A Comprehensive Study of Coastal Erosion at Oluvil: Analyzing the Environmental Impacts and Potential Mitigation Strategies

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Abstract

The construction of the Oluvil Harbour in 2009, intended to promote socio-economic growth in Sri Lanka's Ampara District, has unintentionally accelerated coastal erosion and caused severe ecological disturbances. This study evaluates the extent of erosion and its consequences from 2009 to 2024 using Google Earth historical imagery, field observations, and other existing studies. Findings reveal a cumulative shoreline retreat of approximately 300 meters north of the harbour, while inland impacts include riverbank erosion along the Kali-Odai River (since 2022). These changes have disrupted fisheries, reduced freshwater availability, and diminished fish population density, threatening both marine and terrestrial livelihoods. Inadequate waste management practices further intensify ecological stress, contributing to pollution and resource depletion. To mitigate these impacts, the study highlights several management strategies: ecosystem-based erosion control through mangrove restoration, soft-engineering techniques such as sand nourishment and dune stabilization, improved solid waste management to reduce coastal pollution, and alternative livelihood programs to safeguard community resilience. At the policy level, strengthening the Coastal Zone Management Plan and enforcing rigorous pre- and post-construction Environmental Impact Assessments (EIAs) are crucial to ensure that future coastal developments balance economic progress with environmental sustainability. The findings underscore the urgent requirement for science-based, sustainable management approaches to safeguard Oluvil coastal ecosystems and the livelihoods that depend on them.

Keywords: Sri Lanka, Harbour development, Coastal erosion, Environment sustainability, Management

I. INTRODUCTION

Coastal erosion, defined as the gradual loss of land along shorelines due to the action of waves, tides, currents, and human activities, is a major environmental concern worldwide (Vousdoukas et al., 2020). Climate change-induced sea-level rise, increased storm frequency, and unsustainable coastal development exacerbate shoreline retreat, leading to significant ecological and socio-economic consequences (Luijendijk et al., 2018). Understanding the drivers and impacts of coastal erosion is crucial for sustainable coastal management and resilience planning.

Sri Lanka, a small island nation in the northern Indian Ocean with a coastline of approximately 1,620 km, has experienced varying degrees of coastal erosion across its districts (Raviranga et al., 2016). Eastern Province, particularly Ampara District, is highly vulnerable due to its dynamic sedimentary coast and human interventions. Shoreline retreat in this region has been observed to accelerate after major infrastructure developments, creating both ecological and socio-economic pressures (Dissanayake & Wimalasuriya, 2020).

The construction of the Oluvil Harbour in 2009, designed to accommodate over 250 fishing vessels and cargo ships up to 5,000 metric tons, has markedly altered the local coastal environment (Perera & Amarasinghe, 2021). Early reports recorded land loss exceeding 100 meters by 2014 (Ameer, 2017). Changes in river flow along the Kali-Odai and disruption of sediment transport have intensified shoreline instability.

The ecological and socio-economic impacts of this erosion are profound. Loss of mangrove habitats, salinity intrusion, and degradation of littoral and estuarine ecosystems have reduced fish populations and freshwater availability (Senevirathna et al., 2019). Socio-economic

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consequences include damage to coconut plantations, destruction of over 250 fishing boats during storm events in 2014, and increased vulnerability of communities dependent on fisheries and agriculture (Jayatissa et al., 2020). Inadequate waste management practices further exacerbate environmental stress and compromise ecosystem services.

Against this background, the present study aims to quantify observed land loss along the Oluvil coastline from 2009 to 2024, assess the physical, ecological, and socio-economic impacts of coastal erosion, and propose sustainable management strategies and policy interventions, including ecosystem-based erosion control, waste management improvement, and integrated coastal governance, to enhance resilience and safeguard livelihoods in the region.

II. METHODOLOGY

A. Study Area

This research was conducted in Oluvil, a coastal village located in the Ampara District of the Eastern Province of Sri Lanka (Figure 01). The study area covers a 10 km stretch extending from the Kali-Odai River to the Oluvil coastal zone, encompassing the entire shoreline along this segment. The geographical coordinates of the Kali-Odai River mouth are 7°17'55.66"N and 81°51'56.72"E, while the Oluvil coastal area lies at 7°17'45.21"N and 81°52'1.62"E. The region experiences a tropical climate, characterized by high annual temperatures averaging around 35 °C and mean annual rainfall of approximately 1,973 mm, based on Sri Lanka Meteorological Department records (Department of Meteorology, 2020).

Figure 01: Study Area

B. Data Collection

Data collection was carried out using a combination of geospatial tools, field observations, and literature review to evaluate the extent and impacts of coastal erosion in the Oluvil coastal area. Historical satellite imagery available in Google Earth Pro 7.3.6.10201 (64-bit) was utilized to quantify shoreline changes between 2006 and 2024. The measuring tool in Google Earth Pro was specifically applied to measure the length of the wave breaker from a selected benchmark point along the coast during the period 2009–2024, enabling the assessment of structural influences on shoreline dynamics. First-hand data were gathered through direct field observations, focusing on land loss, damage to infrastructure, and alterations in coastal morphology. In addition, a comprehensive literature review of published scientific articles, technical reports, and local studies was conducted to supplement the satellite image analysis and to interpret erosion rates.

The historical analysis of Google Earth Pro imagery shows major changes to the Kali-Odai river mouth. During the monsoon season, the river mouth often expands due to increased water flows, but contraction is observed in drier mouths. The field component also included an assessment of environmental degradation linked to erosion. Biodiversity status at selected beach transects was qualitatively evaluated, focusing on vegetative cover loss, particularly mangroves and beach flora. Observations indicated that vegetation removal, partly through anthropogenic activities such as plant burning, exacerbated the vulnerability of the coastline to wave action and wind erosion. In addition, unregulated waste disposal by local communities, fishing activities, and other stakeholders was recorded as a significant factor contributing to coastal contamination, potentially affecting near shore water quality and accelerating ecological decline.

Based on the collected data, mitigation strategies were developed for the Oluvil coastal area to overcome coastal erosion and promote environmental sustainability and ecosystem resilience.

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III. RESULT

A. *Estimation of coastal erosion*

Google Earth Pro images from 2006 show that there was a 18m gap between the wave breaker and the land. The harbour construction era began in 2008, and by that time, 54m of land had already been eroded due to an accelerated erosion process. Between 2008 and 2012, erosion continued, degrading nearly 190 m of land. In response to this rapid erosion, a wave breaker was installed in 2012. However, even after its installation, an effective solution to prevent coastal erosion remained elusive.

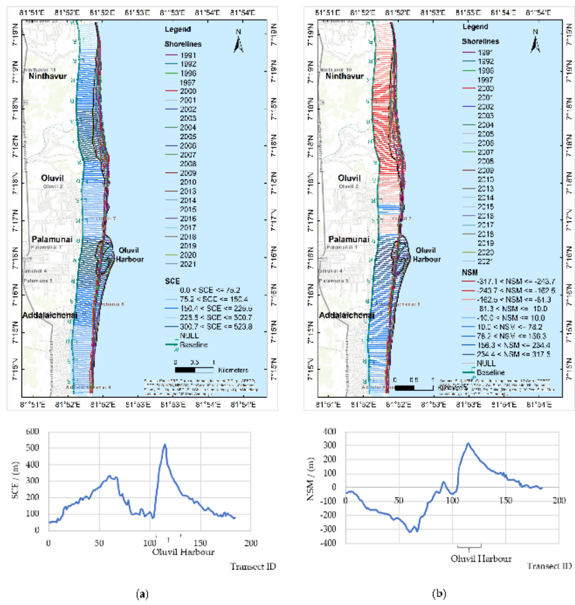
From 2012 to 2024, an additional 203 m of land was lost to erosion. Over the entire 16-year period (2006 - 2024), a total of 309 m of land was degraded (Figure 02). The ongoing erosion process has significantly impacted the Oluvil coastal area's habitat, ecosystem, and sustainability. Factors such as rising water levels and the mouth of the Kali-Odai River have also contributed to erosion. Additionally, the South Eastern University's border is directly connected to the coastal zone and the Kali-Odai River, both of which further accelerate erosion and reduce the land area

Due to persistent flooding conditions, erosion in the Oluvil coastal zone has accelerated, primarily driven by sediment transportation and deposition. The continuous movement of sediments has reshaped the coastal landscape, leading to significant land loss. As a result, the distance from the wave breaker to the land area has increased to 204 m.

Table 01 Length between Wave breaker to Brench Mark from Coastal area

Year	**Length (m)**	**Eroded land length (m)**	**Total erosion (m)**
2006	19	-	-
2008	53	35	33
2010	96	42	75
2012	96	-	75
2014	127	31	106
2016	189	62	168
2018	251	63	230
2020	320	70	300
2022	331	10	310
2024	204	-	**315**

According to Zoysa et al. (2023), the spatiotemporal evolution of shoreline dynamics along the Oluvil coastline in the Ampara District of Sri Lanka over a two-decade period (1991–2021), particularly around the economically significant Oluvil Harbor, was investigated using remote sensing and GIS techniques. Landsat 5 Thematic Mapper (TM), Landsat 7 Enhanced Thematic Mapper Plus (ETM+), and Landsat 8 Operational Land Imager images were used to delineate annual shorelines, with the Normalized Difference Water Index (NDWI) applied to differentiate land from water. The Digital Shoreline Analysis System (DSAS) was employed to quantify shoreline changes through Shoreline Change Envelope (SCE), Net Shoreline Movement (NSM), End Point Rate (EPR), and Linear Regression Rate (LRR). The study revealed that the Oluvil coast experienced both erosion and accretion, primarily influenced by harbor construction. The highest SCE values were recorded within the harbor region, reaching 523.8 m, while NSM ranged from 317.1 to 81.3 m in the northern area and 156.3 to 317.5 m in the harbor and southern adjacent zones. EPR analysis showed maximum rates of 3.0 - 10.7 m/year south of the harbor and 10.7 to 3.0 m/year north of the harbor. LRR further indicated erosion rates in the northern region of 3 to 10 m/year, while the southern beaches advanced at 3 - 14.3 m/year. These findings highlight significant spatial variability in shoreline dynamics, demonstrating the considerable influence of harbor construction on both erosion and accretion patterns.



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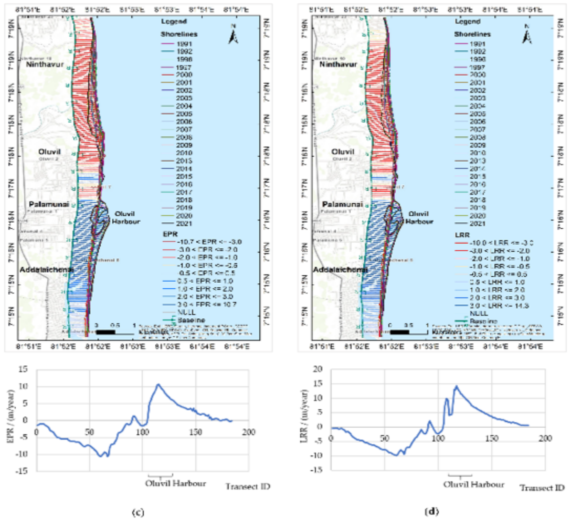

Figure 01: DSAS Statics of the Oluvil coast area: (a) For SCE; (b) For NSM; (c) For EPR; (d) For LRR. (Zoysa et al., 2023)

According to Nijamir et al., (2021), the coastal morpho dynamics of the Oluvil area, identified as a hotspot for coastal erosion, have been significantly impacted in recent years. Analysis of satellite images revealed that substantial coastal morphological changes occurred in the Oluvil coastline between 2011 and 2019.

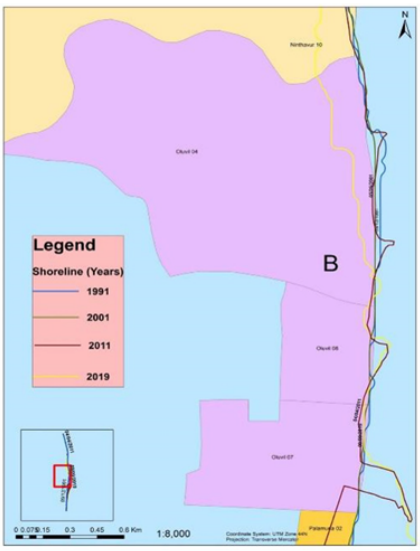

Figure 02: Periodic coastal morpho dynamics of 1991, 2001, 2011 and 2019 in Olvuil area

B. Changes of "Kali- Odai" River Mouth

Due to coastal erosion, seasonal erosion patterns, a reduction in vegetation cover, and the increased volume and speed of water flow, the mouth of the Kali-Odai River undergoes significant changes each year (Figure 04). The continuous reshaping of the river mouth affects sediment distribution, leading to alterations in coastal topography and contributing to land instability. The high-water flow and velocity accelerate the erosion process, gradually shifting the river's course and causing sediment deposition in new areas.

These changes not only disrupt the natural habitat and marine biodiversity but also pose challenges for local communities that rely on the river for fishing, agriculture, and other livelihoods. The loss of vegetation further weakens the soil structure, making the area more susceptible to erosion. Additionally, the interaction between tidal forces, rising sea levels, and human activities such as construction and land use changes to impact the river's dynamics, exacerbating the long-term degradation of the coastal environment.

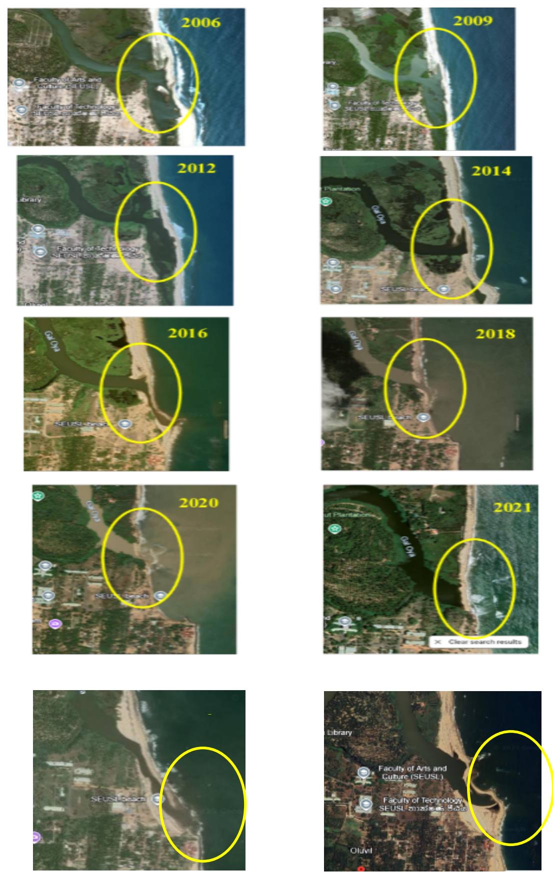

Figure 03: Changes at Kali- Odai River Mouth

C. Ecological periodic changes of the Oluvil

In 2019, showcases a stable and healthy coastal environment with lush green vegetation, including grass, coconut plants and small palm trees. The beach appears wide and intact, indicating a period of accretion where sediment deposition supports vegetation growth. This suggests that, at this time, the coastline was relatively undisturbed by erosion, allowing plant life to thrive and stabilize the area.

In contrast, 2020 reveals significant changes due to coastal erosion. The once-green landscape has disappeared, and the shoreline has visibly retreated, exposing wooden poles in the water, possibly remnants of coastal structures affected by erosion. The sand has been washed away, leaving behind a narrow, unstable shoreline. The presence of strong waves and rough sea conditions suggests that monsoonal influences and high wave energy have accelerated the erosion process, leading to the degradation of the beach environment.

From 2022 to the present, the coastal zone shows signs of partial recovery, with a wider sandy area compared to 2020. However, coastal vegetation is absent, indicating that while sediment deposition has occurred, the ecosystem has not fully regenerated. This suggests a dynamic cycle of erosion and accretion, where the shoreline fluctuates between loss and recovery.

Figure 05: Periodic changes of Oluvil coastal zone

D. Coastal pollution

Improper waste disposal has greatly polluted the coastal area, which has resulted in ecological and hydrological impacts. Kali-Odai River has also experienced an increase in the water level and the rate of flow, which may be because of the displacement of sediments, blockage of the natural drainage system or accumulation of waste beyond the required limit. Plastic bottles, food waste, polythene, chemical containers and other synthetic materials are highly deposited in the coastal zone, not only affecting the natural environment but also causing devastating effects on the coastal environment.

The deposition of these pollutants compromises the quality of fish in the Kali-Odai River, different biodiversity in the area, and the air and water in the coastal ecosystem. Improperly disposed bottles can cause chemical contamination, which can result in toxicity in the aquatic life, bioaccumulation in the food chain and possible health effects on humans who use the river and sea to fish and carry out other activities. Water quality impairment may also cause algal blooms, oxygen depletion, and prolonged habitat loss.

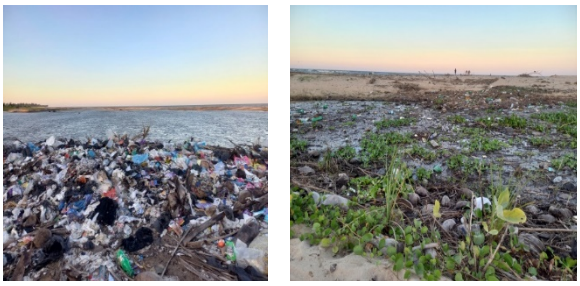

Figure 04: Coastal Pollution at Oluvil coastal zone

IV. DISCUSSION

Coastal erosion at Oluvil highlights the critical interaction between anthropogenic interventions and natural coastal dynamics, particularly following the construction of the Oluvil Fishing and Commercial Harbour. Breakwaters and harbor infrastructure have disrupted sediment transport, leading to severe land loss exceeding 300 m in some areas, while also modifying the Kali-Odai river mouth and accelerating bank erosion. Similar to other coastal zones in Sri Lanka, these changes have undermined local livelihoods dependent on fisheries and agriculture, while unregulated waste disposal has further degraded marine and terrestrial ecosystems (Gunasekara et al., 2021). Therefore, integrated and sustainable mitigation strategies are essential to restore environmental stability and support socio-economic resilience.

Ecosystem-based solutions such as mangrove and dune vegetation restoration are among the most effective strategies for coastal protection. In southern Sri Lanka, mangrove belts provided natural barriers that reduced shoreline retreat while also enhancing biodiversity (Dahdouh-Guebas et al., 2005). Comparable initiatives in Vietnam and the Philippines demonstrated that restored mangrove forests significantly reduced wave energy and storm surges, offering both ecological and economic benefits (Alongi, 2018). For Oluvil, replanting mangroves along the river mouth and beach fronts would enhance sediment retention, mitigate wave energy, and promote ecological recovery.

In addition to ecological measures, engineering and sediment management strategies are critical. Beach nourishment, coupled with hybrid engineering approaches such as dune reinforcement, has been proven more effective than hard infrastructure alone. For instance, hybrid measures applied in the Netherlands' "Sand Motor" project and at Uswetakeiyawa Beach in Sri L anka resulted in longer-lasting shoreline stability compared to traditional breakwaters (Ranasinghe et al., 2018). In Oluvil, introducing sand bypassing systems near the harbor could restore the disrupted littoral drift and balance sediment distribution, similar to successful applications at Durban, South Africa, and the Gold Coast, Australia (Smith et al., 2019).

Beyond erosion control, addressing pollution and waste management is vital to prevent further ecological decline. In Oluvil, unregulated dumping of plastics, polythene, and chemical residues into coastal areas exacerbates biodiversity loss and poses human health risks. Studies in Sri Lanka and Indonesia confirm that poor waste management is a major driver of marine ecosystem degradation (Jayatissa et al., 2020; Jambeck et al., 2015). Therefore, integrated waste collection and recycling programs, alongside strict enforcement of plastic reduction policies, are essential.

Equally important is community participation and policy enforcement. Community-based coastal management initiatives in eastern Sri Lanka demonstrated improved compliance and ecosystem resilience when local fishers were directly engaged (Fernando et al., 2019). International experiences, such as Japan's integrated coastal zone management (ICZM) policies and Bangladesh's community-driven mangrove rehabilitation programs, underscore the importance of combining local knowledge with state policy (Islam et al., 2020). For Oluvil, strengthening Environmental Impact Assessments (EIA), enforcing coastal setback zones, and implementing continuous shoreline monitoring programs would ensure long-term effectiveness.

Overall, the evidence suggests that no single solution is sufficient to address erosion in Oluvil. Instead, a combination of ecosystem restoration, soft engineering, sediment management, waste reduction, and strong community and policy frameworks is required. By integrating lessons from both Sri Lanka and international best practices, a holistic approach can be developed that restores ecological balance, safeguards livelihoods, and ensures sustainable coastal management.

V. CONCLUSION

The Oluvil coastal area has been increasingly vulnerable to environmental degradation due to harbour construction, shoreline erosion, and pollution. The disruption of sediment transport has accelerated erosion, while plastic and chemical contamination has further degraded ecosystems and livelihoods. These challenges highlight the urgent need for targeted and sustainable mitigation strategies. Effective interventions should focus on shoreline restoration through mangrove rehabilitation, dune stabilization, and artificial reef construction, which have been successfully implemented in other coastal regions such as the Philippines and India to reduce wave energy and enhance natural sediment deposition. In addition, integrated waste management programs and strict enforcement of pollution control policies are essential to address the growing issue of marine debris. The adoption of soft-engineering solutions, community-based coastal monitoring, and adaptive management practices can ensure long-term ecological resilience while minimizing the risks associated with hard structures that often exacerbate erosion. By integrating scientific evaluation with participatory coastal zone planning, Oluvil can implement a balanced approach that safeguards both environmental stability and socio-economic development, ensuring that the coastline remains resilient and productive for future generations.

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