoreline variability remain scarce across tropical marine environments. Long-term, spatially resolved data are essential for distinguishing persistent geomorphic loss from seasonal fluctuations and for informing evidence-based coastal management strategies. This 15-year multi-decadal analysis (2010–2025) provides a quantitative assessment of shoreline variability across the Eastern Province of Sri Lanka, addressing data scarcity. Satellite imagery from Landsat and Sentinel-2 combined with automated shoreline detection reveals substantial spatial variation in coastal behaviour across the study area. Analysis of twelve coastal sites reveals distinct geomorphic patterns: six sites experience active erosion (Kalmunai, Oluvil North, Arugam Bay, Vakaraai, Passikudah, and Foul Point) with retreat rates ranging from -0.5 to -3.5 m/yr, four sites show seaward accretion (Okanda, Kattankudy, Oluvil South, and Pulmoddai) with advance rates of $+0.2$ to $+4.5$ m/yr, and two sites maintain stable geomorphic conditions (Nilaveli and Dutch Bay). These site-specific, quantified rates enable coastal managers to prioritise intervention locations and assess the effectiveness of coastal protection strategies. The methodology demonstrates how long-term satellite-derived shoreline monitoring can fill regional data gaps and provide quantitative foundations necessary for sustainable coastal zone management and informed policy decisions in data-scarce tropical regions.

Keywords: Coastal erosion, Remote sensing, Coastal zone management

1. Introduction

Coastal erosion represents a critical global crisis, with approximately 24% of the world's sandy beaches currently retreating at rates exceeding 0.5 m/year. The Eastern Coast of Sri Lanka, spanning the Trincomalee, Batticaloa, and Ampara districts, is a highly sensitive region governed by seasonal monsoonal wave action. Despite its socioeconomic importance for fisheries, settlements, and tourism, this area has historically suffered from limited long-term monitoring and data scarcity. Recent decades have revealed noticeable shoreline instability, particularly near anthropogenic structures such as Oluvil Harbour, which has physically disrupted natural sand transport and created a distinct geomorphic divide. This study quantitatively evaluates shoreline evolution across ten selected hotspots over a 15-year period (2010–2025) using publicly available satellite imagery. The research identifies a critical Southeastern Erosional Corridor and demonstrates that infrastructure development exerts a more dominant influence on sediment transport than natural coastal processes. Figure 1 shows the distribution of selected sites over the Eastern Coast of Sri Lanka.

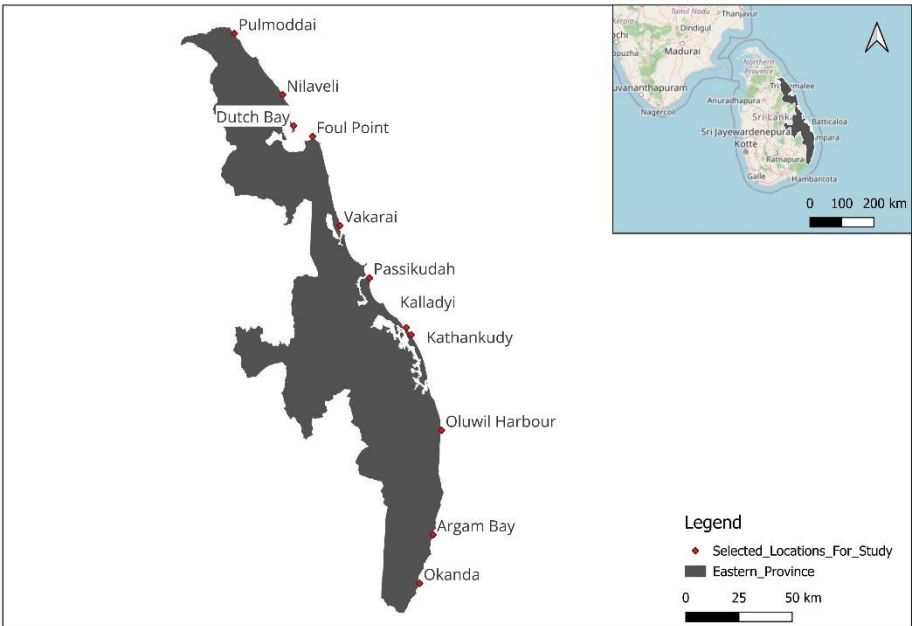


Figure 1: Selected sites for the study on the Eastern Coast of Sri Lanka.

2. Methodology

Multi-temporal satellite data were retrieved from Landsat 5/7/8/9 and Sentinel-2 constellations spanning 2010–2025, available on the Google Earth Engine API. Shoreline extraction employed the Modified Normalised Difference Water Index (MNDWI) with Otsu's thresholding method and the Marching Squares contouring algorithm for high geometric precision. This was done through CoastSat, which is an open-source Python toolkit that extracts long-term shoreline-- change data from satellite imagery (Landsat and Sentinel-2), enabling coastal scientists and engineers to analyse beach- erosion, accretion, and slope dynamics worldwide. Shoreline change rates were computed using Linear Regression Rate (LRR) analysis, while Pearson correlation coefficients and p-values distinguished permanent geomorphic trends from seasonal variability.

3. Results

Six coastal sites experience erosion (Table 1) at rates ranging from −0.1 to −3.5 m/yr, with the Southeastern Erosional Corridor (Kalmunai to Karativu) showing the most severe retreat (−2.8 to −3.5 m/yr). Four sites show accretion at +0.2 to +4.5 m/yr, notably at Oluvil South (+4.5 m/yr), while Oluvil North experiences erosion (−1.2 to −1.8 m/yr), confirming infrastructure-induced sediment disruption ($r = 0.23\text{--}0.33$). Two sites (Nilaveli and Dutch Bay) remain nearly stable at 0.05 m/yr, establishing baseline conditions for the region.

Table 1: Shoreline change rates (m/year) in selected sites.

District	Site	Rate (m/year)	Analysis
Ampara	Kalmunai to Karativu	−2.8 to −3.5	Erosion
	Oluvil (North)	−1.2 to −1.8	Erosion
	Oluvil (South)	+4.5	Accretion
	Arugam Bay	−1.2	Erosion

	Okanda	+0.2 to +0.4	Accretion
Batticaloa	Kattankudy	+0.8 to +1.5	Accretion
	Vakarai	-0.1 to -0.3	Erosion
	Passikudah	-0.1 to -0.2	Erosion
Trincomalee	Pulmoddai	+0.1 to +0.2	Accretion
	Nilaveli	0.05	Stable
	Dutch Bay	0.05	Stable
	Foul Point	-0.1	Erosion

4. Discussion and Recommendations

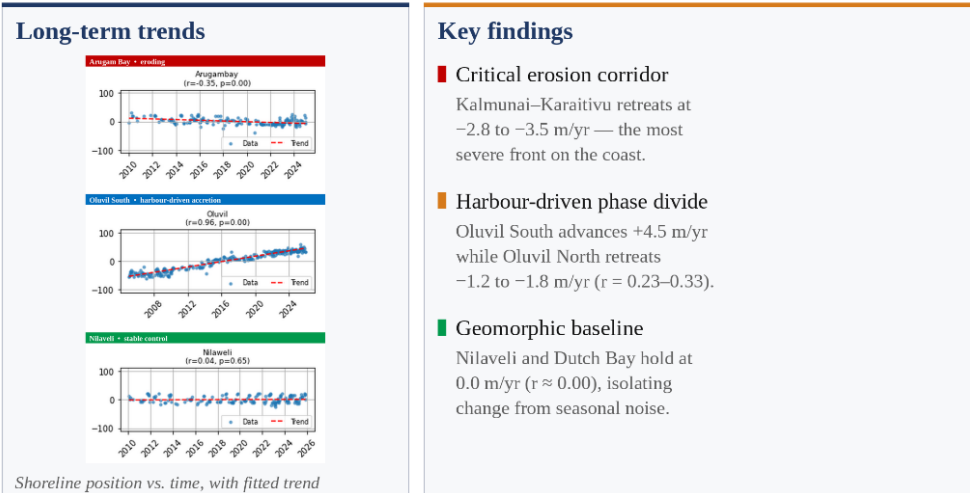
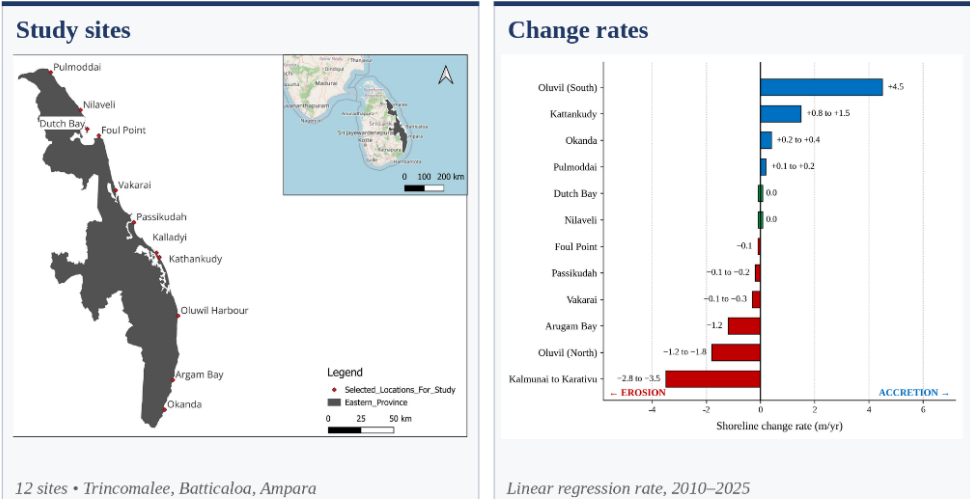
The results unambiguously demonstrate that anthropogenic interventions exert far greater influence on shoreline dynamics than natural processes alone. Critical management interventions include: (1) immediate implementation of mechanical sand bypassing systems at Oluvil Harbour to restore natural sediment continuity; (2) hybrid approaches combining hard structures and beach nourishment in the Southeastern Erosional Corridor; and (3) continuous satellite monitoring of Nilaveli and Dutch Bay as geomorphic benchmarks. These site-specific strategies are essential to achieve sustainable coastal stability and integrated sediment management.

References

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Distinguishing Erosion Hotspots from Stable Control Sites

Multi-decadal shoreline variability, Eastern Sri Lanka (2010–2025)



Engineering infrastructure exerts greater influence on sediment dynamics than natural processes

Method

Landsat 5/7/8/9 and Sentinel-2 imagery • MNDWI shoreline extraction (CoastSat)
Linear regression rate • Pearson correlation and significance testing

Erosion

Accretion

Stable control