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Geomorphological Changes along the East Coast of Sri Lanka

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Abstract: *Eastern coast of Sri Lanka faces periodic cyclones, storm surges and floods that cause realignment and consequent coastline changes in addition to the anthropogenic activities. This study was aimed in the entire coastal area of Batticaloa district (eastern coast) to look at the coastal morphology and its changes over a period of 12 years from January 2005. About 67% of the coastal belts were subjected to accretion and about 53% subjected to erosion. The 2004 tsunami made mega impact on the east-coast and changed the shapes and structures of the coasts in different ways at various scales: about 76% of the coastal belt has been damaged, 23% less damaged and 1% fully damaged. The Batticaloa coast subjected to many human activities and its morphology has been changed due to Casuarina plantation, man-made coastal openings between estuary and sea, tourism and related activities.*

Keywords: *ecosystem dynamics, alteration, tourism, plantation, hazards*

1. INTRODUCTION

Coastal area is the interface between the land and sea of great ecological sensitivity and vulnerability [1]. Sri Lanka is an island, has an extent of coastline approximately 1,620 km including the shorelines of bays and inlets, but excluding lagoons [2]. Batticaloa district, is the eastern coast of Sri Lanka, has the length of coastline varies between 110-120 km [3][4] (Figure 1). The coast consists of a sand belt up to 6 km wide and concave in plan [5]. The coastal area of Batticaloa enriched with diverse coastal habitats including mangroves, salt marshes, beaches, barrier beaches and spits, basin estuaries, marshes and other water bodies [6][7][8][9].

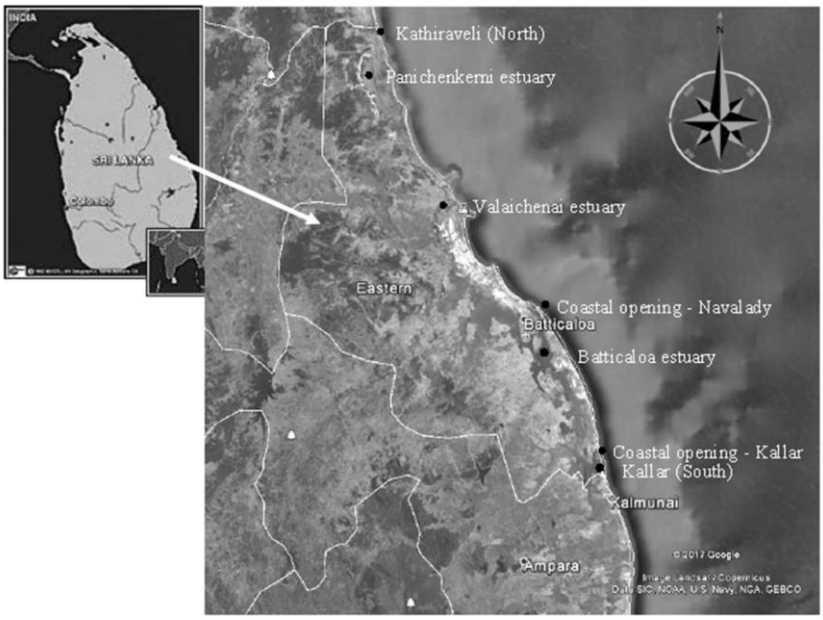

Figure1. *The study area – Batticaloa district. It includes three estuaries and bordered by Kathiraveli at North, Kallar at South, Bay of Bengal at East and two other districts at West.*

Coastal changes are ongoing process that always happened [10]; diverse and complex natural processes continually change coasts physically, chemically and biologically [11]. Human activity adds another dimension to coastal change by modifying and disturbing, both directly and indirectly, the

coastal environments and the natural processes of change [8] [12]. It was evident from the redrawn Sri Lanka map (redrawn in 2018, after 18 years) where the coastal areas were extended and reduced [13]. The primary source of coastal changes in the eastern province of Sri Lanka due to periodic cyclones, storm surges and floods that cause realignment and consequent coastline changes [14]. The coastal morphology also affected by anthropogenic activities such as illegal mining (sand and coral), plantations and encroachment. The 2004 tsunami made mega impact on the coastal areas of the eastern province, and changes the shapes and structures of coastal areas in different ways at various scales [15].

Predicting the rates of changes in between same and different features of coastal areas is extremely important - not only for the people living but also for managing the coast. Coastal areas of Batticaloa district subjected to many activities, especially after the 2004 Asian tsunami and the war ended in 2009 (35 years' ethnic conflict) such as tourism, infrastructure (road and harbour) and coastal plantation. It is vital to have a close look on the environment, for its changes, when it exposed to sudden development activities. Therefore, the aim of this study was to look at the coastal morphology and its changes over a period of time.

2. General Findings of Coastal Geomorphology

The general coastal morphology of the Batticaloa district has the followings

1. Mainly has three major land forms - Bay and Headlands, straight sandy shoreline/beaches and deltas/saline flats.
2. More than 20 numbers of *Thonas*[†] - along the entire coast of Batticaloa district, majority of them seasonally linked with the sea.
3. Three distinct vegetation types: (i) Natural: lower forms (creepers, runners, grass), shrubs and trees; (ii) *Thona* vegetation: plants adapted to freshwater and or brackish water but no salt tolerant forms; (iii) Plantation: human-managed ecosystems such as coconut, cashew, agricultural crops and *Casuarina*.
4. More than ten numbers of coastal *openings* - rivers and estuaries meet the sea, some of them are seasonally open and others permanently opened.

3. Coastal Geomorphology Changes

3.1. Accretion and Erosion

Accretion and erosion are the two natural phenomena that change coastal shoreline. About 67% of the coastal belts were subjected to accretion and 45% of them are undergone higher accretion when comparing the others belts. About 53% coastal belts subjected to erosion and 45% of them are undergone higher erosion when comparing the others belts (Table 1). This finding also supported by GreenTech [14] where 1.2 km^2 of shorelines subjected to accretion and 1.1 km^2 subjected to erosion (Table 2).

Table1. *Shoreline changes along the coastal area of Batticaloa district due to accretion and erosion. Shorelines are listed from North to South direction and considered as belt between sites for convenience. DSDs- Divisional Secretariat Divisions, KPN-Koralai Pattu North, KP-Koralai Pattu, EP-Eravur Pattu, MN-Manmunai North, MSEP-Manmunai South Eruvil Pattu., NV- Natural vegetation.*

No.	Coastal belt	DSDs	Accretion	Erosion	Coastal setup	Tsunami damage
1	Kathiraveli-Puchakerni (North of Batticaloa)	KPN	•		NV	Damaged coast
2	Mavadichenai-Pandithivumunai	KPN	•*		NV	Damaged coast
3	Noolavadi-Sallithivu	KPN		•	NV	Damaged coast
4	Sallithivumunai-Panichankerni	KPN	•	•*	NV	Damaged coast
5	Keelikudah	KPN		•*	NV	Damaged coast

[†] Complex transition water bodies between lagoons, rivers or estuaries. They are an inland areas inundated with fresh water, having seasonal link with the seawater during rainy seasons. The *Thonas* are "technically lagoons" and has different type of plant communities in the coastal area [16]

6	Pulavikudah bay-Pulavi point- Elephant point	KPN	•*	•*	NV	Damaged coast
7	Pasikudah-Kalkudah	KP		•	Thona, Natural vegetation	Damaged coast
8	HardiThottam-Paladithottam	KP	•		NV	Less damaged coast
9	Palayadithona-Kaluwankerni	EP	•		NV	Less damaged coast
10	Kaluwankerni-Punnaikudah	EP	•*	•*	NV	Less damage or negligible impacts
11	Thalavai-Bar light house, Batticaloa	EP/ MN	•*		NV	Less damaged coast; Fully damaged coast at Navalady
12	Light house-Muhathvaram	MN	•*		Infrastructure	Damaged coast
13	Palamunai	MN		•	Infrastructure	Damaged coast
14	Kurukkalmadam-Mankadu	MSEP	•		Coral reefs	Damaged coast
15	Thettathivu-Kaluthavalai	MSEP		•	Agriculture	Damaged coast
16	Loxton, Kaluwanchikudy	MSEP		•	Thona	Damaged coast
17	Ondachchimadam-Periyakallar (South of Batticaloa)	MSEP	•		Estuary	Damaged coast

**indicates comparatively higher scale of shoreline change(s).*

Table2. *Shoreline changes (1956-2007) of Batticaloa district [14]*

DS division	Accretion (km^2)	Erosion (km^2)
Koralaipattu North (KPN)	0.2	0.4
Koralaipattu (Valaichenai) (KP)	0.1	0.1
Eravurpattu (EP)	0.5	0.1
Manmunai North (MN)	0.3	0.4
Manmunai South & Eruvilpattu (MSEP)	0.1	0.1
Total	**1.2**	**1.1**

The coastal zone management plan [7] reported that the net erosion rate of shoreline of Batticaloa district was 0-0.2 m/year and to that of accretion was 0-0.1 m/year. Thus the net loss was 1000-2000 cubic meter per year.

3.2. Asian Tsunami 2004

Tsunami waves covered coastal areas of Batticaloa for a distance of 100 to more than 500 m including coastal *openings*, estuaries and coastal water bodies [15]. Majority of the sea shores and the coasts of Batticaloa district had been altered due to tsunami back wash. Tsunami deposited marine sand inland and then took beach sand into the sea and thus altered coastal morphology in many places. Among the 43 coastal villages, 89% had been exposed to the Tsunami. Coastal ecosystems of different types exposed to the tsunami in different scales: All mangrove ecosystems and agricultural crop lands, 96% of coconut plantation, 84% of natural vegetation, 83% of *Thona* and 83% of *Casuarina* plantation. About 76% of the coastal belt was damaged, 23% of the coastal belt was less damaged and 1% of the coast was fully damaged in terms of its physical features. The satellite images show major changes before and after the tsunami (Figure 2): Sallithivumunai is the typical example of erosion due to the tsunami (Figure 2: A, B); new water bodies were formed; some of the previously existed water bodies had been altered in their shape and size; but in some places water bodies were gone due to backwash of the tsunami waves.

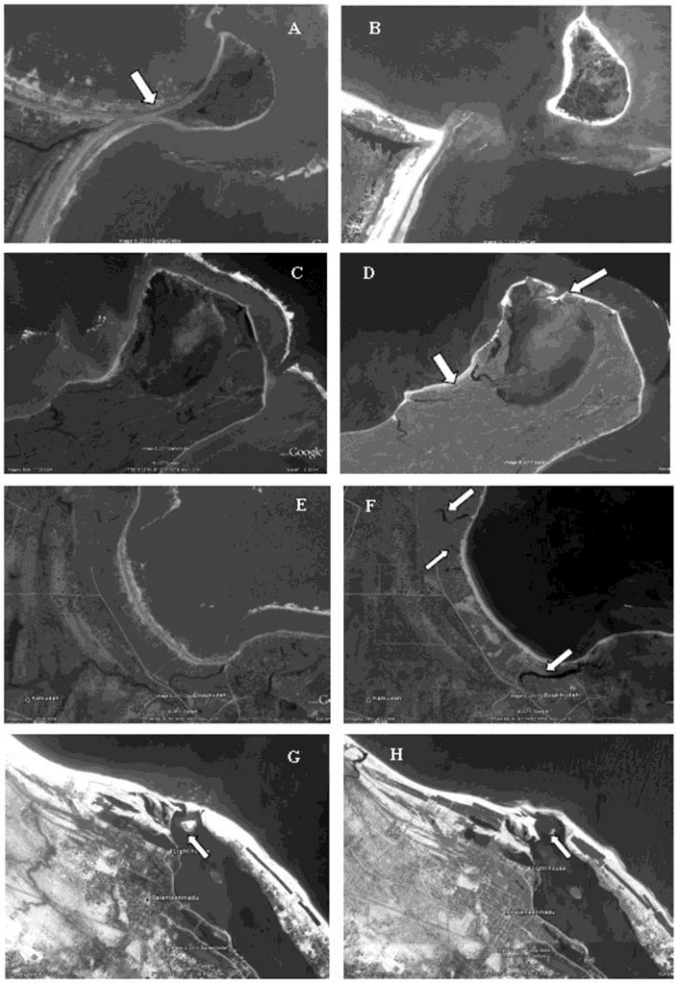

Figure2. *Shoreline changes at various coastal areas of Batticaloa district Sallithivumunai: before tsunami (A) and in 2009 (B); Elephant point: before tsunami (C) and in 2009 (D); Pasikudah: Before tsunami (E) and in 2009 (F); Batticaloa bar: before tsunami (G) and in 2009 (H).* (Source: Google Earth)

Batticaloa estuary is the second largest brackish-water system in Sri Lanka and has two natural *openings* to the sea, which located about 32 km apart at Navalady and Kallar (Figure 2). They open and close seasonally during rainy and dry seasons respectively and referred as "multi annual *openings*" [17]. Study revealed that the bar mouth at Navalady did not close and the other at Kallar did not open aftermath of the tsunami. Due to the closure of the opening at Kallar, mixing of sea water into the estuary has been blocked. This leads low salinity in the estuary thus reduces shrimp production and on the other hand, it facilitates crop cultivation on the western part of the estuary (almost zero salinity), where the estuary water is used. Pre-tsunami conditions did not seriously affect the dynamics of coastal openings between the sea and the estuary.

3.3. Casuarina Plantations

Casuarina plantation was established in the Batticaloa district prior to the tsunami, starting from year 2000 in the southern coast of Batticaloa district aiming to stabilize the coast against erosion and wind action. Coastal *Casuarina* plantation became popular after the 2004-tsunami. Pre-tsunami plantation accounts about 100 ha and post-tsunami plantation accounts about 275 ha. About 40-50 km coastal belt of *Casuarina* was planted in 65 km of the coast line, (i.e. 35-45% of coastal belt of Batticaloa district). The *Casuarina* plantation starts at 50-75 m from Mean High Tide (MHT), with the width of the belt varies between 75 and 100 m and the gaps between the belts was 50-100 m. The belt is contiguous in some places and discrete in others.

Casuarina plantation was significantly changed the vegetation structure of the coastal ecosystems and it does not permit other ground plant forms [18]. The *Casuarina* plantation seems to be planted in a non-scientific manner: less spaces/gaps between the belts; no fire-belts (*Casuarina* is less fire-resistant) and planted as monoculture species. In most of the places, the belt blocks the visibility or scenic beauty of the sea.

Species selection is a crucial and important task during restoring or establishing an ecosystem. A primary approach to restoration or rehabilitation could be allowed through natural regeneration, especially for destroyed or degraded ecosystems. If necessary, supportive actions could be accommodated such as restoring hydrological regime, minimizing disturbances, planting already existed species in a scientific manner [19] [20].

3.4. Man-Made Coastal Opening

The Eastern parts of Sri Lanka receive most of the rainfall during October to January due to North-East monsoon. This is also the cyclonic period, which brings heavy rainfall in a short period of time. The low lying nature of the coastal area of Batticaloa district renders it very susceptible to flooding, especially during the rainy season. Heavy rain flooded Batticaloa district in January and February 2011. Actions had been taken to immediately release the flood into the sea. Therefore, two new coastal *openings* were made at Navalady and Kallar, between the estuary and the sea, in addition to the two natural *openings* already existed in the same places (Figure 1).

Due to the artificial *opening* the coastal morphology was changed drastically at Navalady (Figure 3);

- The *opening* increased itself, due to erosion of the flood water flow into the sea: The opening was increased by 500-600 m (about 70 times greater than the initial *opening*), a depth of 1.5-2 m soil had been eroded at the site of *opening*.
- Severe erosion leads to a loss of 300 m stretch of planted *Casuarina* belt and a 600 m road.
- More than 0.5 acre of the private land had been eroded into the estuary.

Figure3. *Impacts of sea erosion due to man-made coastal opening at Navalady, Batticaloa. Extent of the opening increased by 70 times –estuary on left and the sea on right (A), about 2m depth of soil washed-off (B), private lands gone to estuary (C), opening led to formation of sea-bed (D), 600 m road washed off (E), planted Casuarina eroded (F). Photos: Mathiventhan, T (2011)*

Coastal landforms, affected by short-term perturbations generally return to their pre-disturbance morphology [21], but when a system (ecosystem) is not allowed for natural return, after disturbance, and altered against the natural dynamic process will collapse other interdependent systems and cause negative impacts. Under-water table of the Batticaloa estuary and the surroundings were altered by the man-made *opening* at Navalady: well water reduced in many places around the estuary with the

decline of the water level of the estuary. But, the *opening* caused impacts in opposite way at Kallar: it increased erosion of the estuary, leads the sea water intrusion into the estuary and thus water level had been increased, which leads flooding the areas bordering the estuary.

3.5. Tourism and Infrastructure

Pasikudah is one of the popular tourist spots in the Batticaloa district and declared as a tourist place in 1970 by the Sri Lanka Tourist Development Authority (SLTDA). The impact of the Tsunami on graded accommodation was dramatic, reducing the capacity from 263 units in 2004 to 178 in 2005 [22]. Tourism activities had been popularized and accelerated only after 2009, after 35 years of civil war. Coastal areas of 99 acres of Pasikudah had been acquired for tourism development (with 14 Star class hotels), which changes the coastal settings in the following ways: almost the entire beach front of the Bay has undertaken to manage by the hotels; coastal vegetation, geomorphology and natural settings have been altered; certain hotel owners of the Pasikudah trying to clear living corals, in front of their hotels, for swimming purpose; Increased tourism development attracts many local people to construct private hotels and restaurants, which led the remaining coastal areas into further alterations (natural waterbodies were encroached, filled and blocked; coastal forests, mangroves and shrubs were removed).

It is vital to conserve living corals in its natural settings without disturbances. GreenTech [23] reported that they found in a distance of 500 m from the coast of Pasikudah and considered as one of the best sites in the Eastern Province. These areas have newly recruited branching *Acropora* sp. and some other areas have good coral cover and significant re-growth. Diving, boat services, walking on corals and uncontrolled visitor pressure will further aggravate the loss/damage of existing living corals, marine/shoreline flora and fauna such as algae, sea grass, sea cucumber, *etc*. It is essential to protect them by incorporating existing policies and protection mechanisms from relevant authorities.

4. CONCLUSION

Coastal morphology of the Batticaloa district, Sri Lanka had been considerably changed due to tsunami, natural events and human-accelerated economic activities. Most of the activities failed to consider natural-dynamic process of the ecosystems before implementation. At the same time, no detail scientific studies have been reported on coastal changes, due to global warming and sea-level rise.

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