



## Coastal Erosion Assessment along the Southern Tamilnadu Coast, India

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**Abstract:** Coastal zone is a very multi-faceted, energetic and fragile environment because of the influence of both terrestrial and marine ecosystems. Majority of the world's coastlines are experiencing a wide range of anthropogenic and natural pressures. Anthropogenic threats are the consequence of rapid urbanization, population growth, tourism activities, harbor development, industrialization, over-exploitation of natural resources, waste accumulation and environmental pollution. On the other hand, natural pressures are mainly from sea-level fluctuations and climatic anomalies. This paper mainly focuses on coastal erosion hazard assessment estimated along the coastal precinct between Kanyakumari and Mandapam, southern Tamilnadu coast over a length of about 360 km. Risk assessment was carried out based on the type of coastal erosion indicators found along the shoreline and general spatial distribution of coastal erosion indicators along the investigated area. Results reveal that the study area is under the treat of coastal erosion with high-risk category.

**Keywords:** Coastal erosion, Natural, Anthropogenic, Risk assessment, Tamilnadu

### Introduction:

Coastal erosion is a pervasive phenomenon along the Tamilnadu coastline. However, studies concerning coastal erosion processes and their causes are relatively meager. Chandrasekar (1992); Rajamanickam (1994); Loveson (1994); Angusamy (1995); Chandrasekar et al. (2001) and Anil Cherian (2003) pointed out the irregular erosion process due to anthropogenic and natural factors along the Tamilnadu coast. But no systematic, detailed study has yet been initialized for erosion risk assessment along the shoreline of southern Tamilnadu. So the present work was undertaken as a maiden foray to understand the coastal erosion problem along the coast between Kanyakumari and Mandapam over a length of about 360 km. The area is located between N 70 44' to 90 38' and E 770 38' to 790 22' (Fig. 1). Many fascinating coastal geomorphological features like beach ridges, paleochannels, marine terraces and spits are found abutting the coastal zone. Marine terraces with height to the tune of 5 to 8 m are well developed in the Mandapam, Valinokkam, Manappad and Tiruchendur regions. Geomorphologically, the coastal stretch can be classified as a shoreline of emergence as identified from the beach ridges scattered along the study area (Loveson, 1994; Chandrasekar et al. 2000).

### Materials and Methods:

#### Coastal Erosion Indicators:

Coastal erosion has become an unwavering threat responsible for the social and economic losses along the coast of Southern Tamilnadu. Monitoring studies along the investigated area have revealed that coastal erosion is the prevailing process on majority of the beaches. Quantitative data pertinent for calculating beach sedimentary budget along the investigated area such as sediment load brought by rivers, wave climate and longshore drift analysis are not fully available hitherto. In order to circumvent these deficiencies, the approach used by Souza and Suguio (1996) was used in this study to identify indicators of coastal erosion as well as their spatial distribution along the shoreline and their prevalence in the coastal vicinity. Moreover, these studies have been motivated towards the identification of the cause of the ongoing coastal erosion that will be supportive for integrated coastal zone management of any coastline.

#### Coastal Erosion Hazard Assessment:

In order to estimate coastal hazard assessment, the methodology of Souza and Suguio (1996) has been followed in the present study. It includes two focal components: (i) the total number of types of coastal erosion indicators found along the coastal zone and (ii) general spatial distribution (percentage of surface area)

of coastal erosion indicators along the coastal zone. Table 2 displays the risk classification matrix for coastal erosion along the study area. The results demonstrate that two zones: Zone I (Kanyakumari–Manapad) and Zone III (Tuticorin–Vembar) are located in the high-risk class.

#### **Shoreline Retreat Rates:**

The erosion effect of sea-level rise was expounded by Bruun (1962) and a series of studies have purported to verify the theory (Healy, 1991). The main advantage of Bruun Rule is that it provides a mechanism for obtaining quantitative estimates for erosion induced by past, present and future sea-level rise. For the practical application of Bruun Rule, determination of the appropriate limit of exchange depth and its offshore extent is one of the most perplexing problems. Bruun (1962; 1988) suggested that a typical depth for the limiting depth for active transport of the eroded material offshore by wave action would be between 13 and 18 m. Further, he recommended that, it is possible to evaluate the outer limit of exchange of beach material from sedimentological investigation, indicating the decrease in sediment size towards offshore side.

#### **Results and Discussion:**

Eight types of indicators of coastal erosion process have been recognized during the course of investigation (Table 1). It is important to note that these indicators results from many integrated and complex processes, both natural and anthropogenic causes of short and long-term duration. In the present investigation, Bruun Rule has been applied for different zones of the study area by using the value of maximum depth of exchange of sediments as 20 m as obtained from the course of field studies (Anil Cherian, 2003). The Zones I and III show higher shoreline recession values of 0.01920 m year<sup>-1</sup> and 0.01875 m year<sup>-1</sup>, respectively (Table 3). This could be attributed to anthropogenic interference as evidenced from beach sand mining and urbanization in the coastal vicinity. Zone III is protected by the presence of coral islands in the Gulf of Mannar. These islands can act as a barrier for the coast and reduce the intensity of wave action prevailing along the shoreline. Moreover, these islands have undergone change in their morphology by anthropogenic thrusts such as illegal coral mining. This variation in morphology is reflected in the beaches in the form of changes in hydrodynamic conditions and coastal erosion. In addition, illicit mining and urbanization along Zone III is also a significant factor for the higher erosion rates (Anil Cherian, 2003). Above all, the higher concentration of heavy minerals also depicts the high wave energy conditions, thereby removing the lighter minerals, and ultimately causes a negative sedimentary budget along the beach.

#### **Reasons for Coastal Erosion:**

The causes of coastal erosion along the study area are attributed to natural processes enhanced by anthropogenic activities. The probable natural and anthropogenic causes identified along the study area during the course of investigation are presented in Tables 4 and 5. The coastal erosion risk assessment for each zone has been evaluated based on the above said causes and is presented in Tables 6 and 7.

#### **Zone I (Kanyakumari–Manapad):**

This medium- to high-energy intermediate beach has been playing a role of bypassing effect of sediments from west coast to east coast, since the Holocene time till today, with longshore currents driving predominantly northward (Loveson, 1994). In addition to this, the rocky promontory located near Kanyakumari plays a pivotal role and provides a “cape effect” by blocking alongshore sediment movement and diverting it offshore. Human interference along this zone has caused the destruction of frontal Holocene marine deposits and dunes. Intensive beach sand mining by private entrepreneurs is also an important reason for change in beach morphology and thereby promoting a negative sedimentary budget in this coastal vicinity. As a consequence of severe erosion, engineering works have been made in the form of stone revetments and concrete walls.

#### **Zone II (Manapad–Tuticorin):**

This zone has beach ridges and marine terraces. The various stages of these ridges indicate the sea-level fluctuations during the Holocene. Other natural processes include the “bypassing-cape” effects by which the northward longshore currents travelling from Zone I are diverted seaward in this zone due to the presence of rocky terrain. Besides, anthropogenic activities are also identified from the pilgrim centers scattered along the zone. Occasional mining of fluvial sand from Tambraparani River can also destabilize the coastal zone and render it vulnerable to severe erosion.

#### **Zone III (Tuticorin–Vembar):**

Higher enrichment of heavy minerals is noticed in this zone. However, the area has undergone severe human interventions, although urbanization of this zone is relatively recent. Important natural causes are sea-level rise and its effects, local and regional coastal dynamic processes, the presence of chain of islands in the Gulf of Mannar. The islands act as a barrier to protect the coastline from wave action, but because of the illicit mining of corals from these islands, the morphology has changed and is ultimately reflected in the coastline, which has undergone severe erosion. Littoral drift cell analysis, alongshore sediment transport studies in

conjunction with wave refraction diagram, and heavy minerals studies have very well established the negative sedimentary budget of this coastal zone (Anil Cherian, 2003; Chandrasekar et al. 2010). On the other hand, anthropogenic features like the presence of harbor, illicit mining of beach sand, conversion of lands into salt pans and agricultural lands, fishing activities have also played a vital role in the erosive nature of the coastal zone.

#### **Zone IV (Vembar–Valinokkam):**

In this zone, the anthropogenic interventions are comparatively less as compared with other zones. The role of wave action is comparatively less due to the presence of Upputhanni, Puluvinichalli, and Nallathanni islands along the Gulf of Mannar, which acts as a barrier, impeding the high-energy waves and reducing erosion along the beach.

#### **Zone V (Valinokkam–Mandapam):**

This zone is threatened by natural and anthropogenic interferences, both playing a significant role. The vicinity of this coast attests to mixed morphodynamics, typical of headland bay beach, with intermediate characteristics. Mandapam area is identified by the presence of beach ridges, swales, backwater zones and coralline terrain. Five old beach ridges show curvilinear pattern and three recent beach ridges lie parallel to the coast. Backwater zone divides these two beach ridges. The northern part of Rameswaram area is dotted with terraces, raised beaches, coral stacks and cliffs, while that of the southern side shows complete absence of any of these features. This suggests the upliftment of northern side and submergence of southern side (Loveson et al. 1997). Apparently, the important natural causes are sea-level rise and its effects, local and regional coastal dynamic processes, the trapping effect via bay by which the northward moving sediments are captured and deposited there resulting in the “cape effect”. At present, accelerated coastal erosion is in progress in different parts of this zone due to the overlap of anthropogenic and presently occurring natural causes.

#### **Conclusions:**

Coastal erosion assessment for the southern Tamilnadu coast has been carried out using natural and anthropogenic factors. The results shows that effect of anthropogenic activities have played a pivotal role for present-day negative sedimentary budget. Anthropogenic threats are the consequences of rapid urbanization, population growth, tourism activities, port and harbor development, industrialization, over-exploitation of natural resources, waste accumulation and environmental pollution. On the other hand, natural pressures include sea-level rise and its effects on near-shore sedimentation, present and past coastal circulation

dynamics, particularly associated with coastal geomorphology, global warming and climatic anomalies. The impacts noticed due to beach erosion are persistent loss of land and ecosystem, reduced supply of sediment, destruction of human properties, damages due to wave attack, loss of natural resources, increase of water turbidity and siltation, impact on biota, tourism activities and economic losses. As a maritime continental country, India will have to rely more on its coastal and marine than land-based resources. It is, therefore, vital to have a comprehensive understanding of coastal erosion structures, functions and dynamics in such a way that the conservation and management of coastal zone can be conducted in an efficient and sustainable manner.

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**Table 1:** Indicators of Coastal Erosion Identified along the Study Area

Sl.No.	Erosion Indicators
1	Very narrow or no backshore zone due to the fact that higher water of ordinary spring tide are reaching up to the uppermost portion of the beach.
2	General and progressive landward shoreline displacement results in the decrease of beach width
3	Progressive erosion of marine deposits situated along the coastline
4	Destruction and burial of mangrove and associated vegetation adjacent to the beach due to landward shoreline displacement.
5	Development of artificial structures like walls, terraces, etc
6	Reactivation of ancient uplifted wave cut terraces
7	Heavy mineral concentration on foreshore zone
8	Persistent destruction of shoreline structures, houses and other engineering works on the backshore of the beach

**Table 2:** Risk Classification obtained for different Coastal Zones of the Investigated Area (After Souza & Suguio, 1996)

Coastal Zone	Coastal Erosion Indicators								Distribution on the beach	Risk Class
	1	2	3	4	5	6	7	8		
Kanyakumari to Manapad (Zone I)	X	X	X	-	X	X	X	X	74 %	High
Manapad to Tuticorin (Zone II)	X	X	X	X	-	-	-	-	41 %	Medium
Tuticorin to Vembar (Zone III)	X	X	X	X	X	X	X	-	63 %	High
Vembar to Valinokkam (Zone IV)	-	-	X	-	X	X	X	X	52 %	Medium
Valinokkam to Mandapam (Zone V)	X	X	X	-	X	X	-	X	58 %	Medium

> 60 % - high; > 40 % - Medium (After Souza & Suguio, 1996)

**Table 3:** Shoreline Retreat along the Study Area

Morphodynamic compartment	a (m/century)	h (m)	I (m)	S (m year <sup>-1</sup> )
Zone I	0.03	20	1280	0.01920
Zone II	0.02	20	1210	0.01210
Zone III	0.03	20	1250	0.01875
Zone IV	0.03	20	1120	0.01680
Zone V	0.03	20	1110	0.01665

**Table 4: Natural Causes of Coastal Erosion, Effects and Associate Processes**

Sl.No.	Factors and causes	Effects and associated processes
1	Coastal circulation dynamics	Longshore drifting of sediments, convergence in wave refraction indicates erosion.
2	Beach morphodynamics – beach profile configuration	Dissipative beaches- more susceptible to erosion than reflective beach
3	Effects of long term sea level rise: beach erosion and deposition of sediments to nearshore and offshore	Part of the sand eroded is transported in the alongshore and crossshore direction. Rest is retained in the beach.
4	Evolution of coastal plains: negative sedimentary budget	Interference of palaeosediments with present day sediments
5	Naturally inefficient sediment supply coming from the continent through rivers, nearshore zone, etc or loss of sediment towards them	If the sediment supply is insufficient erosion will take place
6	Short term sea level rise due to storm, or climatic anomalies, etc.	This will result in the shifting of surf zone towards land and severe erosion along the beaches causing the destruction of manmade structures
7	Sand Bypassing effect- caused by headlands, beach rocks, river mouths	Drifting of sediments in different directions
8	Trapping effect - presence of wide bays, tidal inlets and river mouths	Due to the trapping of sediments in bays/ rivers mouths, adjacent beach will undergo severe erosion
9	Negative sedimentary budget by natural process	Sediment deficit indicates erosion

**Table 5: Anthropogenic Causes of Coastal Erosion, Effects and Associated Processes**

Sl.No.	Factors and causes	Effects and associated process
1	Intense urbanization of coast zone with destruction of dunes and or eolian deposits and marine terraces.	This causes erosional process due to the destruction of sand sources, also the mixing of terrestrial area with beach change the coastal dynamics.
2	Construction of sea/land interface structures, placed parallel or non parallel to the shoreline	Drainage channels, jetties, breakwaters etc, interfere the coastal currents thus modifying the approaching wave angle and change sedimentary budget
3	Trapping effect due to artificial structures	Manmade structures trap sediments and cause erosion in the adjacent areas
4	Sand exploitation - mining	Active erosion and change in sediment budget
5	Mining of fluvial sand	Change sedimentary budget and produce erosion on fluvial, estuarine systems
6	Conversion of estuaries, swamps, fluvial plains, etc in to building sites	This reduce the sediment source and cause erosion, many areas prone for flooding
7	Contemporaneous negative sedimentary budget due to anthropogenic interventions	All the above factors also induce negative sedimentary budget.

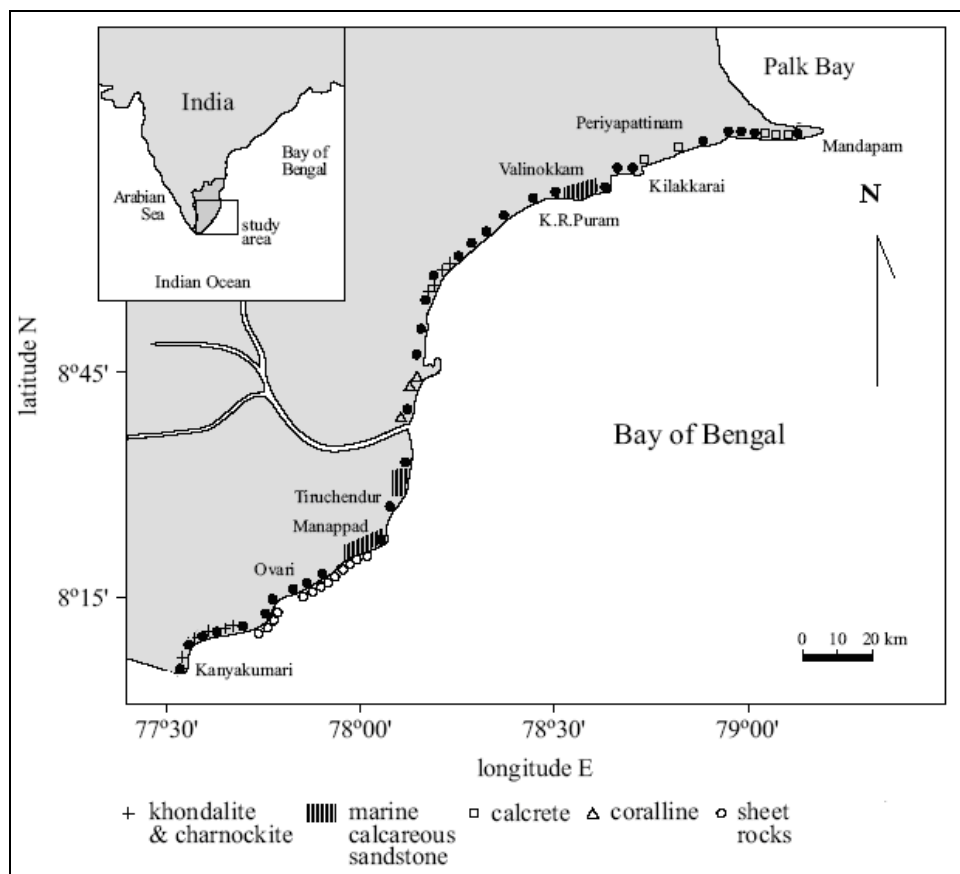
**Table 6: Comparison Matrix obtained for Natural Causes of Ongoing Coastal Erosion**

Coastal Zone	Coastal Erosion Indicators									Risk Class
	1	2	3	4	5	6	7	8	9	
Kanyakumari to Manapad (Zone I)	X	X	X	-	X	-	X	X	X	High
Manapad to Tuticorin (Zone II)	X	X	X	X	-	-	X	X	-	Medium
Tuticorin to Vembar (Zone III)	X	X	X	X	X	-	X	X	X	High
Vembar to Valinokkam (Zone IV)	-	X	X	X	X	-	-	X	-	Medium
Valinokkam to Mandapam (Zone V)	X	X	X	X	-	-	X	-	-	Medium



**Table 7:** Comparison Matrix obtained for Anthropogenic Causes of Ongoing Coastal Erosion (After Souza and Suguio, 1996)

Coastal Zone	Coastal Erosion Indicators							Risk Class
	1	2	3	4	5	6	7	
Kanyakumari to Manapad (Zone I)	X	X	X	X	X	-	X	High
Manapad to Tuticorin (Zone II)	X	X	X	-	-	X	-	Medium
Tuticorin to Vembar (Zone III)	X	X	X	X	-	X	X	High
Vembar to Valinokkam (Zone IV)	X	X	-	-	-	-	X	Medium to low
Valinokkam to Mandapam (Zone V)	X	X	X	-	-	-	-	Medium to low



**Figure 1:** Location Map of the Study Area