Shore protection measures along Indian Coast – Design to implementation based on two case studies

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Coastal areas of the country are subjected to shoreline erosion due to natural and anthropogenic activities. Climate change-induced effects like sea level rise, extreme waves and increased storm activity exacerbate the erosion and causes the shoreline to retreat landwards. In India, mostly conventional concepts like sea walls and groins are used which protects the shoreline but cannot restore the lost beaches. This article discusses success stories of two novel concepts implemented for restoration of beach along the east coast of India – Kadalur Periyakuppam, a fishing village with gentle slope and Puducherry with steep slope protected by seawall.

Keywords: Beach restoration, geo-textile, Kadalur village, Puducherry, submerged reef.

Introduction

MANY beaches along the east coast of India are subjected to erosion, which threatens habitat, property, public infrastructure and the tourist industry. The coastal areas have become more prone and vulnerable to natural and human made hazards, which lead to coastal erosion[1]. In developing countries, coastal erosion is a major crisis and it potentially impacts the coastal population and natural environment[2]. Coastal erosion ravages land, houses, infrastructure and business opportunities and poses a high risk to human well-being, economic development and ecological integrity. The scientifically documented shoreline changes along a 6031 km coastline using satellite images reveal that between 1990 and 2016, about 34% of the Indian coastline was facing coastal erosion, 28% had accretion, whereas 38% was stable[3]. Conventional shore protection measures such as groins and seawalls implemented to protect the coast from high waves does not restore the lost beaches, which are of ecological, economical and socio-cultural significance. Hence, it is of paramount importance for an optimal solution to protect the coast by restoring the beaches, which are sustainable and environmental friendly.

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Site description

Puducherry which is located on the east coast between 77°45′E and 77°50′E and 11°45′N and 12°03′N is subjected to coastal erosion by natural forces and increased urbanization. The coastal erosion started after construction of port breakwaters and started affecting the northern coast of Puducherry. Coastal structures like groins, seawalls built to protect the Puducherry coast from coastal erosion made the sedimentation process more complex making beach slope steeper to extreme waves. Puducherry being a world famous tourist destination, not just protection of infrastructure but restoration of the lost beautiful beach is much essential for economic importance.

Kadalur Periyakuppam, a fishing village located 60 km south of Puducherry is also subjected to large scale erosion due to natural agents such as waves, currents and tides and the situation gets aggravated during cyclones resulting in large scale loss of beachfront. Cyclones such as *Thane* (2011), *Nilam* (2012), *Madi* (2013), *HudHud* (2014) and *Vardah* (2016) have caused severe damage to the Kadalur coast resulting in loss of over 40 m of beach width. The beach is essential for fishing hamlets for boat launching, parking and repair, fish catch landing and processing through salting/sun drying, catch auctioning. So it is essential to restore the lost beach. The location map of Puducherry and Kadalur village is shown in Figure 1.

Satellite image analysis

The shoreline analysis carried out for 1.8 km sandy stretch of Kadalur village indicated that 60–90 m of beach width was lost along the Kadalur coastline between 1965 and 2012 and the erosion rate was about 1.5 m per year. The analysis performed between 2012 and 2016 where the cyclones such as *Nilam* (2012), *Madi* (2013),

HudHud (2014) and *Vardah* (2016) occurred, the shoreline erosion rate has increased to 5 m per year (Figure 2).

Due to various coastal interventions such as port, groins and seawall, the Puducherry coastline of 18 km length was divided into four zones covering the Port and adjoining areas, Puducherry city protected by a seawall, groin field and open coast for satellite image analysis[4] (Figure 3). It is observed that the maximum erosion is about 40 m at distance of 600 m from north breakwater.

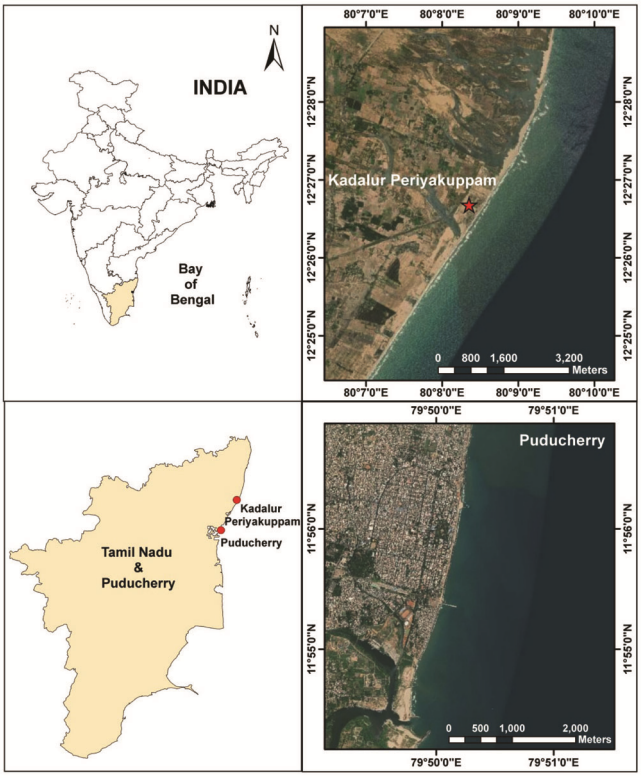

Figure 1. Location map of Kadalur Periyakuppam and Puducherry.

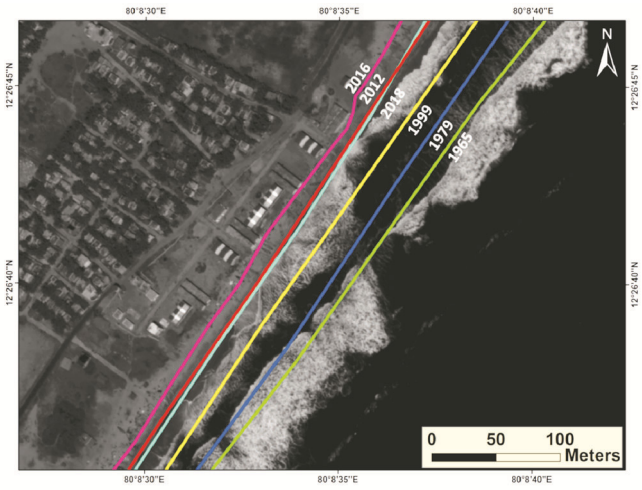

Figure 2. Shoreline mapping of Kadalur Periyakuppam.

The analysis indicates the average rate of erosion and accretion along the Puducherry coast is 4 and 5 m/yr respectively, and the coast needs immediate attention for its protection from natural causes or man-made activities.

Field measurements

For effective design of any coastal protection structure, the nearshore coastal processes have to be studied in detail. The main drivers of coastal processes such as waves, tides, currents, beach profiles, sediment transport and its seasonal variations along the Puducherry coast and Kadalur villages were monitored to understand the coastal dynamics and nearshore transformations.

The tidal observations indicate that the tidal range in March varied between 0.5 m (neap tides) and 0.7 m (spring tides) whereas in November the range varied between 1.3 and 1.0 m and the tides are semidiurnal in nature (Figure 4). Water levels measured play a crucial role in the effective design of coastal protection structure whether to allow the transmission of wave energy by overtopping in case of emerged breakwaters or energy dissipation through wave breaking on a submerged structure.

Wave measurements carried out show that the wave heights during southwest monsoon range from 0.4 to 1.2 m and the significant wave height during the NE monsoon ranges from 0.3 to 1.50 m with an average value of 0.60 m (Figure 5). Frequency distribution of wave heights shows that the waves during southwest monsoon approach from southeast with less waves for about 8 months in a year and during northeast monsoon the wave approach from east with large waves for 4 months. The wave periods range between 3 and 18 sec with 50% of the waves have T_z in the range of 8–10 sec.

Beach profiles monitored along Kadalur village and Puducherry (Figure 6) show that the Kadulur village is characterized by gentle slope of 1 in 80 with 4 m contour located at 300 m whereas Puducherry coast protected by the seawall is characterized by steeper slope of 1 : 25.

Numerical modelling

Detailed numerical studies were carried out to arrive at a solution for restoring the beach. To understand the erosion issues and to identify suitable solution, long-term wave climate is essential. Hind cast wave model was established using third generation wave model for large domain ranging from 0°E to 25°N and 60°E to 120°E, to simulate long-term wave climate in the Indian ocean and validated with the buoy located off Puducherry coast at 30 m water depth (Figure 7)[5]. The coupled wave, hydrodynamic and sediment transport model was established for Puducherry and Kadalur Periyakuppam coasts to

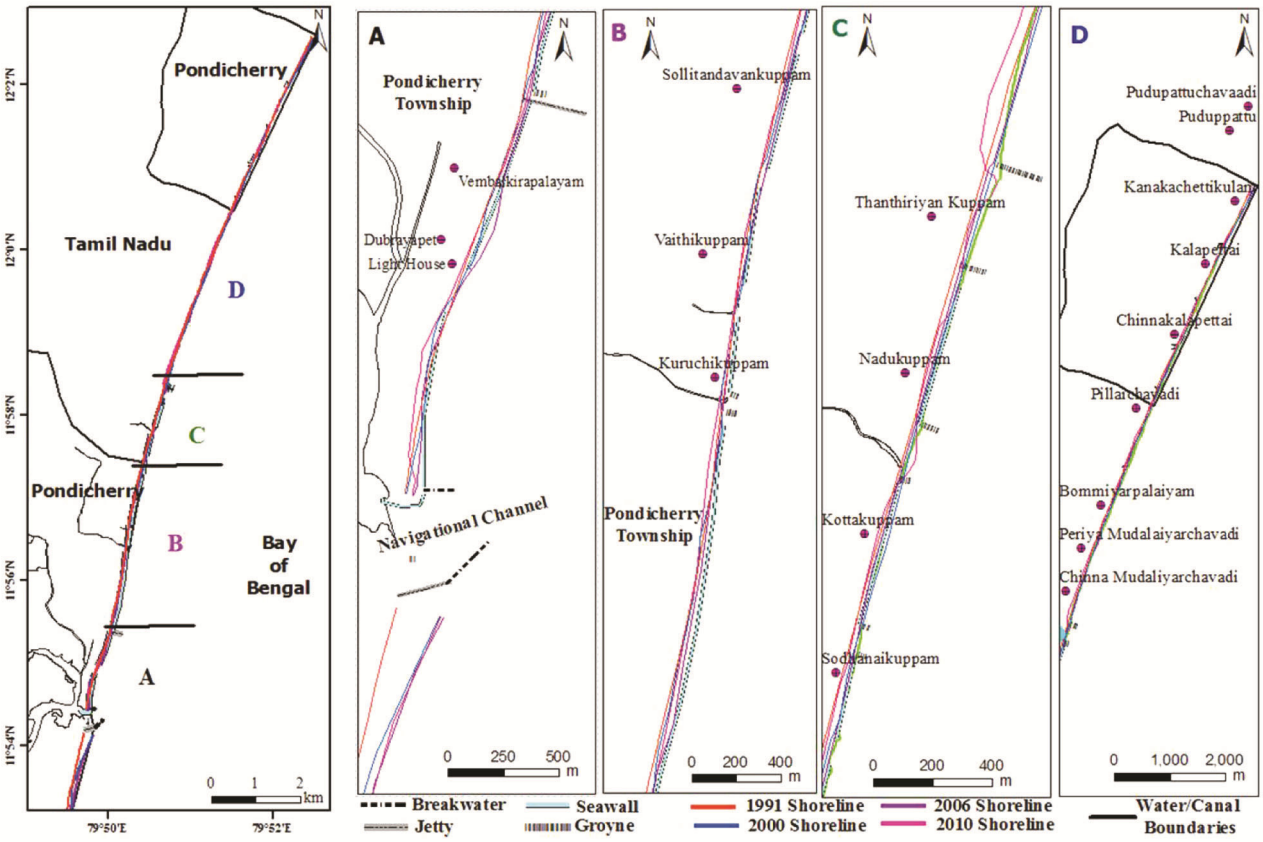

Figure 3. Shoreline mapping of Puducherry.

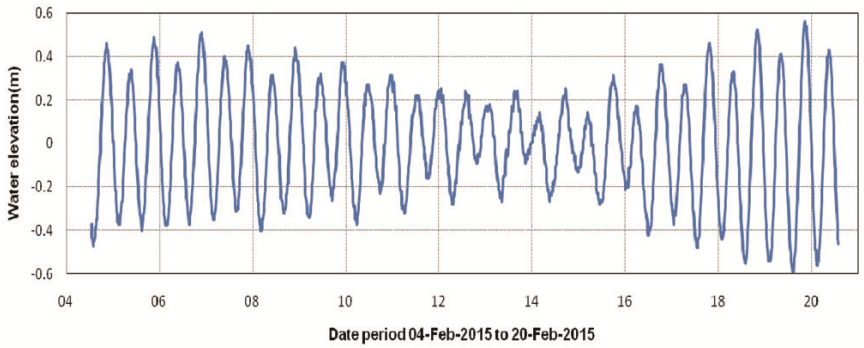

Figure 4. Typical water level along the study area.

understand the shoreline evolution for various configurations of coastal structures by varying the water depths and dimensions[6].

Concepts behind coastal protection

For Kadalur coast with gentle slope of 1 in 80 experiencing more sediment transport during cyclones, the energy of the waves reaching the coast is high leading to increased erosion. The coastal protection should serve the function of reducing the incident high wave energy on the coast during cyclones. However small waves should be transmitted over the structure facilitating natural littoral drift to avoid downdrift erosion. Hence, submerged breakwater offers a better solution to combat coastal erosion. Gaps are proposed in between segments to enable fishing activities and better sediment deposition. Based on the shoreline response obtained from numerical modelling by varying parameters of breakwaters, submerged detached breakwaters with each section of 200 m at 60 m spacing is proposed with geo-synthetic tubes of size 25 m

long and 15 m circumference filled with locally available sea sand[7]. To achieve the design height, three geosynthetic tubes are placed in stacked manner with two at the bottom and one on the top (Figure 8).

The coast adjacent to Puducherry had a stable coastline of about 18° had changed to 11–14° at various stretches due to long-term erosion. It is also observed from estimation of sediment transport with bulk formula using long-term climate, the preferred coastline orientation should be 18°N for stable coast with zero net sediment movement.

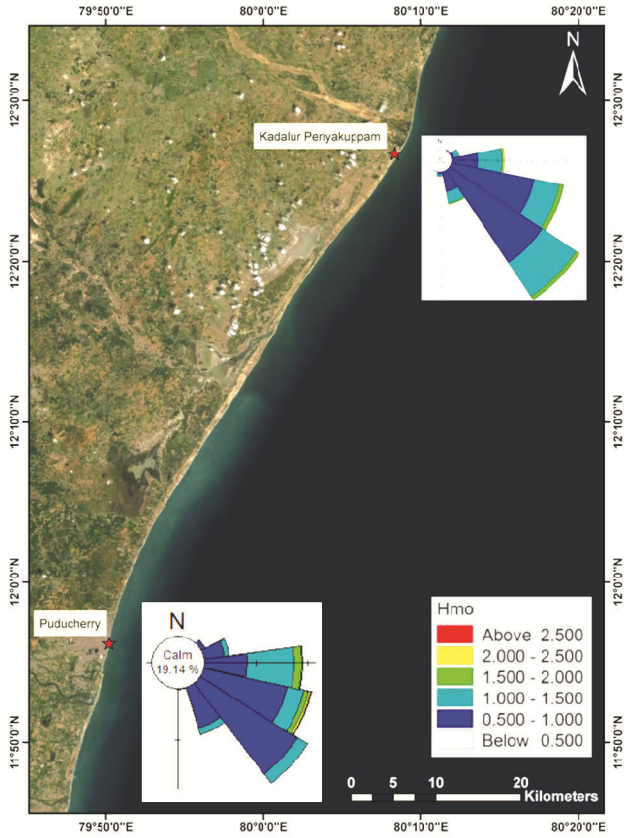

Figure 5. Annual wave rose plots at Kadalur Periyakuppam and Puducherry.

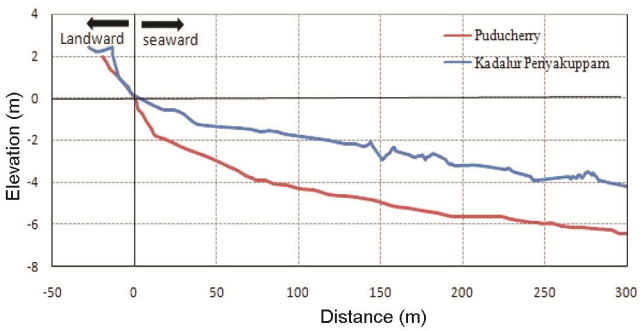

Figure 6. Comparison of nearshore beach profile at Kadalur Periyakuppam and Puducherry.

To create a new beach alignment of preferred coastal orientation (i.e. 18°), a structure should be extended till 170 m into the sea near Puducherry Secretariat. Hence a submerged North reef of triangular steel wedge of dimension 60 × 50 m with height of 2.5 m at the base projecting into the sea for a length of 170 m with width of 110 m at base along with working platform was implemented. To withstand the extreme waves and ease for launching and floatation the wedge reef is made up of steel material. The reef is designed to naturally bypass the sand as the crest of the reef is maintained at lowest low water level. Simulation of event corresponding to southwest monsoon indicates that the nearshore reef structure rotates the waves that will help in reducing the long shore current to the north (Figure 9). During north east monsoon, some of the sand is carried back to the south and to retain the sand in the coastal stretch, an emerged reef is proposed in the south. As Puducherry coast is deprived of sand, beach nourishment to an extent of 3 lakh cubic metre was carried out. The layout of northern nearshore reef and southern offshore reef proposed is shown in Figure 10.

Conclusion

Shoreline changes happening due to natural or manmade phenomena over a larger extent of coastline globally have necessitated more innovative coastal protection methods. Site-specific design and solution for Kadalur village and Puducherry were arrived based on detailed field observations and studies. To protect the coast of Puducherry and to promote tourism, the solution aimed to restore the beach by implementation of submerged reef along with beach nourishment. And cyclone-affected sandy beaches of Kadalur village is restored for fishing activities, by implementation of submerged breakwaters made up of geosynthetic tubes.

Nearshore bathymetry and beach profile elevations were monitored regularly to determine the volume of sand being accumulated after implementation of solution in Kadalur village and Puducherry. It is seen that volume of sediment in the nearshore profiles improved after

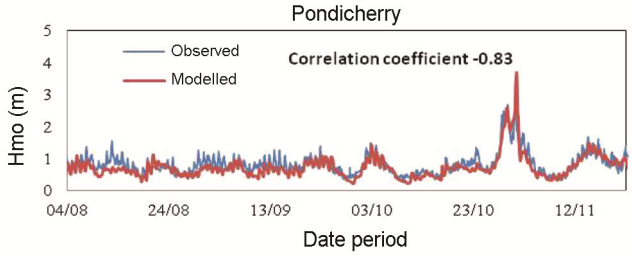

Figure 7. Regional model validation with wave rider buoy deployed off Puducherry coast.

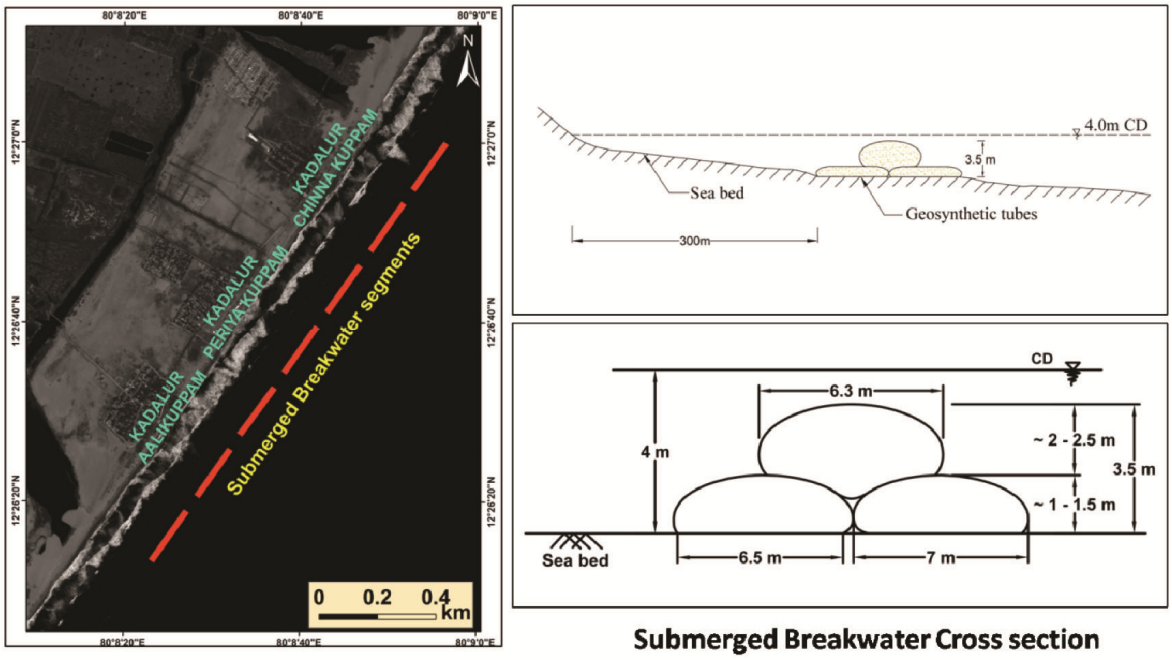

Figure 8. Layout of coastal protection scheme in Kadalur village.

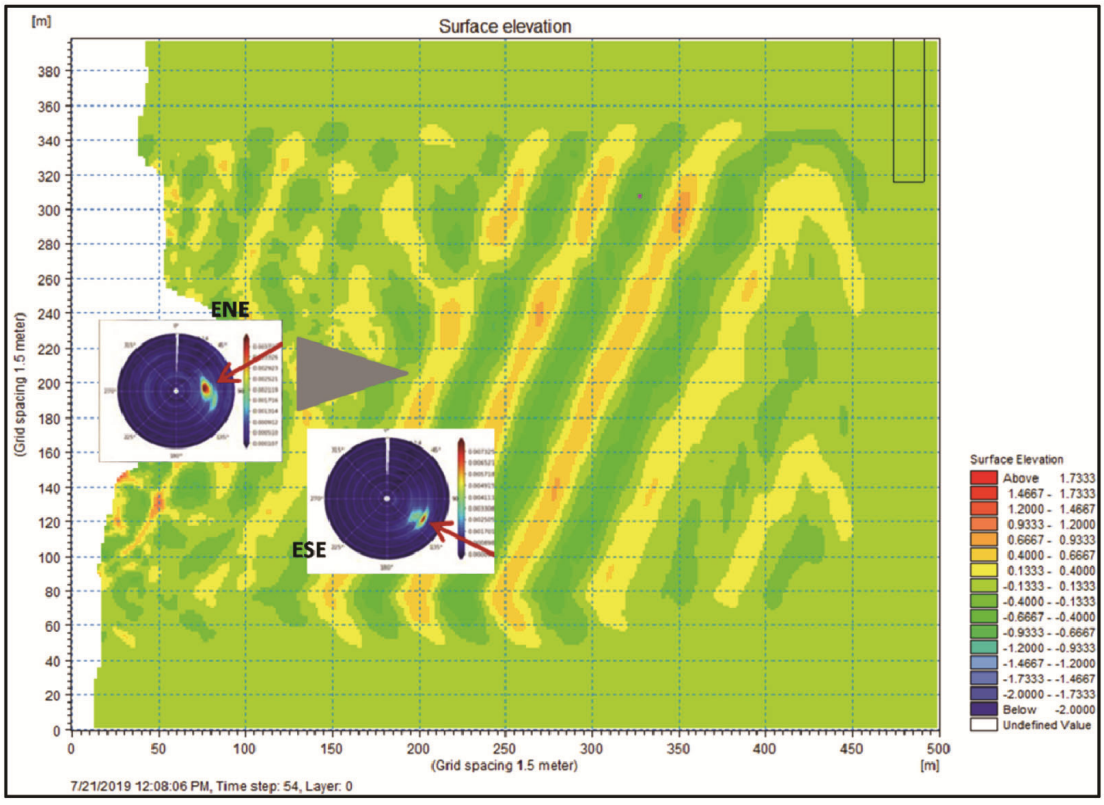

Figure 9. Numerical model study to study the wave current pattern in presence of reef.

implementation of submerged structures resulting in a formation of beach. A wide beach of varying width was formed at both the sites and well appreciated by the public. The uniqueness of the project at both sites is the development of innovative hybrid solution for coastal protection/stabilization. Similar to the sites demonstrated in the

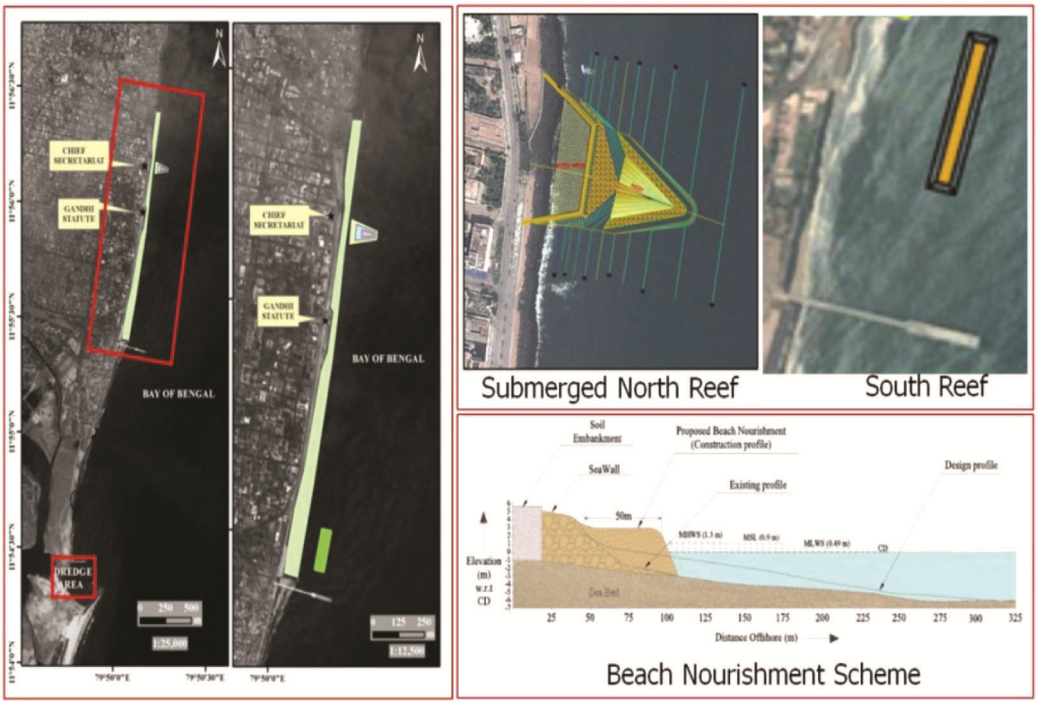

Figure 10. Layout of coastal protection scheme in Puducherry.

paper, there is a need for various sustainable coastal structures through detailed analysis to restore the lost beaches around the country.

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