A GIS-BASED EVALUATION OF THE EFFECTIVENESS OF BREAKWATERS FOR COASTAL CONSERVATION, A CASE STUDY OF THE WEST COAST OF SRI LANKA.

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Abstract

Sea level rise driven by global warming is considered one of the major consequences caused by climate change. As a tropical island, Sri Lanka is one of the most vulnerable countries subject to climate change and one face of it is the increased coastal erosion around the country. The Sri Lankan government has implemented different projects to reduce the country's coastal erosion; one project is constructing breakwaters and groins in areas with high erosional rates. The objective of this study was to measure the difference between the erosional and accretional levels of the Kalutara shoreline during two periods before the construction of hard structures and after the construction of those structures. Shoreline changes between 1985 and 2022 have been extracted from the west coast of Sri Lanka from Kalutara to Beruwala using Google Earth satellite images from two different periods (1985 to 2010 and 2012 to 2022). The first period is the period where the breakwaters' construction was initiated and three satellite images from 1985, 2004, and 2010 have been used to extract the shorelines for this period. The second period is the period where the breakwaters have been fully constructed and eleven satellite images from each year (2012 to 2022) have been used to extract the shoreline for this period. Digital Shoreline Analysis System (DSAS) was used to detect the shoreline change over time by creating 769 and 756 transacts for each period respectively at a simple right angle along the entire coast at 10m intervals. The endpoint and linear regression rates quantified the average erosion at rates of 1.08–1.21 m/year and the average accretion at rates of 1.85–2.05 m/year within the first period. The average erosion at rates of 0.79–0.82 m/year and the average accretion at rates of 0.82–0.86 m/year within the second period. The percentage of transects that are erosional is 80.05% for the first period and it has reduced to 56.75% during the second period while the percentage of transects that are accretional is 19.95% for the first period and has increased up to 43.25% during the second period. The results show that the breakwaters and groins are useful for preventing coastal erosion and promoting sediment accretion.

Keywords: Breakwaters, Climate Change, Coastal Erosion, Digital Shoreline Analysis System (DSAS), Google Earth

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INTRODUCTION

Sea level rise driven by global warming is considered one of the major consequences of climate change. According to experts, the global mean sea level rose at least 10 cm during the last Century, and this rise is most likely to accelerate within the 21st Century due to human-induced warming **(Nicholls, 2003)**. Even though the sea-level rising directly affects the coastal zone, it can also be considered a significant concern due to the high concentration of natural and socio-economic values within the coastal regions. This is because the coastal zone is a major source of human habitation and economic activity, as well as these areas, are important ecologically too **(Holligan & Deboois, 1993; Turner et al. 1996; Sachs et al. 2001)**.

Sri Lanka became the second most vulnerable country to climate change in 2019 **(Global Climate Risk Index 2019, 2019)** and one face of it is the increased coastal erosion around the country. As an island with a coastline of approximately 1600 km in length, the Coastal area of Sri Lanka is densely populated with more than 65 percent of the total country's population **(Senevirathna et al. 2018)**. The Sri Lankan government has implemented different projects to reduce the country's coastal erosion; one project is constructing breakwaters and groins in areas with high erosional rates **(Coastal conservation and coastal resource management department, 2023)**. Some research has been conducted to determine the shoreline changes in Sri Lanka using GIS techniques **(Lakmali, Et Al., 2016, Geeganage & Warnasuriya, 2016, Weerasingha & Ratnayake, 2021)**. However, those were not focused on erosion prevention strategies. **Abeykoon, Thilakarathne, Abeygunawardana, Warnasuriya, & Egodauyana, (2021)** questions the applicability of coastal protective hard structures of Sri Lanka with the help of GIS applications. This study have been concentrating on a wider study area which was occupying the shorelines from Kalutara to Puttalam.

With this background, this study was focused only on the Kalutara area and the objective of this study was to measure the difference between the erosional and accretional levels of the Kalutara shoreline during two periods where before the construction of hard structures and after the construction of those structures.

METHODOLOGY

Shorelines between 1985 and 2022 have been extracted from the west coast of Sri Lanka from Kalutara (6°34'15.08"N, 79°57'34.38"E) to Beruwala (6°30'37.83"N, 79°58'54.15"E) using Google Earth images which is about approximately 7.5km in extend. The Google Earth images from 1985, 2004, 2010, 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019, 2020, 2021, and 2022 have been used to extract the shorelines. Google Earth's historical images option was used to retrieve the data from earlier years and those shorelines were digitized in Google Earth and saved as kml files. Then these kml files were exported into the ArcGIS 10.8 software. These shorelines have been divided into two groups based on the years 1985 to 2010 and 2012 to 2022. The first period is the period where the breakwaters' construction was initiated and three satellite images from 1985, 2004, and 2010 have been used to extract the shorelines for this period. Due to the unavailability of satellite images, only three years were considered for the first period. The second period is the period where the breakwaters have been fully constructed and eleven satellite images from each year (2012 to 2022) have been used to extract the shoreline for this period.

The Digital Shoreline Analysis System (DSAS) that was developed by the United States Geological Survey (USGS) has been used to do analysis and it is a software that is an add-in to Esri ArcGIS Desktop version that enables a user to calculate rate-of-change statistics from a time series of vector shoreline positions **(Himmelstoss et al. 2021)**. DSAS detected the shoreline change over time by creating 769 and 756 transacts for each period respectively at a simple right angle along the entire coast at 10m intervals.

RESULTS AND DISCUSSION

Among the various statistical calculations in DSAS, Liner Regression Rate (LRR), End Point Rate (EPR), and Net Shoreline Movement (NSM) have been used to determine the shoreline changes in the study area. LRR can be determined by fitting a least-squares regression line to all shoreline points for a transect **(Himmelstoss et al. 2021)**. EPR is calculated by dividing the distance of shoreline movement by the time elapsed between the oldest and the most recent shoreline. NSM is the distance between the oldest and the youngest shorelines for each transect and Shoreline Movement **(Saad et al 2021)**.

The endpoint and linear regression rates quantified the average erosion at rates of 1.08–1.21 m/year and the average accretion at rates of 1.85–2.05 m/year within the first period. The average erosion at rates of 0.79–0.82 m/year and the average accretion at rates of 0.82–0.86 m/year within the second period.

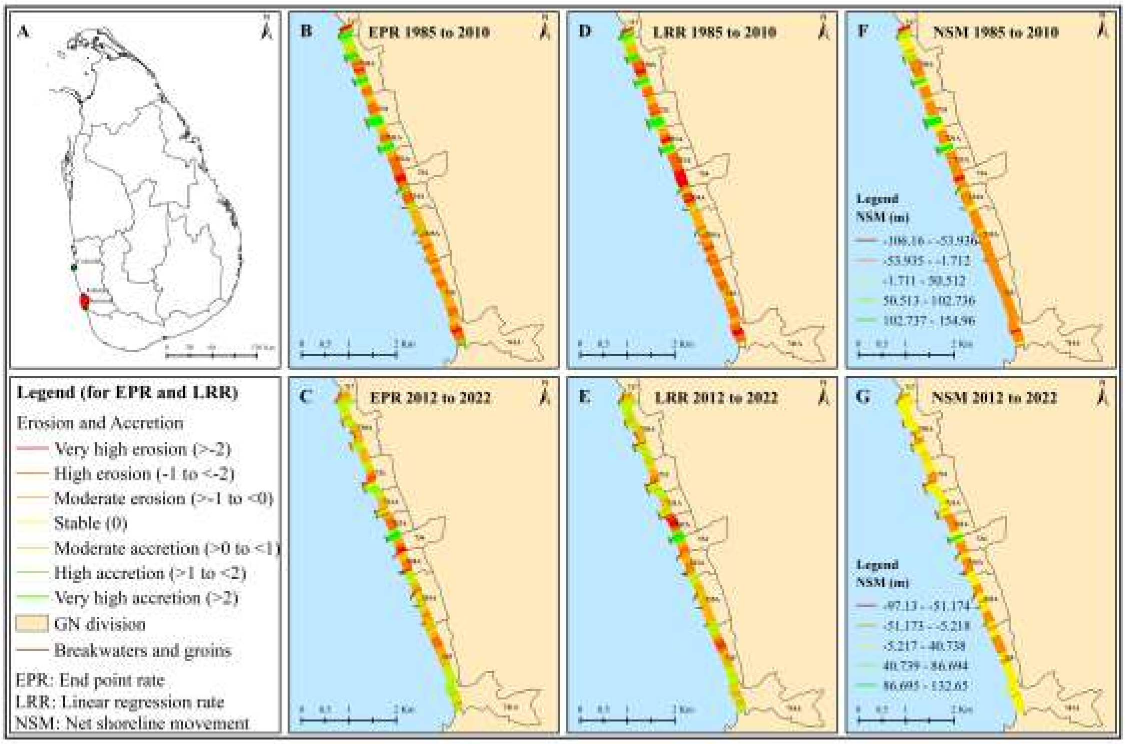

Figure 01: **A**: Location of the study area, **B**: EPR 1985 to 2010, **C**: EPR 2012 to 2022, **D**: LRR 1985 to 2010, **E**: LRR 2012 to 2022, **F** NSM 1985 to 2010, **G**: NSM 2012 to 2022

The percentage of transects that are erosional is 80.05% for the first period and it has reduced to 56.75% during the second period while the percentage of transects that are accretional is 19.95% for the first period and has increased up to 43.25% during the second period. The maximum negative shoreline change is -106.16m and the maximum positive shoreline change is 154.96 m in the first period. In this period, the average of all negative distances is -26.55m, and the average of all positive distances is 49.82m. The maximum negative shoreline change is -97.13m and the maximum positive shoreline change is 132.65 m in the second period. In this period, the average of all negative distances is –9.01m, and the average of all positive distances is 9.44m. (See Figure 01)

During the first period, most of the territory was subject to erosion, although some parts of the beaches were accreted. It was difficult to determine to what extent the breakwaters were constructed by 1985 due to the low resolution of the satellite image. However, by 2010 almost all the breakwaters were constructed and therefore that period has been selected as the first period. Accreted parts are the places where the breakwaters were constructed but in between shorelines seemed to be eroded with high to very high erosion rates. (See Figure 01)

The second period is the period where all the breakwaters are constructed. During the second period, most of the territory was accreted or stable, while some parts of the shoreline eroded.

In both periods, in places where the breakwaters were constructed accretion dominated. In general, breakwaters can be a disturbance to the scenery. Man-made stone or concrete wall on the shoreline is not a pleasant scenery on the beach. However, what can be determined is that these breakwaters divide the shoreline into small segments of separate beaches with more attractive aesthetic views.

CONCLUSION / RECOMMENDATIONS

As a country with a high vulnerability to climate change and as an island, Sri Lanka is a country where coastal erosion has emerged as a major environmental concern. With the high population concentration, location for environmentally sensitive areas as well as locating tourist hotspots, Sri Lankan shorelines are a highly sensitive region both socially and economically.

In Sri Lanka, the coastal conservation and coastal resource management department is the authorized government authority for conserving the shoreline of the country. They have implemented different projects like the construction of breakwaters and groins to protect the shoreline from erosion **(Coastal conservation and coastal resource management department, 2023)**. Such breakwaters have been constructed along the shoreline of Kalutara to Beruwala on the west coast of Sri Lanka during the last decades. This research was conducted to analyse the effectiveness of these structures in the case of coastal erosion.

According to the shoreline changes from 1985 to 2022, the results confirm the productivity of breakwaters when dealing with coastal erosion. These structures are not only capable of reducing erosion but also promoting accretion as well as creating new scenery on the shoreline.

By looking at the visual interpretation (Figure 01) it is possible to identify the shape of the breakwater has a direct impact on its function as a preventing structure of the coastal erosion. That area has not been covered by this study and therefore, it is recommended to conduct future research on that area too.

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