COASTAL EROSION AND PROTECTIVE MEASURES: A CASE STUDY OF ERNAKULAM COAST IN KERALA, INDIA

Abstract

Ernakulam coast is a thickly populated region of Kerala, India, which experiences very rough wave attacks and coastal erosion, especially during the South-West monsoon. Most of the population lives very close to the coast. Continuous erosion is a severe problem with several socio-ecological consequences that pose a high risk to life and property. Different coastal protective measures are widely adopted to compact the impacts of coastal erosion. Traditionally coastal erosion management involves the construction of hard engineering structures, such as groynes, seawalls, and breakwaters. While innovative methods like geotubes are emerging, it is important to understand the effectiveness of existing coastal protective measures to identify the gaps. The paper aims to understand different solutions for managing coastal erosion by examining the case study of Ernakulam.

Keywords: Coastal erosion, accretion, protective measures, seawall, groynes.

Author

Anupama Chandran
Ph.D. Research Scholar
Department of Geography
Central University of Karnataka
Karnataka, India.
chandrananupama110@gmail.com

I. INTRODUCTION

The coastal zone is the transition zones between land and sea. It is a very complex and dynamic environment. The morphological changes in the coastal zone happen primarily due to erosion and accretion activities. The accretion is the accumulation of coastal sediments on the visible region of a beach. It may generate extra land in the coastal zone. Erosion can be defined as a natural phenomenon in which the sand is moved from shore and deposited at a different place by longshore currents and wind acting together. Erosion leads to the permanent loss of valuable land and natural resources along the coastal region.

Coastal erosion has become a widespread problem in the world today. Many countries are suffering from an increased rate of coastal erosion along their shore, which threatens the life and livelihood of people. The coastal dynamics were a natural process prior to human interference. But due to rapid urbanization, development, and high population pressure, the coast is getting radically altered. Like any natural system, coastal ecosystems also have some capacity for self-repair and recovery. But now coastal erosion management has become inevitable to save coastal ecosystems and human life.

1. **Causes of Coastal Erosion:** Erosion, in general, is considered a natural process. It is the gradual wearing away of the earth's surface by the action of the natural forces of wind and water. Waves are the primary agent of erosion in the coastal zone. Waves develop in the mid-ocean and move towards the shore under the influence of wind. The causes of erosion are natural, man-made, or a combination. Natural causes include hydrodynamic effects due to waves, currents and tides, and sea level changes. Sea level rise associated with global warming and climate change is also a concern in this century.

   The components of any coastal system undergo continuous modification with or without human interference. However, uncontrolled human interference could disturb the balance of natural changes; in another sense, it can seriously impact the movement of littoral sediments in the coastal zone. Construction of new structures along coastal zone often results in changes in the morphology of the nearby area. Sand dredging for harbour channels and sand mining for minerals is also known for disrupting sediment supply. The removal of coastal vegetation is another important factor that accelerates coastal erosion. The absence of vegetation will loosen up sand and will trigger erosion.

2. **Measures of Coastal Protection:** The natural and anthropogenic factors combinedly lead to landscape change. Any change in the state of the environmental landscape will have consequences. Consequences have to be dealt with adaptation/mitigation measures. Similarly, coastal erosion is managed with various strategies. To prevent coastal erosion, various types of engineering structures are commonly constructed. They are built to prevent further erosion and restore the eroded beaches to their initial phase. Coast protection measures are classified into two types; hard and soft. Hard coast defence structures include groynes, seawalls, revetments, breakwaters, etc. Groynes are built perpendicular to the coastline from the shore into the sea, while Seawalls are constructed parallel to the coastline near the high tide line. Groynes and seawalls are usually made with timber, stones and concrete. Like a seawall, a revetment is a parallel structure to the shore. Breakwaters are used in connection with harbour protection to dissipate wave energy. There are two types of breakwaters; Shore connected and detached breakwaters.

Soft or non-structural measures include beach nourishment, land reclamation, artificial reefs, and plantation. Beach nourishment is replenishing an eroded beach with the artificial placement of sand. It is also termed sand pumping. Land reclamations involve filling wetlands and other lowlands to create new land generally for settlement and cultivation. It is similar to beach replenishment, but instead of refilling eroded beaches, a new piece of land is created from the sea. Another method is artificial submerged reefs. Coral reefs are a natural gift that can reflect or dissipate wave energy and thus protect the coast. However, it is one of the most destructed ecosystems in the world. Artificial reefs are man-made structures of concrete reef balls or sand-filled polythene bags. Artificial plantation involves planting trees, scrubs, or mangroves to slow wave movement. The roots of the plants can penetrate deep into and hold sand material together. However, plantation should be done based on the area's natural vegetation.

Apine (2011) classified adaptation strategies into three types; defence, adjustment, and retreat. Defence strategy includes hard coast defence structures mentioned earlier. Adjustment strategy includes various methods to cope with the issue, like the elevation of roads and restoration of buildings. Retreat strategy implies major changes in land use. It involves housing relocation to the interiors of the mainland. Retreat as a strategy is generally acceptable only by very few people. It is considered as a final measure of adaptation. According to Gomez et al. (2020), most local households prefer sustainable adaptation strategies to mitigate the impacts of coastal erosion. Soft measures are considered more environmentally friendly than traditional hard coast defence methods. Groynes built with sand-filled geotextile bags are a cost-effective and eco-friendly method to regain the sandy beach (Neelamani, 2018). Geotextiles are the new, cost-effective shore protection measures. It can be used in different forms, such as geotextile bags, containers, and tubes. If strategically placed, geotextile tubes filled with dredged sand will dissipate the wave energy (Ashis, 2015). However, its sustainability under extreme temperature and salinity conditions for a longer period is questionable. In the current scenario, the scope of geotextiles for coastal protection as a long-term sustainable method is in its developing phase.

Studies must also be done before adopting any shore protective structure. Protective structures constructed without considering coastal morphology, littoral drift, and wave dynamics may adversely affect specific coastal stretches. Breakwaters constructed on the harbour are for the safe anchoring/docking of shipping vessels. However, these constructions can block the longshore current flow that is heavily loaded with sediment, which permanently impacts the distribution of the local sediment budget along the coastline. Ultimately this will result in forming a region of accretion along the up-drift side and erosion along the down-drift side of the breakwaters (Sundar et al., 2021).

Similarly, in many cases, seawalls originally constructed to control erosion have been reported to aggravate the problem. According to Jayappa et al. (2003), seawalls damage beaches more rapidly than groynes. Moreover, the seawall is a very expensive and less effective solution. Anyhow the effects of such structures on the coastline are site-specific also. Nowadays, the approach to coastal management has taken a turn in understanding regional coastal dynamics and erosion to adopt the most suitable methods of coastal protection measures.

II. CASE STUDY: COASTAL EROSION CONTROL, ERNAKULAM

1. **Study Area and Methods:** In this study, the coastal area of Ernakulam district in Kerala, which has a total length of 46 km, is examined to understand various coastline protective measures. The district, which lies between 09 47’ 13” and 10 10’44” north and 76 10’ 05” and 77 05’ 24” east, has its coastal stretch extended from Munambam at the north to Chellanam at the south (figure 1). About 80% of Ernakulam is artificial coast managed by hard structures. The seawalls are the major protection measures adopted along the Ernakulam coast. Some parts are protected by groynes or a combination of groynes and seawalls. Breakwater is constructed at the Chellanam harbour entrance to maintain the channel required for the movement of fishing boats. Methods used during this case study include a literature review of similar cases in India. Background information was collected from the literature. An analysis of historical satellite images is done with the help of Google Earth to explore coastline changes that occurred in the study area in past years. Once an understanding of coastal dynamics was gained, a field investigation using GPS was conducted. During field visits, various beach landforms and artificial structures were identified and recorded to create an elaborate photo database. The field investigation shows that the entire coastal stretch has been facing severe erosion for the last few decades in protected areas as well. At the same time, some pockets of active accretion are also identified. The coastal engineering strategies for managing both coastal erosion and accretion are studied and described in terms of construction, age, efficiency and effectiveness.

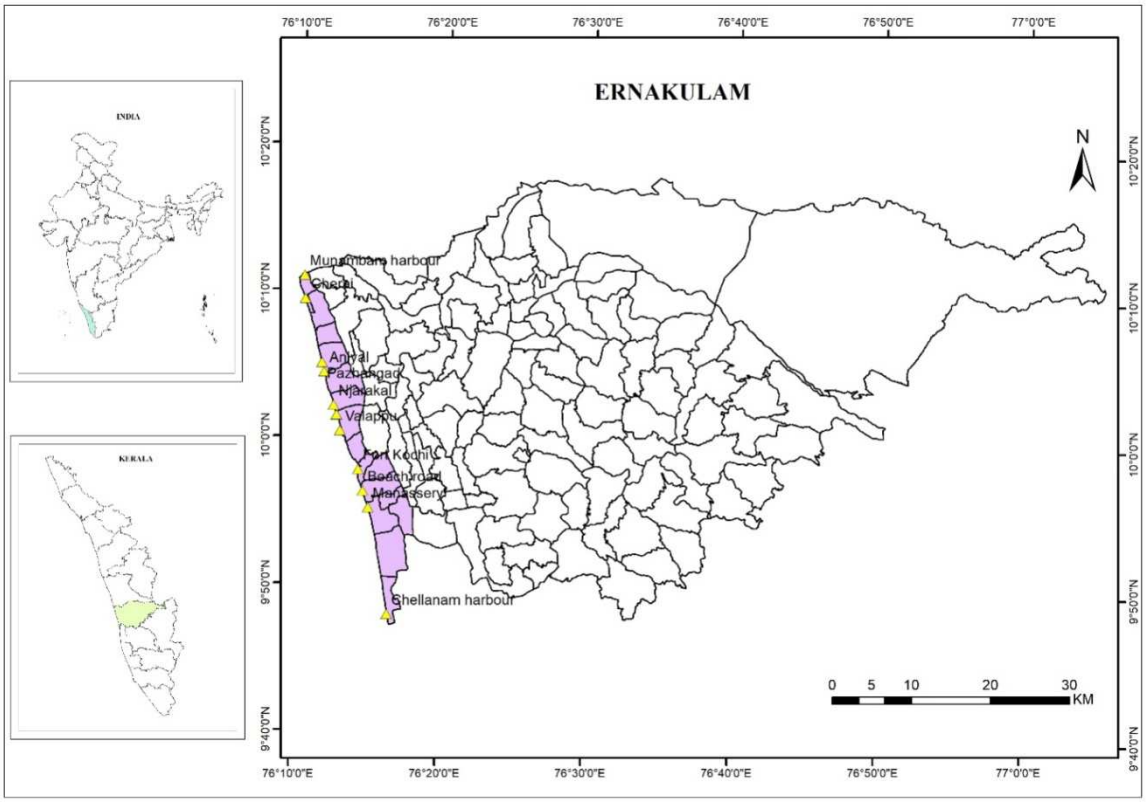

Figure 1: Location map

III. RESULT AND DISCUSSION

One of the longest groynes, locally known as 'Pulimutt' (Malayalam) in Ernakulam, is at the opening of Munambam Harbour, the northern tip of the study area. The presence of this groyne at the mouth of the estuary to facilitate fishing harbour has caused the accumulation of beach sand immediately south of it. This resulted in the formation of Munambam recreational beach (figure 2), well-known for various water sports. Another major location of accretion is mainly found north of the Cochin inlet from Elakunnapuzha to Puthuvype. The Social Forestry Division under the Department of Forest and Wildlife, Kerala, have planted Kattadi trees (Casuarina) in the name of the 'Theeravanam Project' to protect the accreted beach (figure 3). The plantation covers around 1.5 hectares, and the project is still ongoing. The presence of this artificial forest attracts hundreds of tourists every day during sunset. At Elakunnapuzha Beach (figure 4), the seawall is about 100 meters from the sea, while the vegetation line is only about 30 meters away. Near the Valappu beach, the seawall is located more than 500 m inside the present coastline due to accretion. According to the Centre for Earth Science Studies newsletter, Thiruvananthapuram (2007), a spectacular accretion of about 1.8 km was observed over 15 years at Puthuvype.

Figure 2: Munambam Beach

Figure 3: Theeravanam Project

Figure 4: Elakunnapuzha Beach

Apart from the Munambam and Elakunnapuzha – Puthuvype stretch, the rest of the Ernakulam coastal stretch experiences erosion to some extent though it is protected by seawall and groynes. Fort Kochi, the immediate south of the Cochin inlet, experiences significant coastal dynamics for short periods. Hence seawalls and groynes protect it, and temporary sand ridges are common at this well-known tourist place. Sign boards are provided

in there to give a warning for entering into the sea. Apart from these unstable sand dunes (figure 5), this sector has no sandy beach. The seawall pathways at Fort Kochi have been identified as destroyed due to the waves (figure 6). During monsoon months (June to September), wave heights are higher in coastal Kerala. Many places in Ernakulam, like Nayarambalam, Manassery and Chellanam, experience wave attacks and erosion during this period. The beach at Manassery experiences continuous erosion though seawalls were constructed many years ago. Such failures of seawalls as protection structures have been reported from some other locations along the Ernakulam coast. After a few years, seawalls could be damaged or collapsed due to continuous wave action (figure 7). When this occurs, the original seawall is replaced by another layer of bigger and better seawall. In Figure 8, we can see the recently added layer of stones to the older stones of the seawall, which became rounded due to wave-induced weathering.

Figure 5: Warning board at Fort Kochi

Figure 6: Damaged pathways at Fort Kochi

Figure 7: Collapsed Seawall

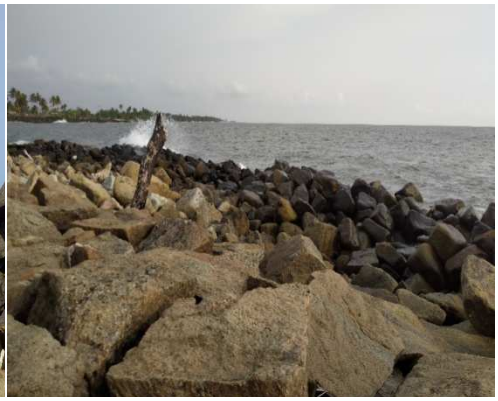

Figure 8: New Layers of Rocks Replaced old ones

Not only the seawalls but groynes and geobags also get damaged in the long term. Geobags, the sand-filled geotextiles, are identified at some stretches like Cherai, Pazhangad and Aniyal Beach. Most of the geobags are completely or partially damaged (figure 9). Figure 10 shows the geobags in Pazhangad Beach, which are found between the seawall and vegetation line. Generally, geobags are provided as a temporary protection measure. This method is very less encouraged in this study area.

Figure 9: Damaged geobags

Figure 10: Geobags at Pazhangad Beach

Figure 11: Seawalls with Gaps

Figure 12: Seawall gap at Beach Road

The seawall is constructed in certain places with some gaps (figure 11). The small beaches at these gaps are beneficial for local fishermen for fishing and also for landing. However, these gaps in certain places like Beach Road Beach (figure 12) lead to coastal flooding. The sea water entering the land through such gaps is trapped in the settlement area resulting in flooding. In the Manassery-Kannamali stretch, which has experienced a retreating shoreline for the past few years and a very rough sea during every SW monsoon, seawalls are very old and mostly collapsed. Geobags as a means of temporary solution are provided in this area. But it also gets damaged within a few months as the sea is active here. The high waves in this region are attributed to the sand dredging activity at the mouth of the Cochin inlet for the ship channel. Different case studies reveal the major influence of port development on the coastal regions (Kudale, 2010). The main impact of the port development is accumulation on the updrift side of the longshore drift and erosion of the downdrift side. It was reported that there was no erosion earlier south of the Cochin inlet at this rate before the construction of the Cochin Harbour channel. The harbour channel here is a barrier against sediment transport in the area.

Chellanam was one of the hotspots of erosion in Ernakulam district. Chellanam coast has experienced significant consequences from tropical cyclones like Okhi (2017). But now, with the construction of the new seawall (figure 13) from Chellanam Harbour to

Puthenthodu, people seem to be relieved from the fear of wave attacks, especially during the monsoon season. With a paved pathway, Tetrapod Seawall is being constructed in this stretch based on the recommendations provided by the National Centre for Coastal Research in Chennai. Construction is partially completed. However, the absence of wave attacks and coastal flooding in the area at the onset of monsoon this year indicates the success of the Tetrapod seawall. The paved pathways with the seawall are the best example of integrating coastal protection into sustainable Tourism. As this tetrapod seawall proved effective, demand arises to extend this project to other places.

Figure 13: Tetrapod seawall at Chellanam

The field investigation identified different coastline protective measures ranging from seawalls to geobags at the Ernakulam district coast. Most places are mainly protected by seawalls though they are very old and damaged in many locations. Seawall construction is very expensive, and it needs continuous monitoring and maintenance. Seawall is more to protect the interior land from the sea than to protect the coastline. The construction of groynes intermittently has been found to help protect and restore the beach. That might be why local people prefer Pulimutt/groynes instead of the seawall. Nowadays, local fishermen, especially in the places like Manassery, Saudi and Kannamali, have to travel far every day to go fishing due to the lack of beaches in their area. Such places where people are thickly populated needed protection and a safe beach for their livelihood and recreation. In such scenarios, beach replenishment can be the best option to regain eroded beaches. Apart from some tree plantations in the accreted land, no other soft defence methods are practised on the Ernakulam coast. It was revealed from the study that no single measure offers a complete solution to compact erosion. However, combined measures provided more effective protection. As for now, avoiding expensive hard coast defence structures is not completely possible. Combining hard and soft solutions is sometimes necessary to improve the efficiency of the options. Such hybrid solutions should be embraced very immediately.

IV. CONCLUSION

Like the coast of Ernakulam district in Kerala, most beaches around the world experience erosion. Several hard and soft protection measures are also widely used to compact erosion. There is no single global solution for erosion problems, as the degree and pattern of erosion vary across regions. Innovative methods like combining hard and soft measures are gaining popularity recently. Choosing a suitable adaptation strategy for a

specific location is important to governance. Hence, a local/regional study of nature and the cause of coastal erosion is essential to adopt a suitable coastal management plan. The protective structures should be selected by considering the coastal morphology, wave dynamics, sediment movement, and environmental sustainability. Otherwise, it can have negative impacts as well. A well-planned sustainable solution will protect the coast and coastal ecosystem. Moreover, integrating sustainable protection measures with tourism activities will lead to the nation's economic growth. For that, holistic development of all coastal engineering activities is needed.

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