JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

IMPACT ON THE SHORELINE DUE TO THE PORT CITY DEVELOPMENT OFF COLOMBO ON THE WEST COAST OF SRI LANKA

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Abstract

This research provides comprehensive analysis of shoreline changes along the west coast of Sri Lanka, with a particular focus on the Colombo port city development. The primary objective of the study was to analyze shoreline changes using high resolution images obtained from Google Earth Pro. The DSAS 5.1 toolbox in ArcGIS was employed to 13 images during the period from 2005 to 2022 and the analysis done. Statistical calculations done with using analysis. The results unveiled a maximum erosion rate of 9.65 meters/year and a maximum accretion rate of 20.85 meters/year within the study area. Percentage of significant erosion in study area is 12.05 and percentage of significant accretion in study area is 29.55 based on linear regression rate calculation (LRR - rate of change of shoreline per year). Weighted Linear Regression (WLR - when fitting trend line, Weighted Linear Regression gives more importance to accurate data points) calculations also show similar results as linear regression rate calculation. In study area, average erosion is about 9.15 meter and the average accretion is about 42.55 meter according to Net Shoreline Movement (NSM - distance between the oldest and the youngest shorelines) calculation. However, the study found minimal shoreline impact within a 10-kilometer radius around the port city, as a result of series of breakwaters constructed and other development projects along the coastline of port city. The shoreline change is a complex interplay by natural processes and human activities emphasizing the economic significance of the Colombo coastal suburbs. The study emphasized erosion at the Kelani River mouth due to the development's impact. The port city expansion extended the shoreline by approximately 6-7 kilometers into the sea. However, overall, the port city project appeared to have a limited impact on the shoreline.

Index Terms – shoreline changes, coastal erosion, accretion, limited impact

1. INTRODUCTION

The west coast of Sri Lanka, like many other coastal regions worldwide, is subject to the complex interplay of natural processes and anthropogenic activities that influence erosion and accretion of shorelines. However, the west coast of Sri Lanka experiences a higher degree of anthropogenic influence compared to other coastal areas, primarily due to the presence of Colombo, the nation's economically invaluable city. Colombo serves as the epicenter for trade and commerce, boasting the Colombo Port and Colombo Harbor, both strategically located on the west coast of the island.

Recognizing the need to address challenges faced by the Port of Colombo as early as 2005, the Colombo Port Expansion Project was initiated. In 2007, the Asian Development Bank (ADB) played a pivotal role by providing a substantial loan of USD 300 million, formalizing the loan agreement in 2008. (*Colombo Port Expansion Project*, 2008) The project's core objective, established in 2008, was to bolster the competitiveness of the Colombo Port by expanding its capacity to accommodate larger vessels. This strategic endeavor was essential to attract mainline vessels, reduce freight charges, and stimulate economic activities. Importantly, this project was closely aligned with Sri Lanka's national policy in 2010, which placed emphasis on infrastructure development and fostering public-private partnerships. By 2012, the first phase of the project, involving the construction of critical harbor infrastructure, was successfully completed, followed by the operationalization of the South Container Terminal (SCT) in 2014 through a private sector concession. Consequently, the Colombo Port expansion project resulted in the extension of the coastline by approximately 6.4 kilometers. (*Sri Lanka Ports Authority - SLPA*, n.d.) Thus, it is evident that the western coast of Sri Lanka has been significantly impacted by the Colombo Port expansion project. *Figure 1-1*

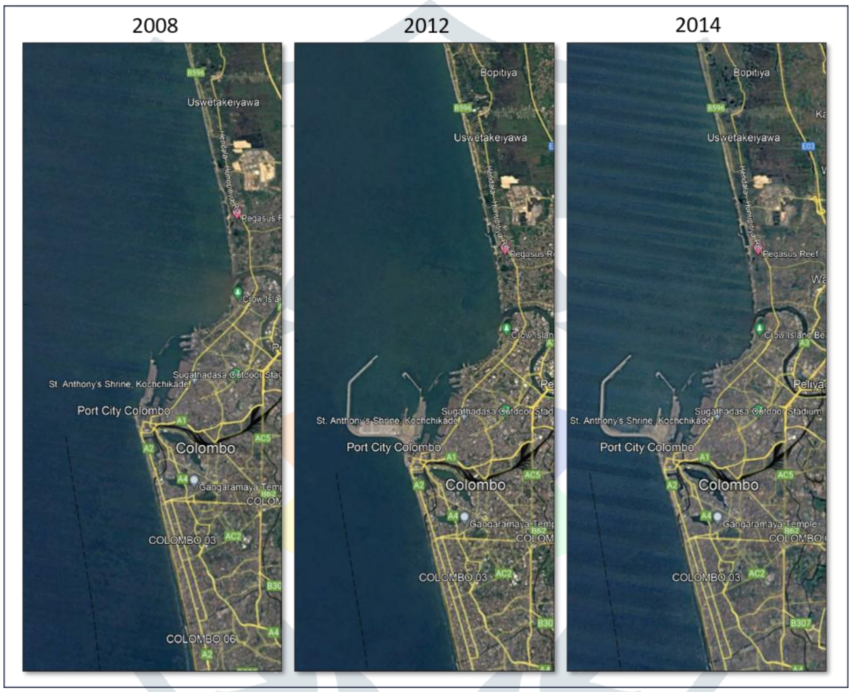

Figure 1-1Colombo Port Expansion Project 2008 to 2014.

Another substantial development initiative on the west coast is the Colombo Port City Development Project. This visionary project encompasses 269 hectares of reclaimed land from the sea and represents an ambitious endeavor in Sri Lanka. The overarching vision is to establish a world-class city in South Asia, while the mission is centered on creating a livable, sustainable urban environment complete with top-tier infrastructure and amenities. The project is divided into five districts, each serving distinct purposes, including a financial hub, central park, island living, marina, and international island. This project, facilitated by foreign direct investment from CHEC (China Harbor Engineering Company) Port City Colombo, is bolstered by contributions from both local and foreign entities. Notably, substantial progress had been reported as of August 2018, encompassing extensive reclamation works and ongoing infrastructure development. (*Environmental Report Clears Colombo Port City*, n.d.)

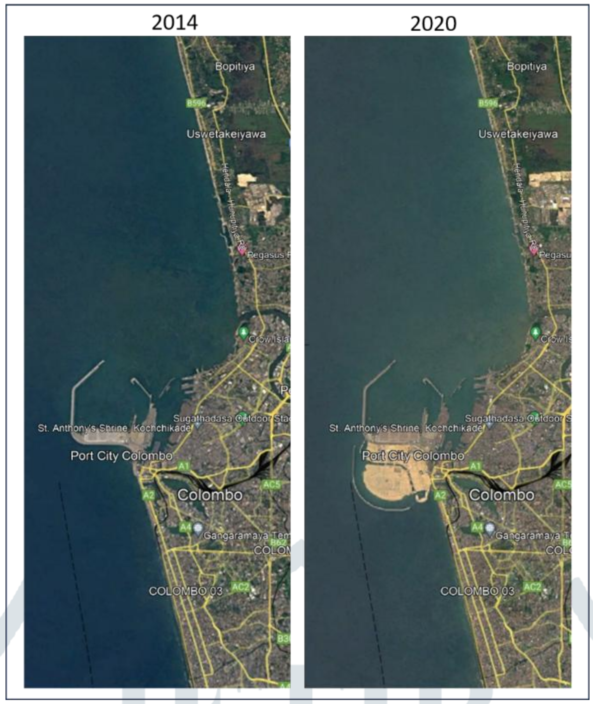

Figure 1-2. Colombo port city development project. in port city development project 5.4-kilometer-long breakwater extends 2 kilometers perpendicular to the coastline on the southern part of the port.

Within the context of the Colombo Port City Development Project, a 5.4-kilometer-long breakwater extends 2 kilometers perpendicular to the coastline on the southern part of the port (*Environmental Report Clears Colombo Port City*, n.d.) *Figure 1-2.* It is essential to note that the development of the port city can be viewed as an extension of the Colombo South Port. In the western coastal region of Sri Lanka, longshore currents predominantly flow south to north *Figure 1-3.* Against this backdrop, the primary focus of this scientific research endeavor is to comprehensively investigate and assess the impact of the Colombo Port City Development Project on the coastline of the west coast of Sri Lanka.

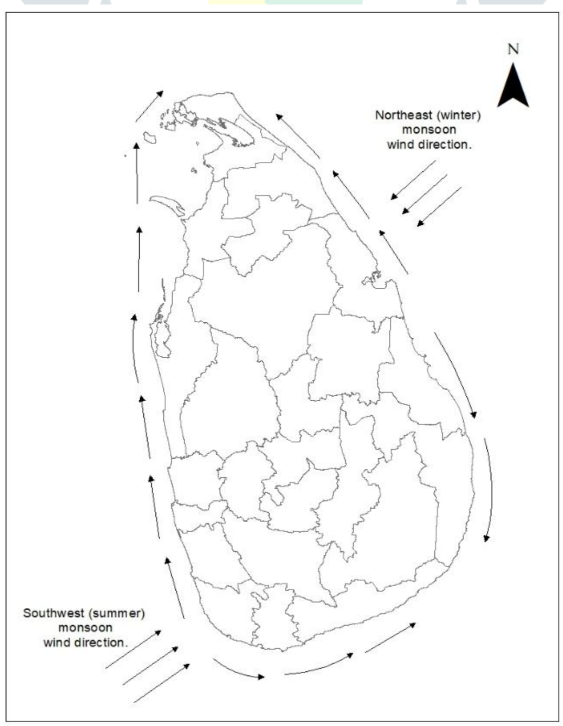

Figure 1-3 Long shore current direction around the Sri Lanka. Because of south west monsoon, in western coast of Sri Lanka, the longshore current direction in south to north. and in eastern coast of Sri Lanka, Because of north east monsoon, the longshore current direction is north to south.

Studying the coastline, coastal erosion, and environmental impacts along the western coast belt of Sri Lanka is importance due to the significant ecological, economic, and social implications associated with this region. The western coast is not only a hub for economic activities such as fisheries, tourism, and trade but also hosts diverse ecosystems, including mangroves and coral reefs. Coastal erosion is the one of the main reasons for substantial threat to the stability of these ecosystems, leading to habitat loss and potential declines in biodiversity. Additionally, with rising sea levels and changing climate patterns, understanding the dynamics of coastal erosion becomes crucial for developing effective strategies to mitigate and adapt to these changes. Furthermore, the western coast of Sri Lanka is densely populated, and coastal erosion can result in the loss of valuable land, infrastructure, and homes, impacting the livelihoods of local communities. Moreover, environmental degradation along the coast can trigger broader consequences, such as increased vulnerability to natural disasters and disruptions to critical services. Therefore, a comprehensive study of the coastline, coastal erosion, and environmental impacts is essential for sustainable development, conservation efforts, and the resilience of both natural ecosystems and human communities in this crucial region.

This research aims to delve into the intricate dynamics of coastal change, erosion, and accretion patterns resulting from these monumental development projects. By employing rigorous scientific methodologies and data analysis, we seek to uncover the ecological, environmental, and socio-economic consequences of these developments on the fragile coastal ecosystem. Through a holistic understanding of these impacts, this research will contribute valuable insights for sustainable coastal management and informed decision-making in the face of ongoing coastal transformations.

In the subsequent sections of this research report, we will delve into the methodology, data collection, analysis, and findings, ultimately providing a comprehensive evaluation of the effects of the Colombo Port expansion and Port City Development on the west coast of Sri Lanka.

2. LITERATURE REVIEW

The impact of port city development on the shoreline along the west coast of Sri Lanka, particularly in the Colombo region, has become a subject of increasing concern and scrutiny in recent years. This comprehensive literature review aims to synthesize and analyze existing knowledge and research findings pertaining to this crucial issue. The construction and expansion of port facilities in Colombo, notably the Colombo Port City project, have raised numerous questions about their environmental and socio-economic consequences, creating a need for a detailed investigation.

Numerous studies have explored the potential threats to the coastal ecosystem associated with port city development in Colombo. These threats encompass habitat disruption and degradation, alteration of sedimentation patterns, and increased coastal erosion. A noteworthy development is the South Port Project, featuring a 5.4 km-long breakwater extending 2 km perpendicular to the coast. Initially, concerns were raised about its potential to create erosion north of Colombo. However, extensive monitoring over the last four years has indicated that erosion has not taken place (*Environmental Report Clears Colombo Port City*, n.d.). This can be attributed to the construction of the breakwater, which has increased the wave shadow, thereby extending it northwards. Consequently, wave conditions have become calmer, leading to the stabilization of the shoreline between the Port and the Kelani River. Nevertheless, it is important to acknowledge that the Port City Development may pose challenges such as impeding/silting up of the outlet location, which could obstruct the discharge from the Beira Lake.

To address this issue, a preliminary study was conducted to determine the optimal design, location, and alignment of a proposed groyne. This study involved the placement of a 200 m long groyne just south of the Beira outlet, creating a 50 m wide outlet. The collection of sand south of the groyne is expected to create a beach at the Galle Face end. This beach could serve as a recreational area, and the sheltered sea conditions resulting from the groyne may be suitable for swimming and bathing (*Environmental Report Clears Colombo Port City*, n.d.).

In the context of Sri Lanka, the first beach nourishment project took place in 2012 along a 1.8-kilometer stretch in the Uswetakeiyawa area, carried out by the Coast Conservation Department (Ratnayake et al., 2018). This project involved the utilization of approximately 300,000 cubic meters of offshore sand from the Indian Ocean. Subsequently, three breakwaters were constructed in the same area to protect and stabilize the nourished beach. Beach profile data indicated both sand accretion (addition of sand) and erosion (loss of sand) in the nourished area. However, there was an overall enhancement in the sand volume. Satellite images captured between 2010 and 2015 revealed irregular changes in the beach profiles following the construction of the breakwaters, indicating that the beach's shape and size were not stable during this period. Field observations and calculated relationships related to the breakwaters highlighted either subdued salient (protruding) or gap erosion (erosion between breakwaters) at specific locations along the nourished beach, indicating the significant impact of breakwaters on beach morphology. It is important to note that no permanent or periodic tombolo formations were observed at Uswetakeiyawa beach, which distinguishes the beach's characteristics (Ratnayake et al., 2018).

However, it is crucial to acknowledge certain challenges in the Uswetakeiyawa beach nourishment project. Specifically, sand retention structures, likely put in place to prevent erosion, were incorrectly oriented, contributing to rapid erosion of the nourished beach. Additionally, the use of sand with an inappropriate grain size for nourishment may have further exacerbated erosion. These issues collectively pose a threat to the beach's recreational and aesthetic value. Nonetheless, it is anticipated that the beach will naturally recover to its pre-nourished state within approximately 12 months (Azoor et al., 2015).

Estimation of shoreline change using satellite images has proven to be a highly effective method due to the dynamic nature of coastlines (Warnasuriya et al., 2018). Shorelines are constantly influenced by various factors, including wave actions from the ocean or other water bodies, tides, natural hazards such as storms and tsunamis, and human activities such as construction, dredging, and coastal development. These factors can lead to erosion, sediment deposition, alterations in the natural coastline, and changes in the shape and position of the shoreline.

In 2020, a noteworthy beach nourishment project was initiated in Mount Lavinia, Sri Lanka. This project adopted a holistic approach to beach nourishment, employing both hard and soft engineering methods to address coastal erosion. Among the hard engineering strategies employed, the construction of rock armor or boulder barriers played a significant role in fortifying the shoreline. However, the project predominantly relied on soft engineering methods, which are globally recognized as successful and environmentally friendly approaches to coastal protection (*Ministry of Defence - Sri Lanka*, n.d.). Notably, the 5 km stretch of beach extending from Mount Lavinia headland to the Wellawatte canal outlet remained stable throughout the project, with no evidence of erosion. The beach's natural variability was primarily attributed to seasonal changes in the wave climate influenced by the region's monsoonal climate patterns (Pattiaratchi et al., n.d.). The project sourced its sand from a deposit located approximately 2-6 km from Rathmalana, effectively utilizing sand pumping techniques to transport it to Mount-Lavinia beach. Once there, the sand was thoughtfully spread over the edge of the Mount Lavinia coast, resulting in the creation of a 15-meter-wide beach at Wellawatte (*Official-PR-Sand-Nourishamnet.Pdf*, n.d.). Furthermore, the supply of sediment from rivers and coral reefs can contribute to shoreline accretion. Understanding and monitoring these contributions are vital for comprehending how they influence shoreline change over time.

3. RESEARCH METHODOLOGY

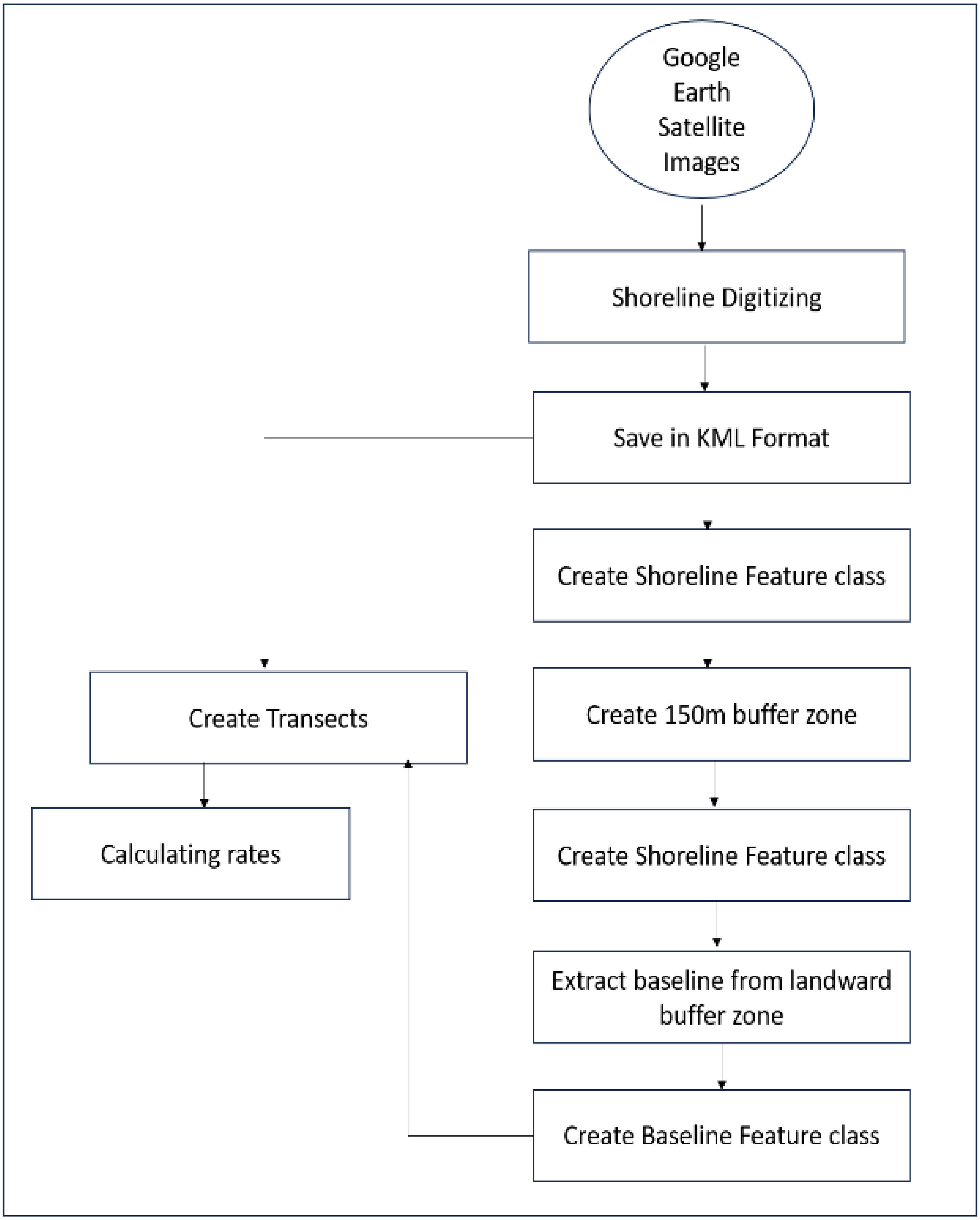

Figure 3-1Methodology

3.1 Study area.

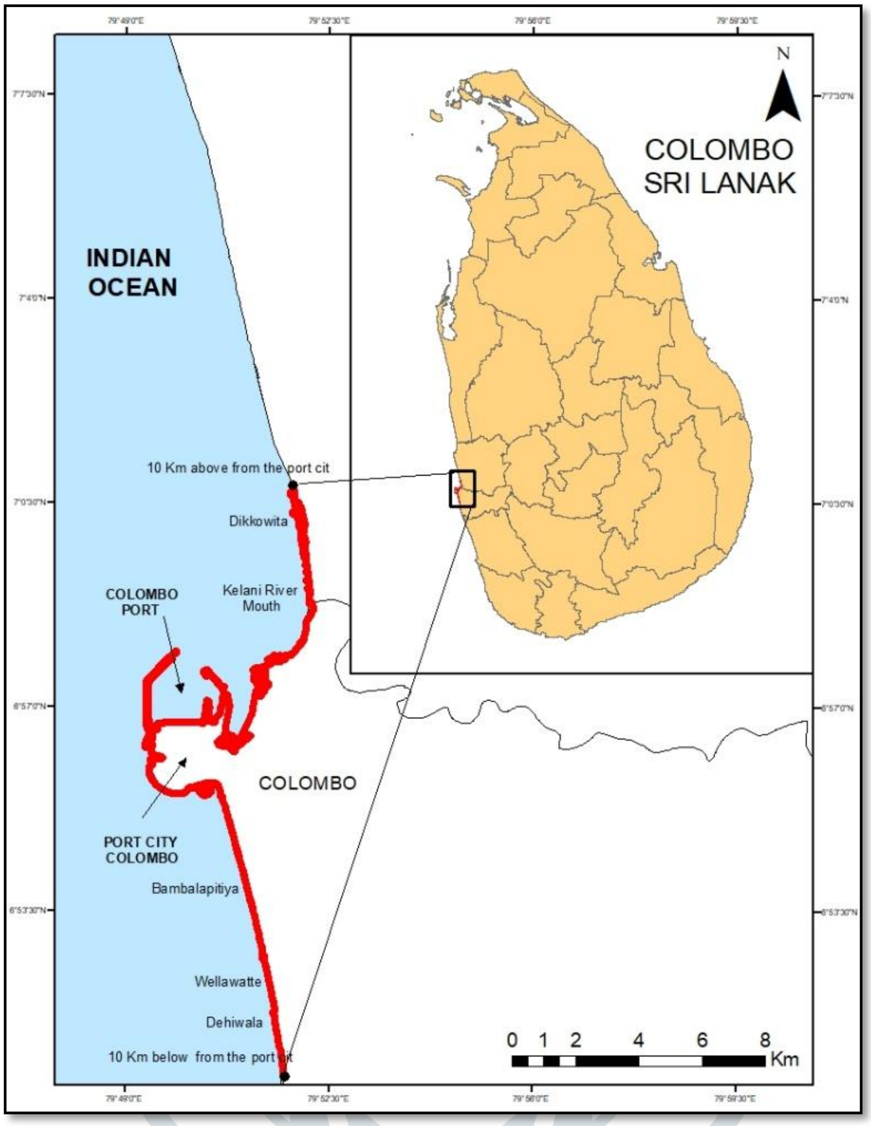

Figure 3-2 Study area.

The focus of this research encompasses a defined region within the Western province of Sri Lanka, situated along the coastal line within a 10-kilometer radius of the Colombo Port City Development Project. This area spans across both the Colombo and Gampaha districts and is delineated by the Kelani River, which serves as the boundary between the two districts.

The geographical coordinates of the Colombo port city are as follows:

- Latitude: 6.9378° N
- Longitude: 79.8368° E

The research area extends 10 kilometers both to the north and south of the Colombo port city development project. To the north, it reaches coordinates at:

- Latitude: 7° 0'48.64"N
- Longitude: 79°51'51.32"E

- Latitude: 6°50'39.69"N
- Longitude: 79°51'42.68"E

Within this defined region, several prominent divisions exist from north to south, including Dikkowita, Kelaniya, Crow Island, Colombo, Kollupitiya, Bambalapitiya, Wellawatte, and Dehiwala. The area falls within the wet zone of the country and experiences an annual average temperature of 26.5 °C (79.7 °F) alongside an annual average rainfall of 2387 mm (94.0 inches). This region is notably influenced by the southwest monsoon, which shapes its climatic conditions.

3.2 Tools and software

In my research, I harnessed advanced geospatial tools to conduct an in-depth analysis of shoreline dynamics. The methodology began with the utilization of Google Earth Pro, a powerful geospatial software application developed by Google. This platform provided us access to a rich repository of high-resolution satellite and aerial imagery. Leveraging this resource, we embarked on a meticulous process of digitizing shoreline boundaries from these images, ensuring a high degree of precision and accuracy in our data acquisition.

Subsequently, I turned to ArcMap, an essential component of Esri's ArcGIS suite, renowned for its robust spatial analysis capabilities, data management tools, and cartographic functionalities. This software allowed us to further explore the dynamics of the study area's shoreline. To enhance our analysis, we seamlessly integrated DSAS (Digital Shoreline Analysis System) into ArcMap. *Figure 3-3* DSAS brought with it sophisticated analytical capabilities, including the calculation of erosion and accretion rates, and the ability to present our findings through statistical data and graphical representations.

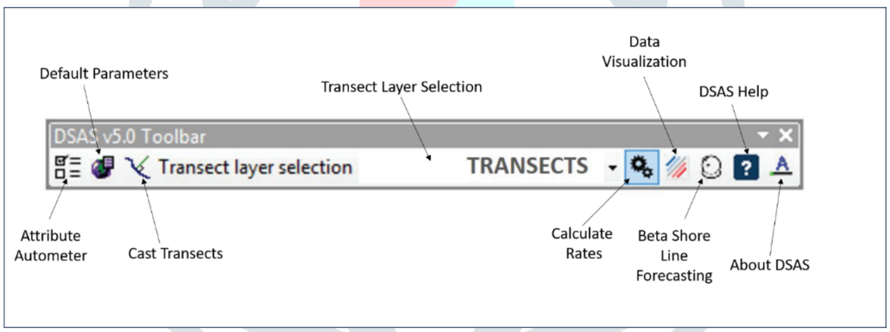

Figure 3-3. DSAS (Digital shoreline analysis system) tool bar.

Google Earth Pro, ArcMap, and DSAS software facilitated a comprehensive and scientifically rigorous investigation into shoreline dynamics. The synergy of these tools enabled us to gain invaluable insights for our research endeavor. By leveraging these advanced geospatial technologies, we were able to unravel the intricate patterns and changes in shoreline dynamics, contributing significantly to our understanding of coastal environments and their evolution.

3.3 Shorelines digitizing from Google earth pro (version 7.3.6.9345)

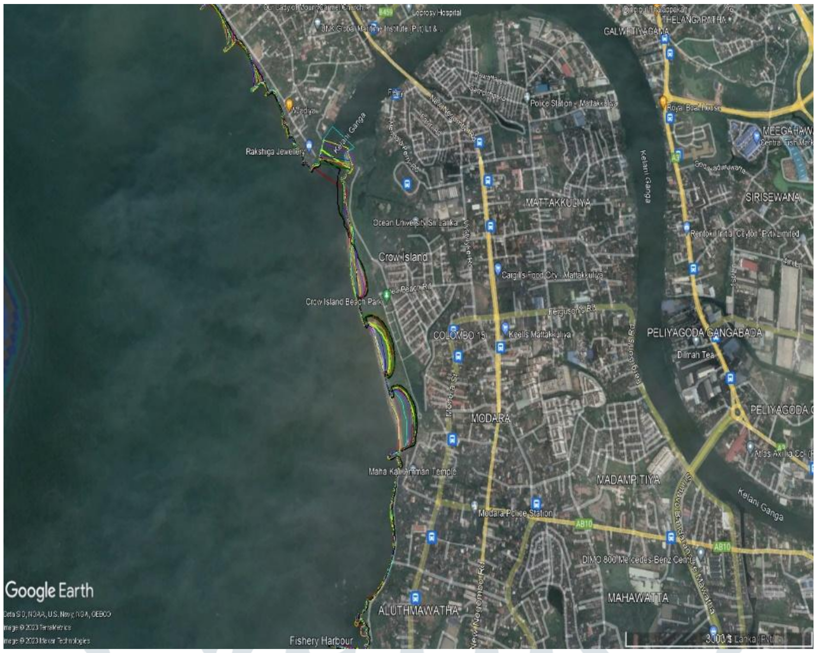

Figure 3-4. Digitizing shorelines manually from google earth pro-7.3.6.9345.

The process of shoreline extraction began with the adjustment of image tilts within the GE (Google Earth) software, aimed at minimizing geometric distortions. Additionally, efforts were made to maintain a consistent scale across all images during the digitization process. Shorelines for various years were delineated using satellite images from the GE platform, ensuring that the same eye altitude of 500 meters was applied to all images to eliminate errors stemming from zoom level variations. Thirteen years were digitized in total, spanning from February 1, 2005, to January 1, 2022. The resulting shoreline data for each year was saved in the KML (Keyhole Markup Language) file format. *Figure 3-4* Subsequently, these KML shoreline files were converted into "Layer files" using ArcMap 10.4.1 software. All shoreline data extracted from Google Earth were then overlaid and managed within a personal geodatabase using ArcMap 10.4.1 software.

3.4 Shoreline change analysis from ArcMap combine with DSAS

Shoreline change analysis plays a pivotal role in understanding the dynamic evolution of coastal regions over time. Accurate measurement and systematic analysis of these changes are essential for scientific research, effective coastal management, and environmental preservation. In this comprehensive methodology, we present a rigorous scientific framework for conducting shoreline change analysis, utilizing advanced geographic information system (GIS) tools and techniques. Our primary objective is to calculate the End Point Rate (EPR), a critical metric for comprehending coastal dynamics.

3.4.1 Data Preparation and Geospatial Alignment

A solid foundation for shoreline changes analysis begins with meticulous data preparation and precise geospatial alignment. We initiate this process by selecting an appropriate coordinate system, opting for the WGS 84 Universal Transverse Mercator (UTM) projection, Zone 44N, renowned for its accuracy in representing our study area.

Within this spatial framework, we embarked on a comprehensive digitization process. Each point along the shoreline is georeferenced with painstaking precision, ensuring that every data point corresponds accurately to its real-world location. This meticulous digitization served as the cornerstone for all subsequent analyses.

3.4.2 Creation of Shoreline Feature Class

To ensure organized data management and easy access throughout the analysis, we systematically organized the digitized shorelines into a dedicated shoreline feature class. *Figure 3-5* This feature class acts as a comprehensive repository for all shoreline-related data and is duplicated into a personal geodatabase, reinforcing data integrity and enhancing overall data organization.

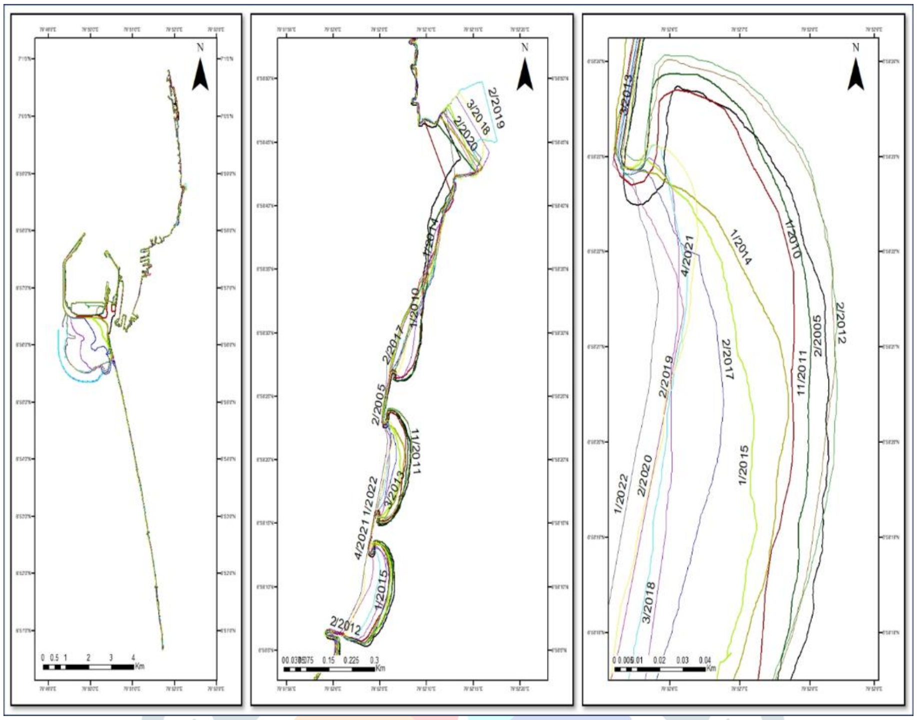

Figure 3-5. Copy to shoreline-to-Shoreline feature class.

To comprehensively assess coastal vulnerability, we generated a buffer zone extending 150 meters from the shoreline using the buffer analysis tool. *Figure 3-6* These buffer lines were then merged to form a continuous boundary, effectively encapsulating the coastal region under scrutiny.

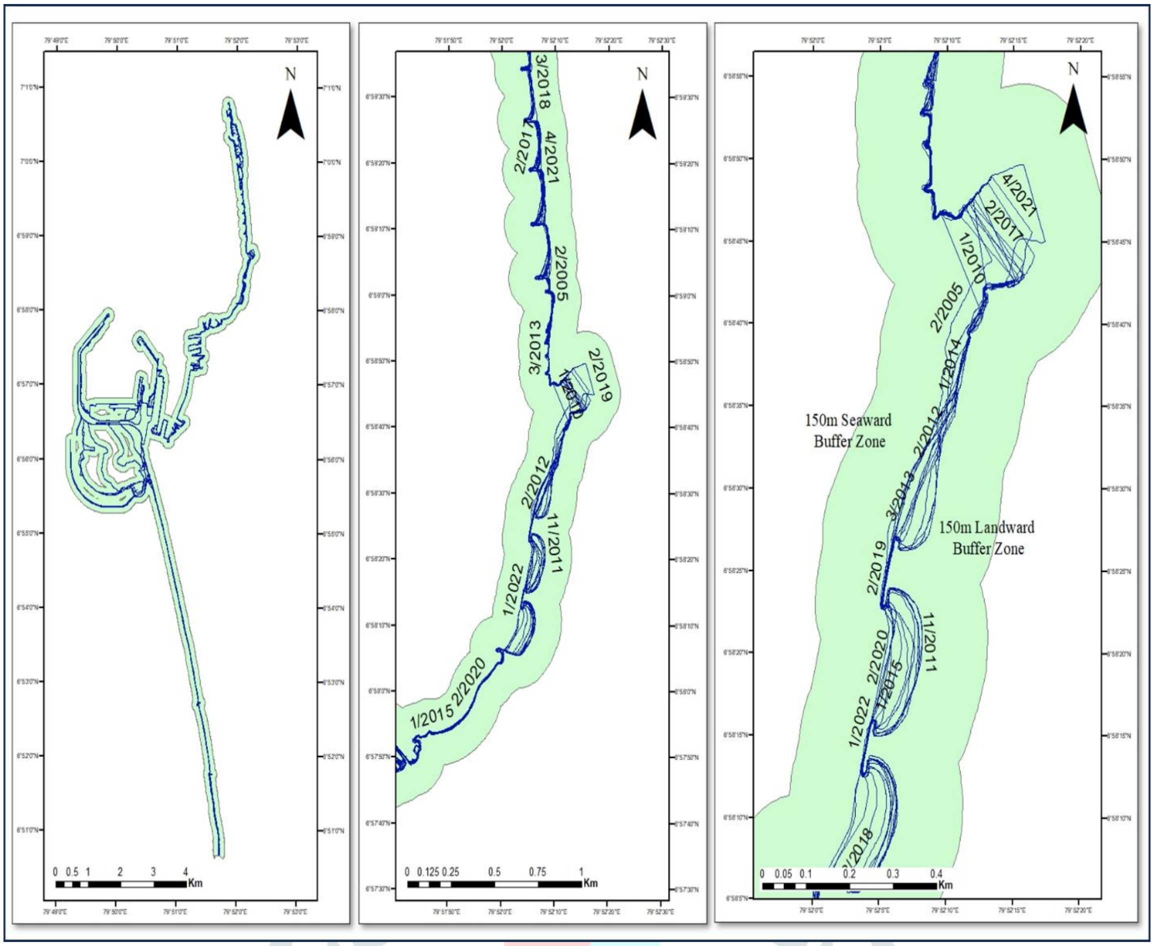

Figure 3-6. 150m buffer zone.

3.4.3 Establishment of the Baseline

A stable reference line, known as the baseline, is indispensable for the precision of shoreline change analysis. Positioned along the landward side of the buffer zone, the baseline accurately captured the intended path along the coastal area. *Figure 3-7* To ensure precision, the trace tool is employed, resulting in an accurate representation of the baseline's trajectory.

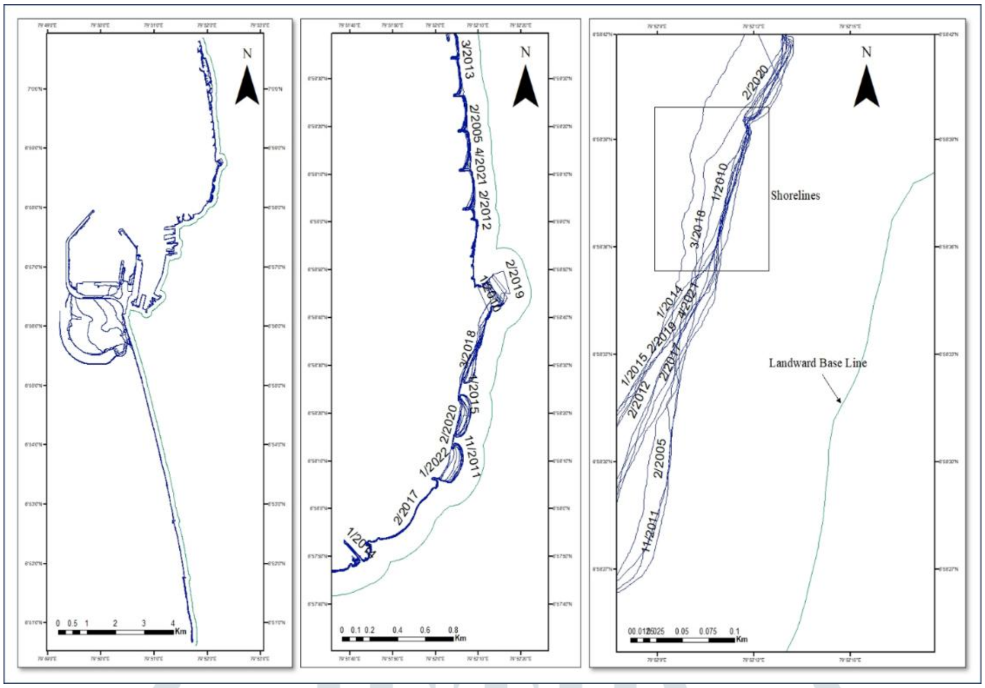

Figure 3-7. Landward Baseline creating using landward side of buffer zone. Green color line represents the landward buffer zone.

Subsequently, the buffer zone is meticulously removed from the baseline feature class, leaving only the baseline itself. This baseline serves as an immovable reference line against which shoreline changes are meticulously assessed.

3.4.4 Generation of Transect Lines

Transect lines served as the backbone of our systematic shoreline change analysis. *Figure 3-8* To ensure precision and uniformity, we utilized the Digital Shoreline Analysis System (DSAS) toolbox. Each transect extended perpendicularly from the established baseline to the shoreline. In our study, we maintained a consistent maximum search distance of 400 meters from the baseline, ensuring comprehensive coverage of the study area, 50m transect spacing.

To further enhance the accuracy of our analysis, a smoothing distance of 50 meters is applied to these transects, effectively reducing noise and delivering a refined representation of the shoreline's geometry.

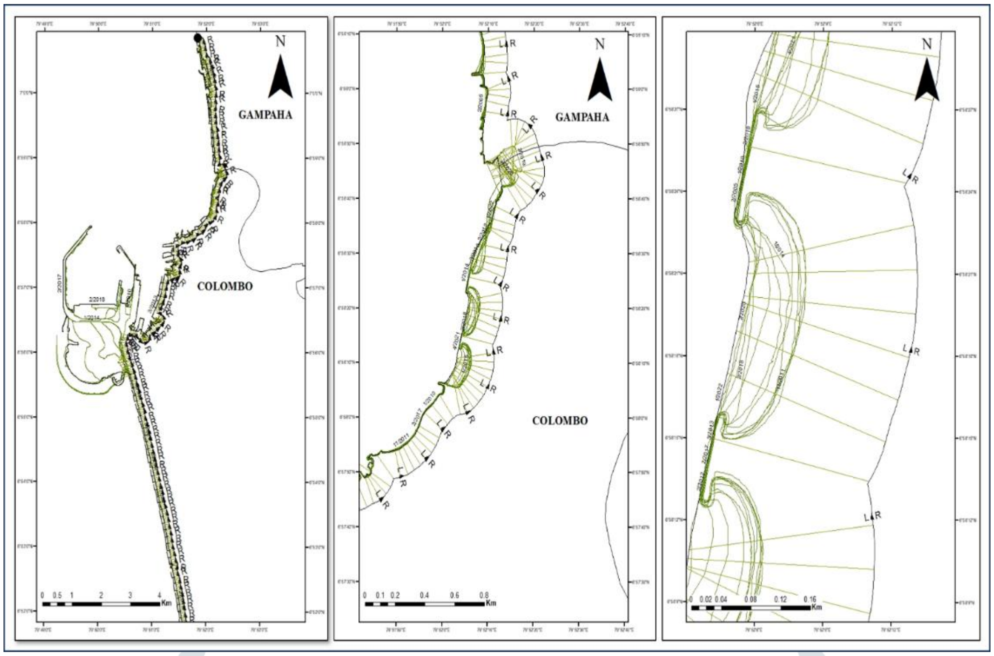

Figure 3-8. Created transect line in study area.

3.4.5 Statistical Analysis of Shoreline Change

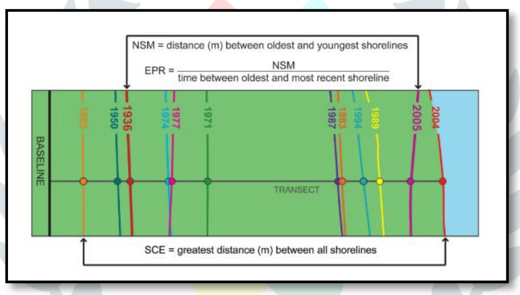

Figure 3-9. NSM (Net Shoreline Movement), EPR (End Point Rate), SCE (Shoreline Change Envelope)

The core of our methodology involved a rigorous statistical analysis of shoreline change, encompassing various key metrics that illuminate different aspects of coastal dynamics. *Figure 3-10*

Details of the selected statics to calculate are as follows;

- Net Shoreline Movement (NSM): NSM quantifies overall shoreline change by measuring the distance between the oldest and newest shorelines for each transect. This metric offers fundamental insights into whether the shoreline is advancing or retreating, providing crucial information about its dynamic behavior. *Figure 3-9*
- Shoreline Change Envelope (SCE): SCE identifies the maximum distance between shorelines intersecting a specific transect. It highlights the extent of shoreline variability and pinpoints areas of potential erosion or accretion, enhancing our understanding of coastal vulnerability. *Figure 3-9*
- End Point Rate (EPR): EPR is a pivotal metric that calculates the rate at which the shoreline is changing. It does so by dividing the distance the shoreline has moved by the time elapsed between the oldest and newest measurements. EPR quantifies the speed at which the shoreline is shifting, offering a crucial indicator of its dynamic nature. *Figure 3-9*

- Linear Regression Rate (LRR): LRR quantifies the rate of shoreline change per year, providing a standardized measure of coastal evolution over time. It allows for the assessment of long-term trends in shoreline dynamics and supports predictive modeling.
- Weighted Linear Regression (WLR): To ensure the robustness of our analysis, we employ weighted linear regression when fitting trend lines. This technique assigns more significance to accurate data points, minimizing the impact of outliers and enhancing the reliability of trend analysis.

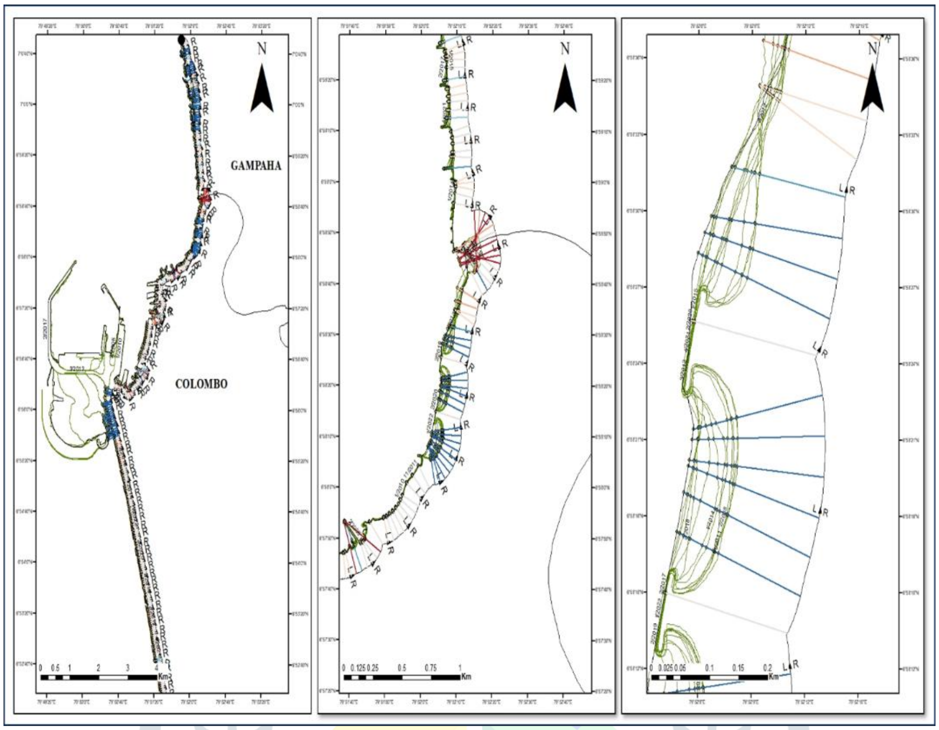

Figure 3-10. Final calculated statistics.

In conclusion, this methodology presents a systematic and scientifically rigorous approach to shoreline change analysis using advanced GIS tools and techniques. The combination of these statistical tools empowers researchers, policymakers, and environmental managers to make informed decisions regarding coastal protection, resource allocation, and environmental preservation in the face of dynamic coastal environments. By adhering to these meticulously outlined steps, scientists and practitioners can conduct comprehensive shoreline change analyses that contribute to the sustainable management of coastal regions and advance our understanding of coastal geomorphology

4. RESULTS AND DISCUSSION

In this extensive and meticulously conducted research study, we embarked on a comprehensive exploration of shoreline dynamics, employing a diverse array of analytical methodologies that included NSM (Net Shoreline Movement), EPR (End Point Rate), LRR (Linear Regression Rate), and WLR (Weighted Linear Regression). Our central objective revolved around the investigation and comprehension of the intricate patterns governing shoreline behavior within our study area, which encompassed a substantial total of 444 transects. In this comprehensive endeavor, we present our findings with the utmost commitment to scientific rigor and methodological precision.

4.1 Shore line change envelop. (SCE)

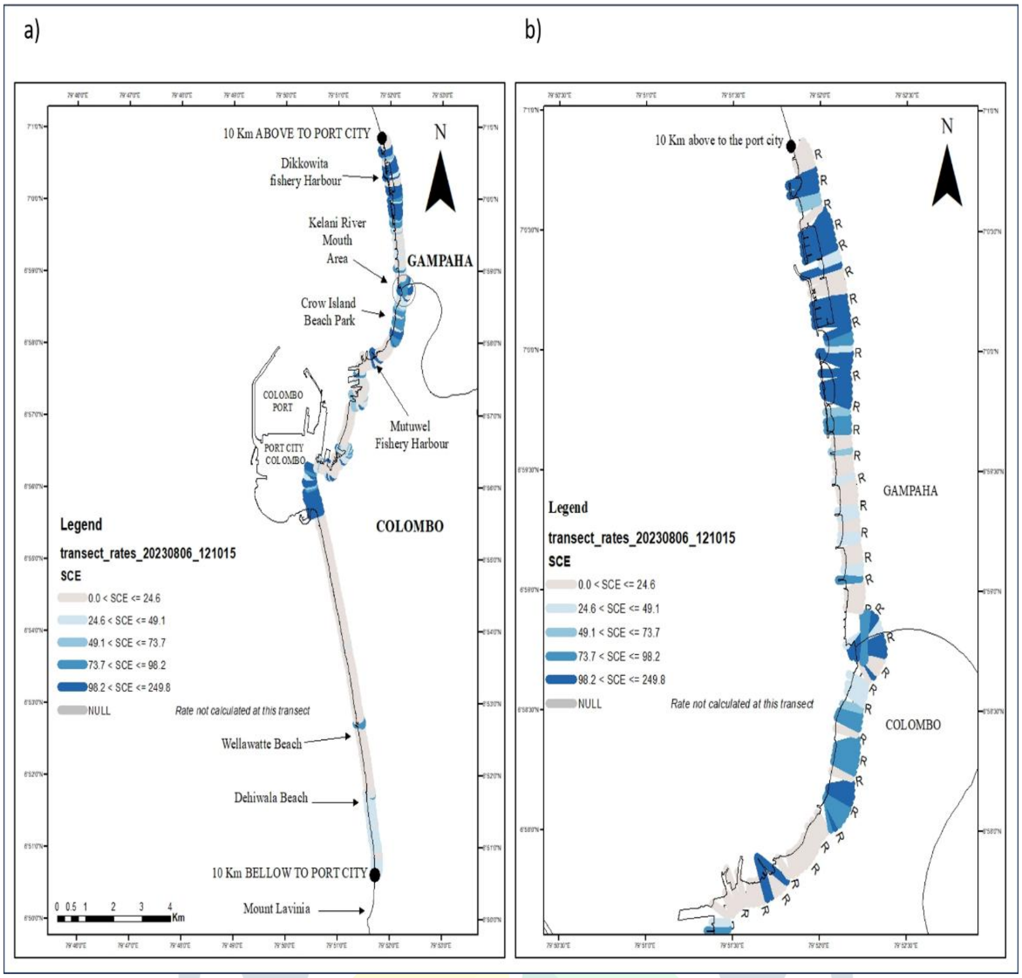

Figure 4-1. Shore line change envelop (SCE), distance is calculated in meters(m). a) SCE of whole the study area. (Both 10Km above and below from the Colombo port city development project.) b) SCE of 10Km above from the port city development project.

The Shoreline Change Envelope (SCE) *Figure 3-9* depicts the range of variation in shoreline distances. It is characterized by a maximum shoreline distance of 249.73m m and a minimum shoreline distance of 0.48 m and the average distance is 45.51m. *Figure 4-1, Figure 4-2*

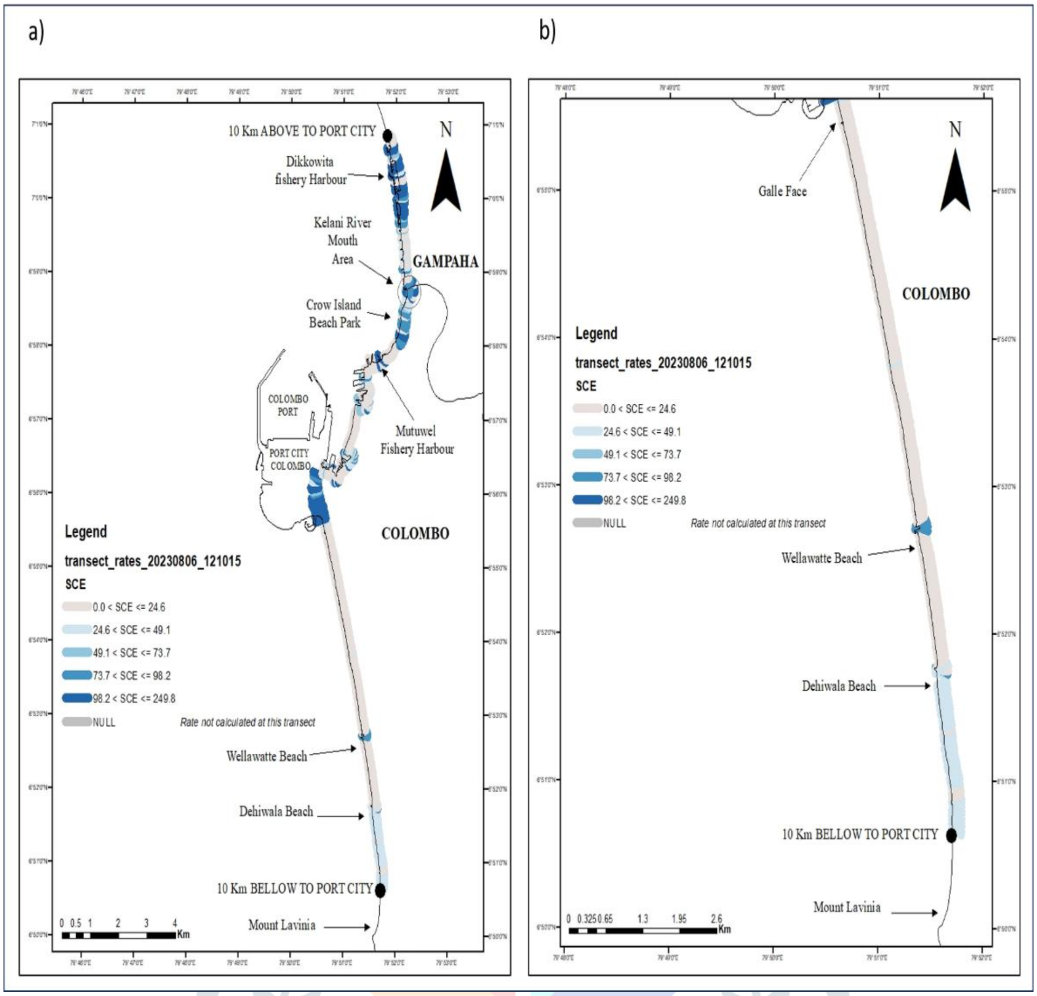

Figure 4-2. Shore line change envelop (SCE), distance is calculated in meters(m). a) SCE of whole the study area. (Both 10Km above and below from the Colombo port city development project.) b) SCE of 10Km below from the port city development project.

4.2 Analysis of Net Shoreline Movement (NSM):

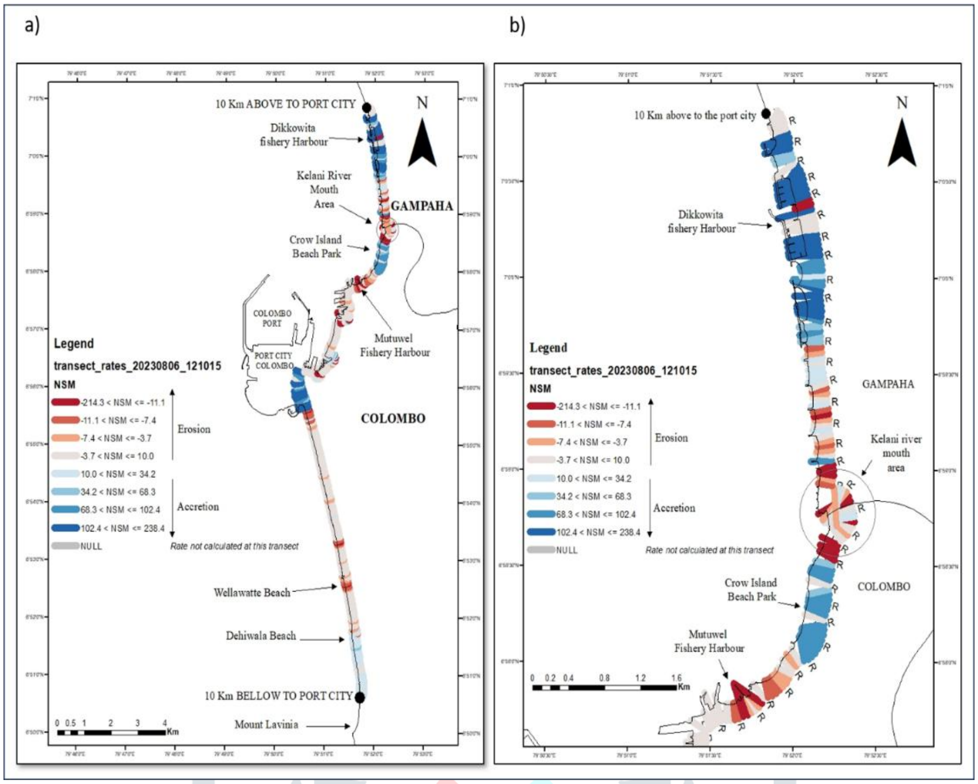

Figure 4-3. Net Shoreline Movement (NSM), distance is calculated in meters(m). a) NSM of whole the study area. . (Both 10Km above and below from the Colombo port city development project.) b) NSM of 10Km above from the port city development project.

Our meticulous examination of the 444 transects unveiled that a noteworthy subset of 183 transects, amounting to 41.22% of the total transects, were positioned within retreating shoreline areas. The most remarkable observation was the Mutuwel Fishery Harbor, where a formidable shoreline retreat of an impressive 214.3 meters was documented. *Figure 4-3* On average, the broader study area experienced shoreline retreat measuring 9.15 meters. In stark contrast, 261 transects, constituting 58.78% of the total, were identified within advancing shoreline areas. The most conspicuous instance of shoreline advancement occurred at the Port City Development Site, spanning an impressive 238.36 meters. *Figure 4-3a, Figure 4-4a* the average shoreline advances across the study area measured an equally impressive 42.55 meters.

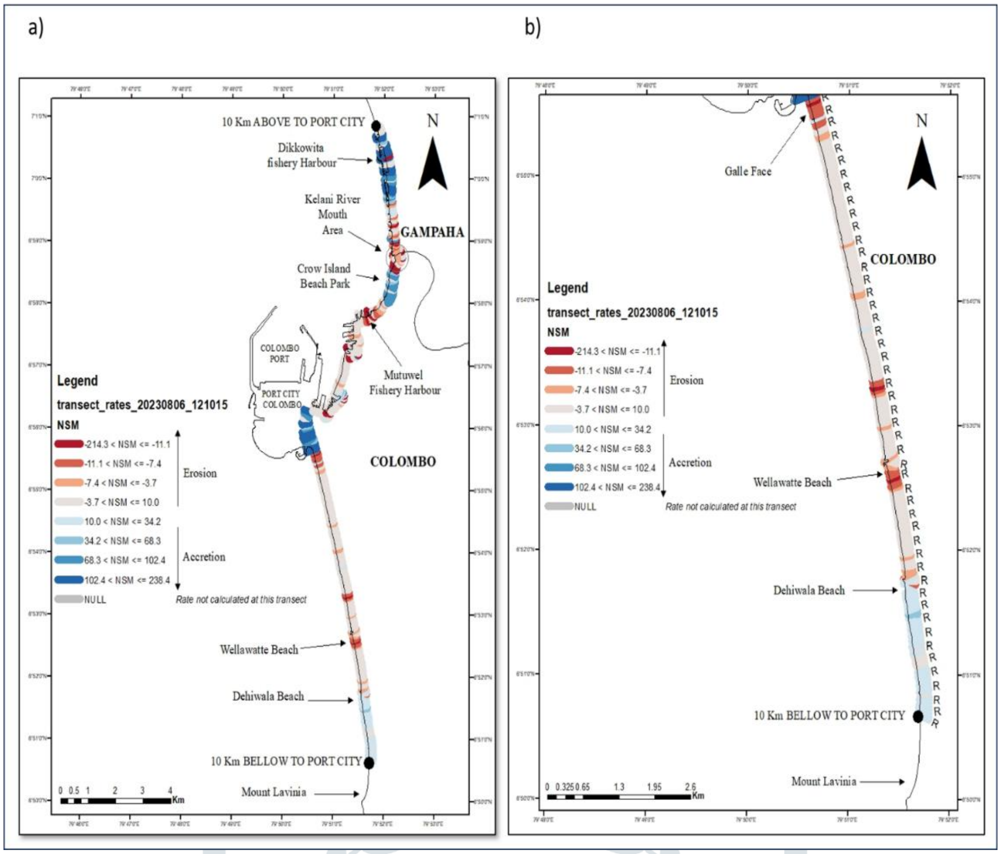

Figure 4-4. Net Shoreline Movement (NSM), distance is calculated in meters(m). a) NSM of whole the study area. (Both 10Km above and below from the Colombo port city development project.) b) NSM of 10Km below from the port city development project.

4.3 Analysis of End Point Rate (EPR):

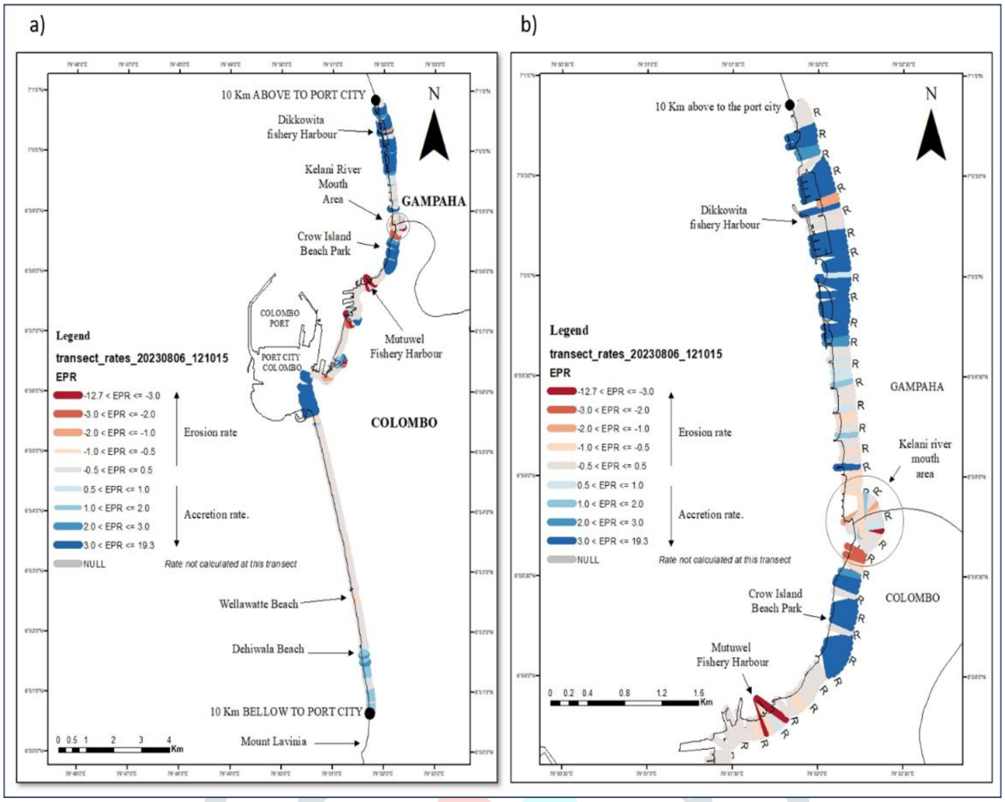

Figure 4-5 End Point Rate (EPR), Rates are calculated in meter per year (m/yr.). a) EPR of whole the study area. (Both 10Km above and below from the Colombo port city development project.) b) EPR of 10Km above from the port city development project.

Our meticulous calculations through the EPR methodology revealed that 183 transects were nestled within erosional areas, comprising a substantial 41.22% of the total transects. Of particular note was the Mutuwel Fishery Harbor, where shoreline erosion occurred at an annual rate of 12.67 meters. *Figure 4-5* On average, the study area witnessed an annual shoreline erosion rate of 0.56 meters, emphasizing the ongoing dynamic nature of coastal regions. In contrast, 261 transects were strategically located within accretional areas, constituting 58.78% of the total transects. The Port City Development Site stood out with a remarkable annual shoreline accretion rate of 19.24 meters. *Figure 4-5, Figure 4-6* The average annual shoreline accretion rate across the entire study area was a noteworthy 2.84 meters.

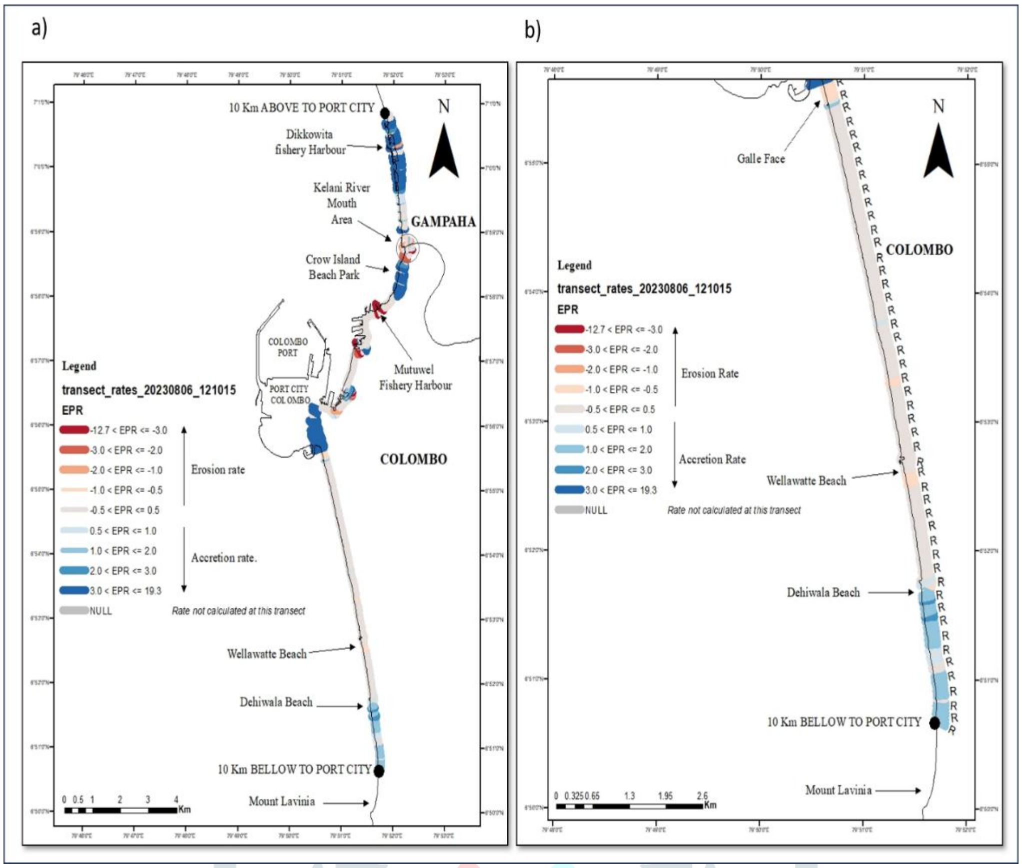

Figure 4-6. End Point Rate (EPR), Rates are calculated in meter per year (m/yr.). a) EPR of whole the study area. (Both 10Km above and below from the Colombo port city development project.) b) EPR of 10Km below from the port city development project.

4.4 Analysis of Linear Regression Rate (LRR):

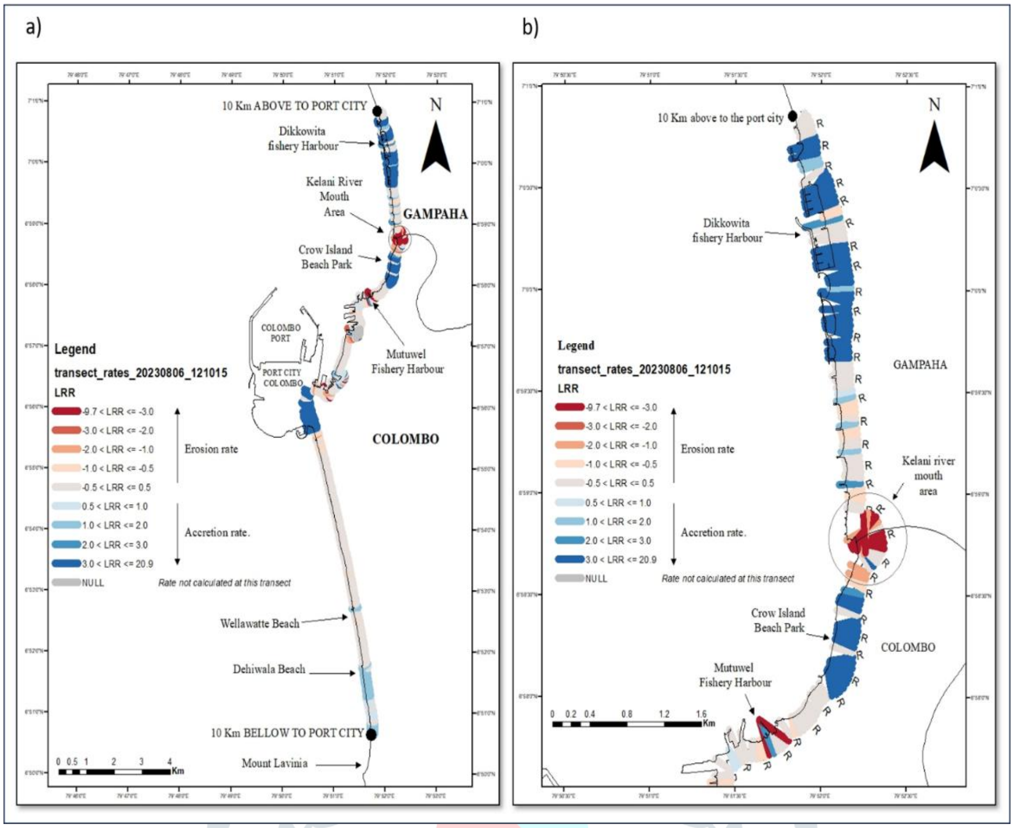

Figure 4-7. Linear Regression Rate (LRR), Rates are calculated in meter per year (m/yr.). a) LRR of whole the study area. (Both 10Km above and below from the Colombo port city development project.) b) LRR of 10Km above from the port city development project.

In our in-depth LRR analysis, we meticulously examined the distribution of transects and found that 203 of them, representing 46.14% of the total transects, lay within erosional areas. The Colombo Port area was particularly noteworthy, with an annual shoreline erosion rate of 9.65 meters. *Figure 4-7a*, *Figure 4-8a* On average, the broader study area exhibited an annual rate of shoreline erosion amounting to 0.69 meters. Furthermore, 237 transects, comprising 53.86% of the total, were identified within accretional areas. The Port City Development Site showcased a remarkable annual shoreline accretion rate of 20.85 meters, underscoring the importance of understanding and harnessing accretional processes. The average annual accretion rate for the entire study area stood at 2.86 meters.

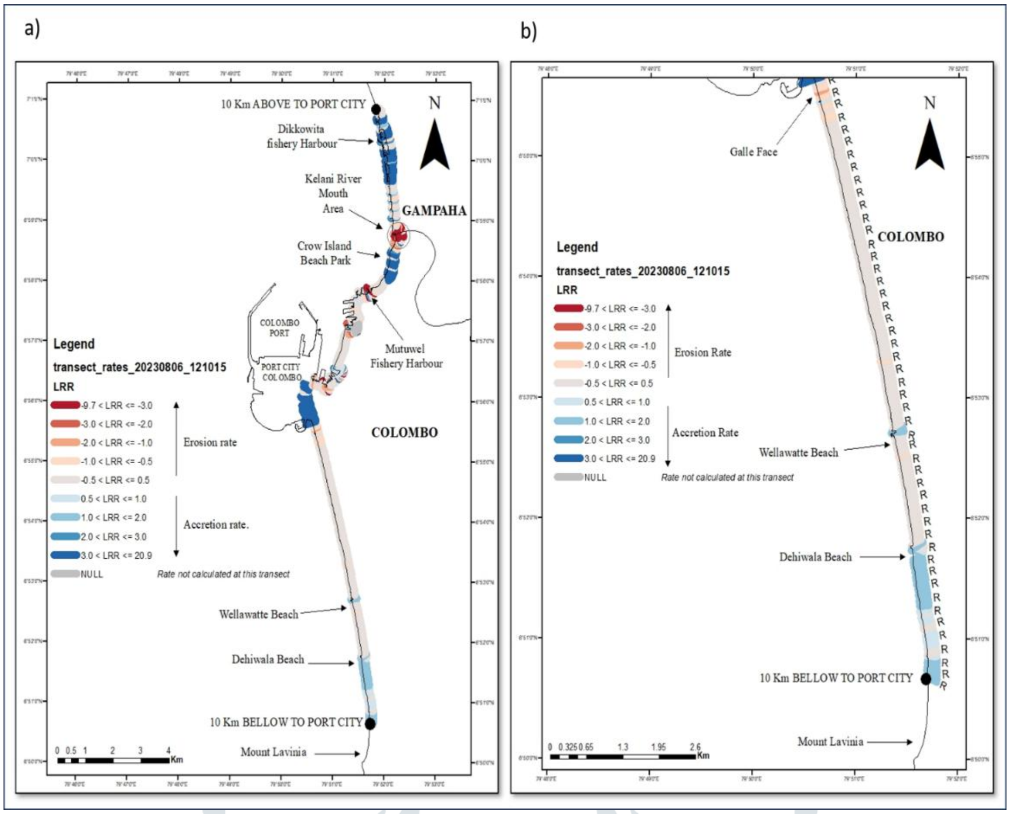

Figure 4-8. Linear Regression Rate (LRR), Rates are calculated in meter per year (m/yr.). a) LRR of whole the study area. (Both 10Km above and below from the Colombo port city development project.) b) LRR of 10Km below from the port city development project.

4.5 Analysis of Weighted Linear Regression (WLR):

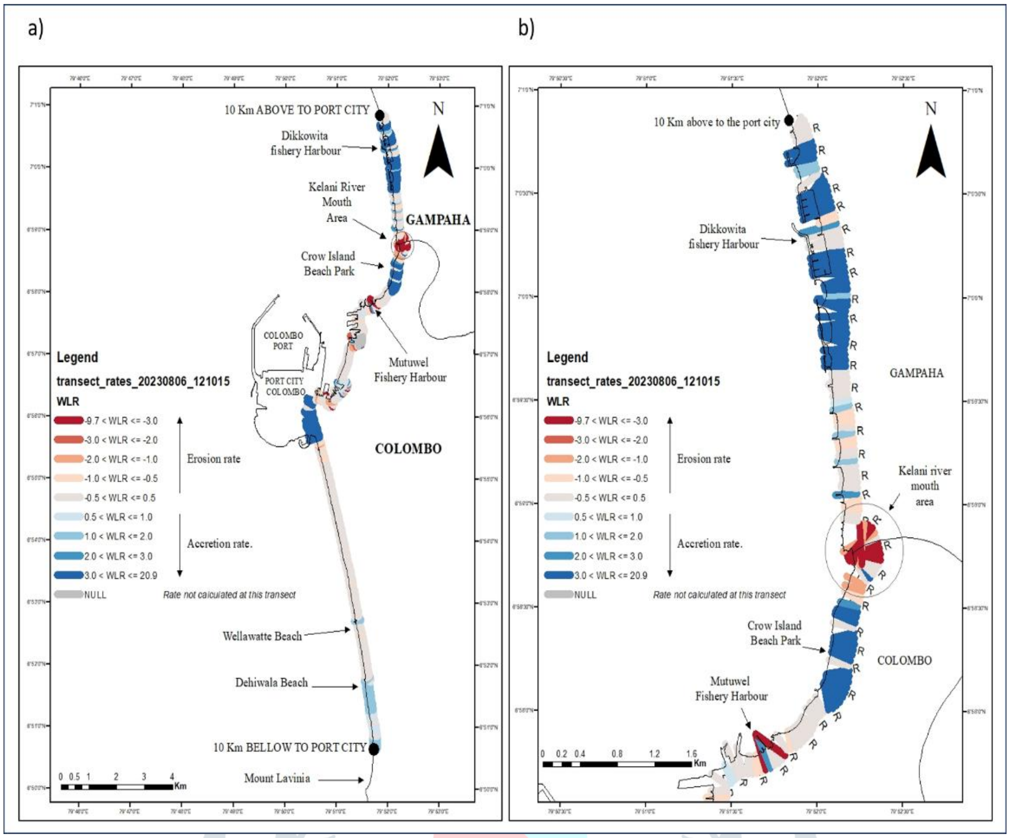

Figure 4-9. Weighted Linear Regression (WLR), Rates are calculated in meter per year (m/yr.). a) WLR of whole the study area. (Both 10Km above and below from the Colombo port city development project.) b) WLR of 10Km above from the port city development project.

WLR (Weighted Linear Regression) analysis was also same as LRR results.

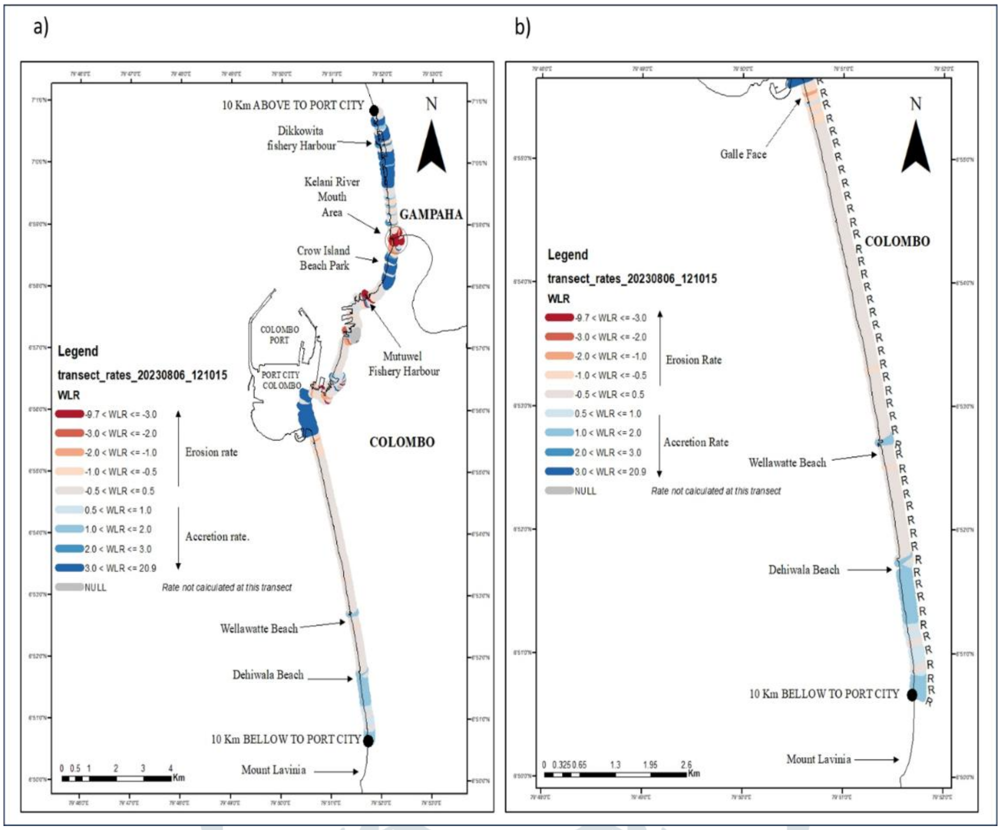

Figure 4-10. Weighted Linear Regression (WLR), Rates are calculated in meter per year (m/yr.). a) WLR of whole the study area. (Both 10Km above and below from the Colombo port city development project.) b) WLR of 10Km below from the port city development project.

Table 1 summary of DSAS analysis result

	SCE (m)	NSM (m)	EPR (m/yr)	LRR (m/yr)	WLR (m/yr)
Min	0.48	-214.3	-12.67	-9.65	-9.65
max	249.73	238.36	19.24	20.85	20.85
Average	45.51	-9.15	-0.56	-0.69	-0.69

The findings of this study shed light on the complex dynamics of shoreline changes in the vicinity of the Port City Development Project in Sri Lanka. It is evident that erosion and accretion patterns are influenced by a combination of natural factors and human interventions, including breakwater structures and beach nourishment projects.

One key observation is the presence of erosion areas within Mutwal Fisher Harbor and the Kalani River mouth. However, it is essential to note that the highest erosion values are associated with the breakwater structure in the northern part of Mutwal Fisher Harbor. This finding suggests that this erosion may not be solely attributed to the Port City Development Project but rather to the presence of the breakwater structure, which is an independent coastal engineering effort.

In contrast, the erosion observed at the Kalani River mouth appears to be influenced by various natural phenomena. These natural factors can include tidal patterns, currents, and sediment transport processes, which are beyond the control of the Port City Development Project.

The study also highlights the significant accretion areas that have developed north of the Port City, particularly in Crow Island beach and the associated area of Dikowita fishery harbor. These accretion areas can be attributed to the construction of multiple breakwater structures between 2005 and 2022. The breakwaters have altered sediment transport patterns and promoted the accumulation of sediment in these areas.

A noteworthy instance of accretion is observed in the Dehiwala beach area, where shoreline accretion of 10 to 64.8 meters was recorded. This accretion is linked to a beach nourishment project in Mount Lavinia in 2020. The project involved the pumping of sand to Mount Lavinia Beach, effectively creating a beach to the north. Longshore currents further contributed to the accretion by transporting sediment from south to north. Importantly, this demonstrates that the Port City Development Project, due to its location and longshore current patterns, has had a limited impact on shoreline changes in this area.

The west coast of Sri Lanka has experienced substantial accretion as a result of the Port City and harbor construction, extending the shoreline by 6-7 kilometers perpendicular to the coast. This expansion of land into the sea has resulted in significant accretion areas. However, the study's findings suggest that beyond a 10-kilometer radius from the port city, there are no significant shoreline changes directly attributable to the Port City Development Project.

In summary, this research underscores the importance of considering both natural and human-induced factors when assessing shoreline changes. It highlights that while the Port City Development Project has led to considerable accretion in its immediate vicinity, other factors such as breakwater structures and beach nourishment projects have also played crucial roles in shaping the coastline. Understanding these complex interactions is vital for sustainable coastal management and future development projects in the region.

5. CONCLUSION

In conclusion, this research has provided valuable insights into the dynamics of shoreline changes around the Port City Development Project in Sri Lanka. The study has revealed that shoreline alterations in this area are influenced by a combination of natural processes and human interventions.

The presence of erosion areas within Mutwal Fisher Harbor and the Kalani River mouth was identified, with the highest erosion values associated with a breakwater structure situated in the northern part of the harbor. However, it is important to note that this erosion is primarily linked to the presence of the breakwater and not directly attributable to the Port City Development Project. Erosion at the Kalani River mouth appears to be predominantly influenced by natural phenomena.

On the other hand, the construction of multiple breakwater structures between 2005 and 2022 has led to significant accretion in areas such as Crow Island Beach and the vicinity of Dikowita Fishery Harbor. The accretion observed in the Dehiwala Beach area is closely associated with a beach nourishment project in Mount Lavinia, where sand was pumped to create a beach to the north. Longshore currents have also contributed to this accretion, mitigating the impact of the Port City Development Project in this region.

Notably, the west coast of Sri Lanka has experienced substantial accretion due to the Port City and harbor construction, extending the shoreline considerably. However, beyond a 10-kilometer radius from the Port City, the study suggests that there are no significant shoreline changes directly attributable to the Port City Development Project.

These findings emphasize the need for a comprehensive understanding of the complex interplay between natural processes and human interventions in coastal areas. Such insights are crucial for informed decision-making and sustainable coastal management practices. As future developments continue to reshape the coastal landscape, it is imperative that we consider the broader context of shoreline dynamics to mitigate potential environmental impacts and ensure the long-term resilience of coastal ecosystems.

6. ACKNOWLEDGEMENT

I would like to express my heartfelt gratitude to all those who have played a significant role in the completion of this mini project thesis during my third year at the Ocean University of Colombo.

First and foremost, I extend my sincere thanks to my supervisor, Mrs. Anusha Wijesundara, for her invaluable guidance, encouragement, and support throughout this project. Her expertise and unwavering assistance have been instrumental in shaping the success of this endeavor.

I would also like to acknowledge Dr. Jagath Rajapaksha, the Academic Head of the Department of Oceanography at the Ocean University of Colombo, for his mentorship and invaluable insights that have guided me in the right direction during this academic journey.

To my colleagues and friends, I am deeply grateful for your constant encouragement, insightful discussions, and willingness to lend a helping hand whenever needed. Your collaborative spirit has truly enriched this project.

I want to express my appreciation to the professionals and experts who generously shared their knowledge and expertise, helping me overcome challenges and refine my analytical approach.

Lastly, I extend my heartfelt thanks to my family for their unwavering support, understanding, and encouragement. Your belief in my abilities has been my constant motivation.

To everyone who has contributed, whether big or small, to this mini project thesis, thank you for being an integral part of this journey. Your contributions are deeply appreciated and will always be remembered.

Sincerely,

W.M.M.R. Madurawala.

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