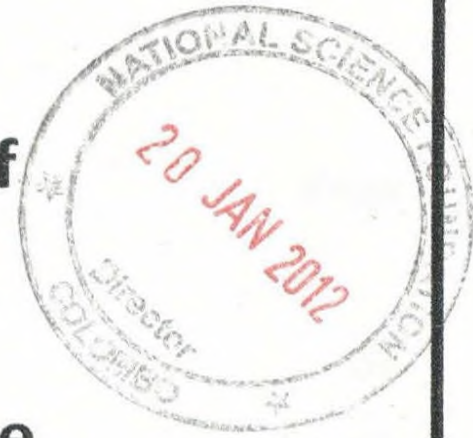


**Environmental Impacts of
Tsunami Disaster in the
Southwestern coastal zone
Of Sri Lanka**



**National Science Foundation
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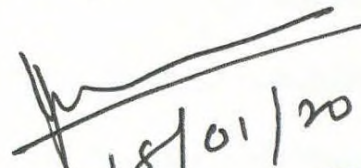
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Information of the project

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Recommendation of Head of the Department

Recommended


18/01/2012

Head.
Department of Geography,
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Environmental Impacts of tsunami Disaster in the south-western coastal zone of Sri Lanka

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Summary of the project

The South western coastal zone of Sri Lanka is stretching from weligama to Bentara, consisting important landforms and ecosystems such as, beaches, sandbars, bays, headlands, lagoons, estuaries, corals and mangroves. They contribute to preserve the existing coastal environment and also they influence to establish specific economic activities such as Fisheries industry, tourism and coir industry. But most of these resources and coastal features were completely or partially damaged or changed giving rise to additional environmental problems by the tsunami disaster on 26th December 2004.

This study was under taken to examine how the tsunami waves have impacted on coastal landforms and ecosystems and also to suggest interventions needed for conservation and rehabilitation of the affected resources. Therefore, this study can be useful to minimize the destructive influences of tsunamis in future.

The magnitude of affected landforms and ecosystems were identified through the interpretation of aerial photographs and analysis of satellite images before and after tsunami. Using Geographical Information system (GIS), the tentative geomorphological maps were constructed to demarcate the damages and changes of coastal features.

This was verified through the field work. In addition, questionnaire survey was useful to identify the many more environmental problems.

Results showed that 75% of landforms and 90% of ecosystems were seriously damaged by the tsunami waves. This has damaged 68% of mangroves, 70% of sand barriers and sand spits, 83% of lagoons and river outfalls, 42% of beach rocks, 73% of corals, 25% of bays and 80% of revetments. In addition, several water bodies and wells were polluted and sedimented with debris and garbage. Almost 300 inland coral mining pits were converted to ponds and resulted in creating man made wetlands. 25% of estuaries were blocked by depositions and 12% of outfalls were narrowed. 7.5 Meters of river banks in width were also eroded broadened and damaged.

The result of this study, and recommendations could be useful for future policy planning and implementation.

1.0 Introduction

The coastal belt of Sri Lanka was severely affected by the tsunami disaster on 26th of December 2004. It has caused thousands of deaths in addition to destruction of million rupees worth properties and the most significant damages were on the natural environment.

The Disaster management center and district secretaries of Sri Lanka initially recorded that over 40000 lives were lost. 5565 people were missing and 84612 displaced in additions 15196 got injured by the tsunami waves. Most of properties such as, homes, buildings, infrastructures facilities, industries were also damaged. Ninety thousand houses were completely washed away and 150000 lost their lives. Estimated value of the total damages was nearly one billion US \$ Dollars. (see table 01) The part of southern coastal area; from weligama to Bentara also was heavily damaged comparing to other coastal areas. 2742 people were lost their lives and 40000 families were affected. 25000 families were displaced (Censns department,2005 and Disaster management center,2005)

In addition to changes of socio- economic conditions, physical environment is the most damaged sector due to the tsunami. The coastal landforms and ecosystems of the southwestern coast were impacted in Macro and micro scales.

The southwestern coastal zone of Sri Lanka consists of important landforms and ecosystems, such as beaches, sand dunes, bays, headlands, lagoons, estuaries, corals and mangroves. (See table 02) These coastal features have a decisive role in sustaining the living natural resources on which so many people in this region depend on. They also caused to establish socio –economic activities such as, fisheries industry, tourism and urban activities etc. But, most of them were severely affected by the tsunami on 26 December 2004. According to the records of coast conservation Department in 1997, three thousand seven hundred seventy six coastal habitats can be observed in

Matara and Galle districts. Most of these resources were completely or partially damaged by the tsunami waves travelled up to 1 Km inland at certain places. It destroyed vegetation, changed land forms, created vast amounts of debris released pollutants and contaminated soils and fresh water supplies. (De Silva, 2005) Also, It has created many more environment problems, such as, coastal pollution, coastal erosion, degradation of landforms and coastal habitats. With the occurrence of the tsunami, these environmental problems in the southern coastal zone have tremendously increased. (see chapter 07)

2.0 Objectives of the study

The objective of this study was to examine how the tsunami waves have impacted on coastal landscape and ecosystems.

In addition to above major objective, this study concerned on the following aspects,

- (a) Identification of geomorphological features within the study area.
- (b) Analysis of coastal changes on landforms and ecosystems in the southwest coastal zone.
- (c) Analysis of environmental problems and issues caused by the tsunami disaster.
- (d) Determination of physical and human factors affected to spatial change of tsunami waves.
- (e) Recognition of mitigation options and remedies to overcome those problems.

Table 01-Tsunami damages in Sri Lanka – 2004

Province	District	Affected families	Displaced families	Deaths	Injured	Missing	Damaged Houses	
							Completely	Partially
Northern	Jaffna	14767	10827	2640	1647	540	6084	1114
	Killinochchi	2297	407	560	670	0	246	-
	Mullattiva	6745	6007	3000	2590	421	5033	424
Eastern	Trincomale	30547	30545	1078	1328	45	4830	3835
	Batticaoa	63717	12494	2975	2375	346	13530	5839
	Ampara	58729	38866	10436	6581	161	18889	8641
Sothern	Hambantota	14069	3334	4500	434	1341	2303	1744
	Matara	19398	2235	1342	6652	608	2362	5659
	Galle	24583	23278	4248	313	564	7032	7680
Western	Kalutara	9433	7059	279	401	69	2683	3835
	Colombo	9647	8140	79	64	12	3388	2210
	Gampaha	6827	308	6	3	5	278	414
North western	Puttam	232	18	4	1	3	23	72
Total		260991	143518	31147	23059	4115	66681	41467

Source: District secretaries of the affected Districts-2005

3.0 Importance of the study

The south-west coastal zone of Sri Lanka is a very important area both in socio-economically and environmentally. Its natural landscape is the result of varieties of landforms and ecosystems. The south-west coast of Sri Lanka is an attractive landscape because of its varieties of land forms and ecosystems. Not only the esthetic value of the area, but also they were influenced to establish specific socio economic activities. With the influence of these geographical features many economic activities such as fisheries, tourist and coir processing are located in this area.

Table 02-Distribution of coastal habitats in the southwest coastal area (Hectare)

District	Mangrove	Marshland	Sand ridges	Beach barrier spits	Lagoons and estuary	Other water bodies
Matara	06	80	-	191	-	234
Galle	187	561	-	485	1144	783
Kalutara	70	91	04	77	87	476

Source: Coast conservation Department,1997

Landforms and ecosystems caused to control the natural disasters in to some extent, i.e. floods, storm waves. However after the 2004 tsunami disaster, coastal landforms and ecosystems in the area were seriously damaged leading to imbalance of the coastal systems. Even though, many studies have been paid many attention on examining the human and socio-economic impacts of tsunami, they are not yet satisfactorily addressed the problems concerning the entire environment of the coastal area. A few studies carried out so far have not been paid attention on these sectors in environmental aspects. As such, this has been analyzed the impact of tsunami an geomorphological features such as landforms and ecosystems in addition to environmental problems.

Also geographers and geologists pointed out that Sri Lanka has a high risk for tsunami after the 2004 one. This study can be useful to minimize the destructive influences of tsunamis in future. Awareness programs and pre preparedness for the general public and planners are important to reduce disaster damages.

When the tsunami occurred in 2004, there was not any knowledge of tsunami disasters and preparedness of such thing. That was the main reason to increase the highest damages. If the people had a well preparedness, the damages caused to the people and their properties could be minimized of seventy five percent. Therefore, this study can be useful for pre preparedness and planning in the future.

4.0 The study area

The area of this study was conducted in the south-west coast of Sri Lanka stretching from weligama to Bentara. This area represent seven divisional secretariat in Matara and Galle districts. Weligma is one of the selected D.N division in Matara and Habaraduwa, Galle, Hikkaduwa, Ambalangoda, Balapitiya and Bentota represent in Galle district. Among the four hundred eleven Grama Niladari divisions in above mentioned divisional secretariats, one hundred fifty four G.N.divisions were affected by tsunami. The worst damaged occurred in weligama, Habaraduwa, Galle, Hikkaduwa and Balapitiya.

This area is a densely populated with concentration of many socio- economic activities. As a result of heavily impacted of tsunami on this area, over 6000 people lost their lives and 1172 people have been displaced. Nine thousand three hundred ninety four houses completely damaged and also most of the socio-economic activities were verstyly damaged. (Ministry of women's Empowerment and social welfare, 2005) In addition there were drastic destructions on coastal landforms and ecosystems of southwest coast of Sri Lanka. Hence, South-west coastal zone is selected as the study area covering these specific aspects.

The study area stretching from polwatta river outfall at weligama to Bentara Ganga outfall, which is demarcated by mean sea level in the west and tsunami affected boundary line (TABL) in the east. It is a narrow coastal belt and located between 5° , $55^1-6^{\circ}, 25^1$ in north latitudes and $80^{\circ}, 00^1- 80^{\circ}, 30^1$ in east longitudes covering approximately 100Km from south to north. (see fig 01)

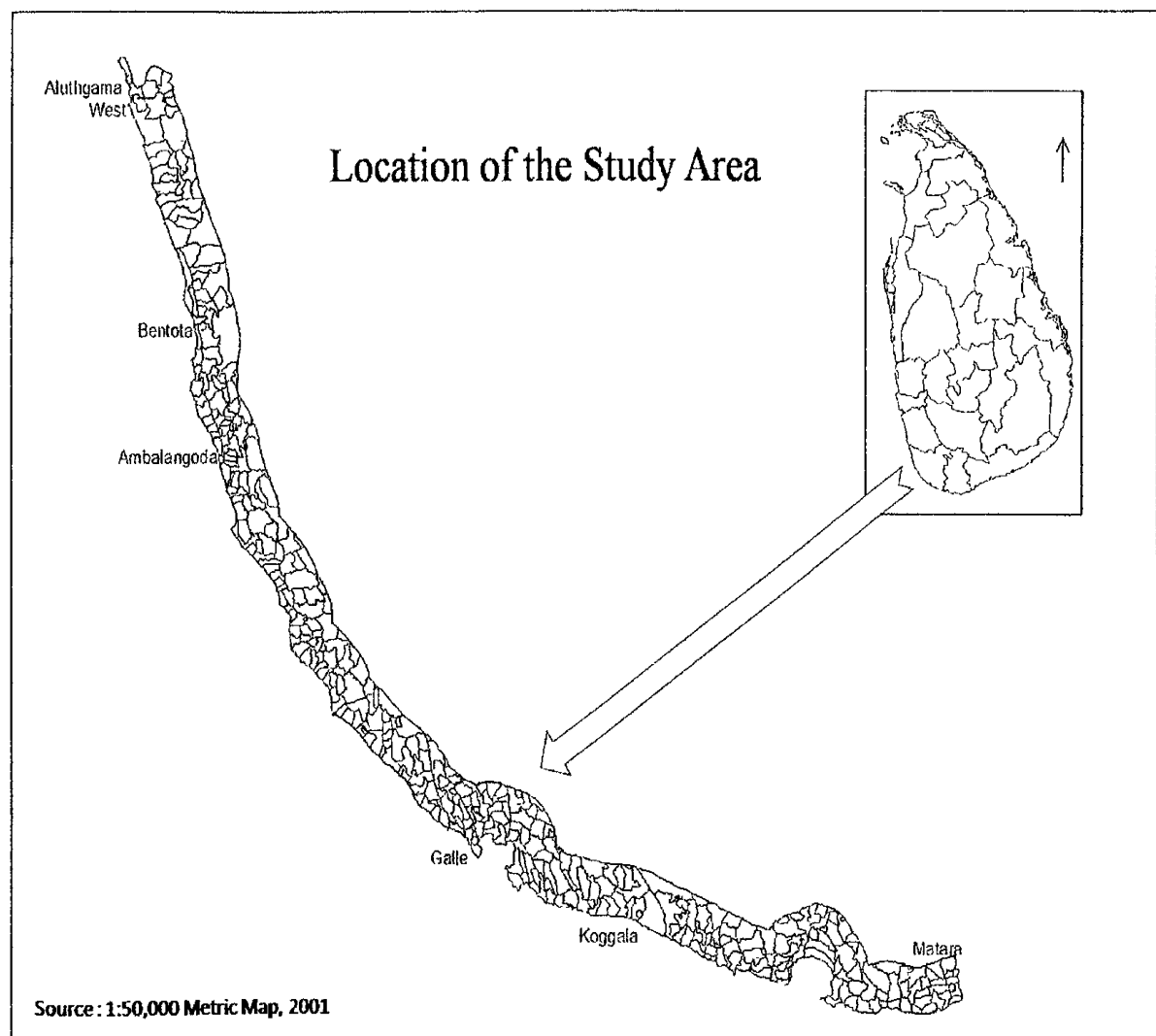


fig 01-The Study Area

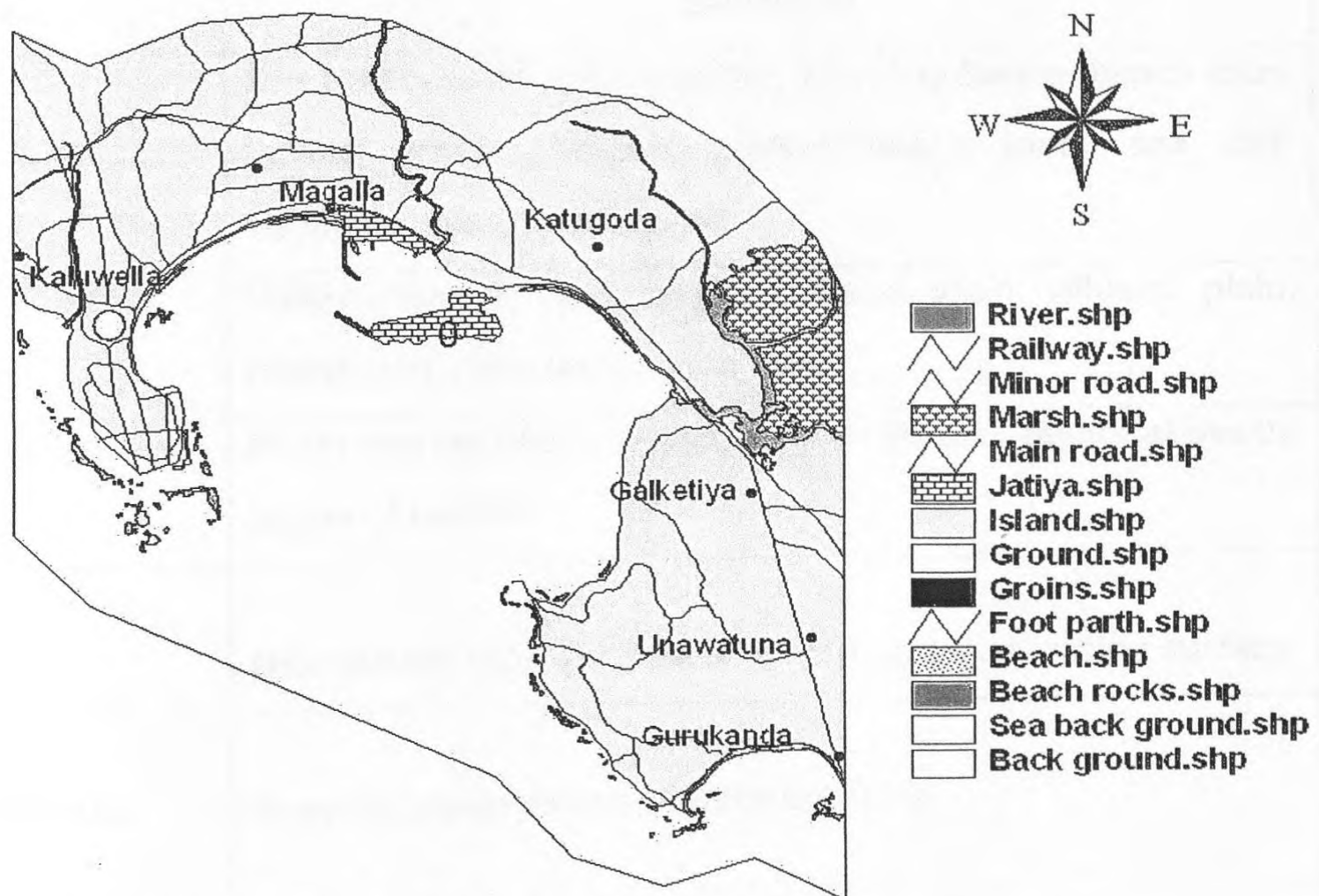
5.0 Methodology

Required data for this study have been collected from available primary and secondary sources. For the identification of socio- economic damages in the study area, secondary data was collected from district secretariat office, Disaster Management Center and senses department in Sri Lanka.

To make above mentioned study successful several methods were used to collect the primary data. Tsunami mapping, Questioner survey, target group discussion and field observation were used to relevant data collection.

The magnitude of affected geomorphological features and eco systems were identified through the analysis of satellite images before 2004 and after tsunami in 2005. Arcview GIS software was used to hazardous mapping and damage analysis in the area. Pre and after tsunami maps overlay technique of the Arc view software can be used to determine the changes and damages of geomorphological features. Using these data, a tentative geomorphological map was constructed to demarcate the damages to the coastal resources and this was verified through the field works.

Affected Coastal Features in Galle Area



Source: Prepared by Satellite Image-Ikonos,2005

Fig 02-Tsunami affected coastal features in Galle.

Environmental Problems, such as coastal erosion, water pollution, sedimentation, and parameters of tsunami waves were collected using questionnaire survey and target group discussion.

6.0 Environmental impacts on coastal landforms.

The south-west coastal area of Sri Lanka consists of coastal landforms originated by various kinds of processes. They are beaches and allied features, bays and headlands, beach rocks, alluvial plains, Fluvio-marine plains, denudational hills and planation surfaces. These are originated with the influence of marine, fluvial, Fluvio-marine and denudational processes. (see table 03)

Table 03 – Distribution of coastal land forms

Process	Landform
Marine	Sea beach, sand spit, sand bar, bay, bay barrier beach caps, berms, former barrier, pocket beach islets, sea cliff, headland, beach rock, coral
Fluvial	Valley, former river channel flood plain, alluvial plain, marshland, river terrace, estuaries
Flurio-marine	Flurio-marine plain, lagoon, former lagoon, lagoonal beach, lagoonal outfall
Denudation	Denudation hill-high /low, rock out crops, planation surface
Main made/ Human activities	Groynes, revertments, mationery walls

Sea is the major agent in landform formation in the study area. It consists of number of marine agents such as waves, currents and tides. In addition, short term and long term sea level changes have affected to form landforms. Sea beaches, bays, islets, terraces sea cliff, headlands can be observed within the area originated by marine process. They are distributed parallel to the coastline from south to north.

The fluvial process is the dominant process in creating land forms next to marine process (weerakkody, 1997). Rivers are the main source of formation of landforms and bringing sediment material to the coast .The amount of material brought through the polwatta ganga, gin gnaga ,Madampe ganga, Randobe ganga and Bentara ganga deposited to form to landforms. As a result of these depositions alluvial plains, river terrace and lagoons, flood plains are originated.

Some landforms have been originated as a result of admixing marine and fluvial processes. They categorized as flurio-marine process (swan,1983) Flurio- marine and lagoons are the major flurio-marine land forms in the area.

Generally rocks are weathered by chemical, physical and organic action under the influence of climate, relief and morphology. Weathered material transported by water, wind and waves and ultimately deposited in lowlands. They have been caused to erosion and denudate of the surface topographic features (Bird,1976). The denudational landforms consist of denudational hills. planation surfaces and rock out crops. Denudational hills extend for about 80% of the area. planation surface and rock outcrops are 20%.

Human activities have affected on the changes of landforms in the coastal area similar to natural processes. The changes made by engineering constructions are prominent among human activities. Revetments and Groynes are some examples of manmade landforms. Especially eroded coastal areas from Akurala to Bentara are the best examples in the area. They are useful to preserve the coastal environment.

Although these landforms contribute to preserve existing coastal environment, specific landforms were badly damaged completely or partially. Some of them were changed by the tsunami waves. Seventy five percent of total landforms were heavily damaged. Marine landforms of them were highly damaged by the tsunami waves.

Bays, lagoons, estuaries, beaches, sand spits, beach rocks, sandbar and coastal structures are the specific coastal landform which was heavily damaged by tsunami. The main reasons for that are the area is plain with micro relief than 10 meters and a straight coast with lower plan curvatures. This has damaged 70% of sand barriers, sand spits and beaches 42% of beachrocks, 25% of bays and 80% of revetments.

The damage of beach in the coastline was different from place to place and the highest damage was recorded from Akurala to Hikkaduwa area. It is about 1.3Km in length and 10m in width towards the land (see table 04)

Table 04 – Distribution of high damaged beach in the area.

Area	Damage in meter	
	length	width
Ambalangoda	90	10
Madampe	225	10
Seenigama	300	09
Malavenna	200	7.5
Telwatta	100	06
Akurala South	500	10

source: Field surveying and satellite image processing (2005)

The beaches in the area where coral reefs have been mined for coral lime, were worst destructed. Also, beach composition has been changed in the specific areas on Unawatuna, Hikkaduwa and weligama. These areas mostly contaminated due to sewage from land broken materials. Littering was from moderate to high all area, with a combination of both manmade artifacts such as, pieces of boats, furniture, machinery, building materials and plant material. Damage to sandy beaches due to tsunami with sand migration has been high in kapparatota, weligama and Akurala etc.

In the study area, beachrocles are broadly extended in the areas of Ahangama, Unawatuna, Thalpe, Hikkaduwa, Seenigama, Malavanna, Telwatta and Akurala. According to field surveying and satellite image analysis, 6% of beach rocks were completely, damaged in these areas and 27% were semi damaged. About 28% of beach rocks covered with fluvio-marine sediment and debris and 8% of them were not damaged at all.

Eighty eight percentage of groynes and 73% of revertments which were constructed to protect the coast line were also damaged. Five thousand meters of groynes and fifteen thousand meters in length of revertments had been overlaid. But most of them were bodily damaged. That is about 4000 meters and 10000 meters consuctively. Groynes were the highest damaged in Hikkaduwa, Ambalangoda and Akurala.

In addition, the tsunami waves have caused to change coastal features by shrinking and spreading estuaries, eroding the coast and blocking the estuaries. Such changes can be observed in the estuaries of polwatta ganga, koggala oya, Ratgama Lake, Hikkaduwa ganaga, Madampe and Bentara ganga. 25% of them were blocked by deposition of sediments and 12% of outfalls were narrowed. 80% of these estuaries severely eroded by the waves and 12% were also narrowed. (see fig 02) for a example, Hikkaduwa ganga Was not functioning in general manner and its flow was obstructed by the deposition of sediments of debris. Ratgama and Midigama river banks were also eroded and damage is about 7.5 meters in width.

7.0 Damages of eco systems and environmental problems

The coastal environment consists of different kinds of eco systems such as, lagoons, estuaries, corals, mangroves and sea grass beds. Although they are important of survival of coastal area, most of these habitats (see table 02) were also subjected to considerable damage from the tsunami.

Table 05 –Damage of coastal structures in the study area.

Area/Place	Before tsunami				After tsunami			
	Groyne		Revertment		Groyne		Revertment	
	Length m	Width m	Length m	Width m	Length m	Width m	Length m	Width m
Mididgama	100	5	-	6	-	6	-	6
Kathaluwa	100	6	-	6	-	6	-	5
Ahangama	200	6	-	6	-	6	-	6
Unawatuna	100	6	-	6	-	5	-	6
Galle	300	5	-	5	-	5	-	4
Ratgama	200	4	-	4	-	4	-	5
Boossa	150	5	-	6	-	6	-	5
Hikkaduwa	1500	6	2500	3	1055	4	1650	6
Malawanna	-	6	550	5	200	5	330	4
Kahawa	50	6	500	6	25	5	400	5
Seenigama	-	6	1100	6	100	6	700	6
Akurala	1500	5	800	5	1300	6	460	4
Paraliya	1000	6	1500	4	955	6	1200	4
Telwatta	100	6	1400	4	100	5	600	5
Madampe	90	6	250	6	60	4	125	6
Ambalangoda	-	5	400	5	-	5	250	6

Source : Satellite image analysis (2004 and 2005)

Coral reefs are important, since they reduced force of tsunami waves collapse with the sea bed topography. Damaged coral reefs are observed of the southwest coast at Mirissa, Weligama, Unawatuna, Rumassala and Hikkaduwa coasts. Also a rapid survey carried out by IUCN on coral reefs at five sites in the south and southwest coast of Sri Lanka has shown that they have been totally destroyed. Most of coral reefs were damaged by rubble movement or pieces of debris movement scoring the reefs and

sediment deposits from the land. Seventy five percentages of total coral reefs were damaged in the area.

Impact was much less than anticipated and damage had been restricted to the depth up to four meters in most places. The extent of impacts varied from reef to reef depending their topographical location. The main impact is due to vigorous water movement through fragile coral thickets such as, *Acropora*, *Pocillopora* and *Montipora*. They were damaged by material such as Gill nets, polythene and cloths on the live corals. In addition to that, large quantities of bulky materials such as, cement blocks, fiberglass objects, tree trunks, roofing materials caused to destruction of the reefs. (Kumaranathunga, 2005)

Mangrove is the most important affected ecosystem of the area. They form an important plant community at intertidal areas of rivers, streams and lagoons where they are known to play the following essential role. They provide a major habitat for fish and shrimps to complete their life cycles and thus form an important component in lagoon fishing. Mangrove forest also plays a key role in reducing the destructive force of waves, especially in estuarine areas where the water is funneled through the river mouth and manmade canals. They minimize bank erosion and act as a protective barrier against erosive winds and they provide firewood to the community. Mangrove swamps also function as sponge to reduce damage of agricultural areas when intrude by sea waters. (Silva.M.P.2005)

The pandanas (*watakeiya*) growing freely on beach frontages defense the coast while sand dunes serve as major protective barrier against strong waves. Accordingly, the level of protection of lives and property by the mangrove forests against tsunami varied from place to place. Some places which were highly distributed coastal vegetation were less damaged as a buffer against tsunami waves. Therefore, this research revealed that the importance of the seashore vegetation as a buffer against

tsunami as well as wind generated wave and storm surges. But, the investigation indicated 70% of mangrove was severely damaged. Extensive damage to mangroves is reported at river mouths and estuaries in the special areas of polwatumodara, Ginganga, Koggala oya, Ratgama lagoon, Madu ganga, Randobe, Kosgoda lagoon and kaluwamodara ganga. (see fig 03) At these sites, the tsunami waves have encroached in to long distance of over one kilometer.

Lagoons and estuaries can be identified as specific ecosystems of the study area. Mangrove plants and species of living being with an environmental adaptation have been living within these ecosystems. They are aquatic reptiles, amphibians and Athropodians. Although these ecosystems are the food productive centers for the living beings. They have become undamaged by the influence of tsunami waves. Polwatumodara, kapparatota, koggala, Ratgama, Kosgoda and kaluwamodara were subjected to considerable damage by sea water encroachment and debris deposition.

Fishing industry was struck in these areas and large portions of valuable coastal vegetation were destroyed and lagoon hydrology was altered. Also, most of lagoon mouths have undergone changes. At many sites the spread of Lagoons and river mouths were observed. These areas have been become seriously damaged because of the tsunami waves have encroached in to long distance through the estuaries. The sand barriers which were accumulated of lagoon mouths were completely washed out and the tsunami waves have encroached over one kilometer in to the land areas. The investigation indicated 80% of the lagoons and estuaries were severely damaged.

Sea grasslands grow healthily in shallow water areas in the sea close to estuaries. These places which are full of Algae, plant plankton have supplied enough food for aquatic living beings. Patches of important grasslands have been damaged with debris and about 75% of them washed out by tsunami waves.

Considerable damages and changes to marshlands were also observed. They have filled with debris and sea water intrusions. Some of them are spreaded by sea water intrusion. They can be seen especially in the Adurala coastal area. About 300 inland coral mining spits were temporally converted in to ponds and resulted in creating or developing man made wetlands, especially in Akurala. However, some of the damages that took place during the disaster have being recovered during later period and the rest still remains as not reported.

In addition to above mentioned impacts, the tsunami has created many more environmental problems such as, coastal erosion, coastal pollution, land degradation and sedimentation of the low land areas.

Coastal erosion is a serious problem caused by tsunami and most of the coastal areas were seriously eroded because of the high power of the tsunami waves. As sand was washed away towards the deep sea and some sand come on to the land caused this serious erosion. Because of the power of the wave soft rocks have been washed away and only hard rocks were left alone. As the results of this, plantations and vegetations have been also destroyed. Straight and concave coastal areas were mostly eroded and the places covered with mangrove plants, pandanas growing were less damaged and the places without buffer plantation were fully destroyed.

In the southwestern area, the sea erosion is about 80% by means of normal sea waves. At tsunami it was increased up to 90% in the specific coastal areas on koggala, Akurala, Midigama, Polhena, Unawatuna etc.

Coastal pollution had also been a serious problem. As debris brought by tsunami waves and debris from the land deposited in the coastal area and they have affected to water and land pollution.

Water pollution occurred because of the sea water brought by the tsunami and washing away of the toilet pits to the sea water well water was polluted because they have become full of debris. According to the study done by Ruhunu University on purity of well water, It was identified 80% of well water has been polluted. This was determine considering of PH value, temperature and the composition of well water. As 80% of the wells were situated on highland they were protected. (S. Gurusinghe, 2005) According to another study on the quality of well water in Kumbalgama and pategama areas situated in Matara, It was found the rate of iron and the turbidity of water in all wells exceeds the standard quality of water of the world health organization. Salinity of the water of the rivers and other water bodies mixing with salt water and collecting of garbage have been increased. Ratgama lagoon, Madu ganga, Kosgoda areas are the example of places affected badly.



Fig 03-Coastal erosion by 2004 tsunami in koggala beach.

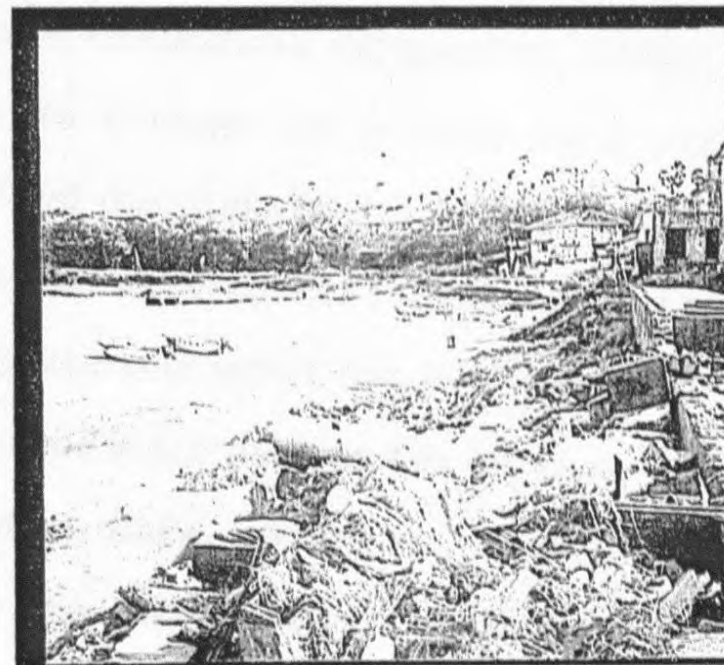


Fig 04-Coastal pollution by 2004 tsunami In Unawatuna area

Another serious problem found in water ways is sedimentation of lowlands and wetlands. These areas are filled with silt, sediments and eroded materials etc. Because of this rivers and lagoons were blocked. Blockage of drainage paths by sand deposits and debris caused water logging in places could be identified.

8.0 Controlling factors of tsunami damage (changes of tsunami damages)

The study area has become heavily damaged by the 2004 tsunami. Although the speed of tsunami waves is similar at every coastal area the damages were not same. The damage was spatially different from point to point within the area. In some places, the damage was serious and in other places it is not so much. The damage of some areas was moderate. The reasons behind such differences can be attributed to physical factors such as the location of the coast, the shape, the relief, the indentedness, vegetation cover and human factors such as coral mining, mangrove destruction, sand mining, and coastal constructions. Also, they have affected in controlling characteristics of tsunami waves such as, velocity, height, distance and direction of waves (Weerakkody,1993).

The general elevation of the area is less than 30 meters. The places about 30 meters are hilly areas with sea cliffs and headlands. Mirissa, Unawatuna, Kapparatota, Thalpe, Ahangama are the example for such places and the damage was in these areas was lower than the other areas. But, elevation of 90% of the study area is a flat plain less than 10 meter. That was the main reason the tsunami waves went towards the land at a great speed along these plains. At these places tsunami water has run about 1km into the land especially in river and lagoon mouth and more damageable areas can be identified within these areas. Weligama, Ahangama, Galle, Hikkaduwa, Akurala and Thelwatta are the best examples for that. But the damage was low in the high elevation areas with sea cliffs, and headlands situated in Mirissa, Unawatuna, Rumassala and kaikawala. An Islands situated in front of the coast also very less comparatively.

A part from the elevation, there are three geological parameters affected to change the tsunami impacts. They are indebtedness of the coast, plan curvature and coastal orientation.

According to curvature, it can be identified the concave and convex features. The places towards the sea as convex and the places towards the sea as convex and the places situated as bays can be identified as concave coast relatively concave places were more damaged than convex places. Weligama bay is the best example for that. The cause for this is the low relief with less curvature and straight coast were seriously destroyed. The reason for this was, there were no obstructions against the waves.

The indebtedness coast basically formed stretching by pocket beaches and headlands. Such coasts are micro morphological features. Those are headlands, lagoons, river outfalls, beach rocks and sea cliffs etc. According to these natural features, the forces of the tsunami waves have been differentiated. The cause for these differentiate was the wave's refraction against these headlands and cliffy areas.

The orientation of the coastline is significant in terms of its relation to direction of wave approach. This is determined by measuring the direction in which a perpendicular sea wards to a straight line that links adjacent headlands or coastline protuberances is aligned when we consider the orientation of the coastline, the tsunami waves have been refracted according to the coastal location. The area faced direct to the sea has got enormous damages. The amount of damages has been changed from place to place depending on distribution of coastal vegetation, human activities and constructions. For an example, constructed coastal structures from Ambalangoda to Madampe parallel to the main road have been affected to decrease the tsunami damage. Also, in the some areas of mangrove plants growth reduced the damage.

The southwestern coastal zone of Sri Lanka consists of very important landforms and ecosystems such as, beaches, and barriers, bays and headlands, lagoons, estuaries, coaras, mangroves and sea grass beds. These features give esthetic value to the environment and also, they cause for coastal conservation and to control the sea

erosion, water pollution and flooding. Therefore, they have contributed to preserve the existing coastal environment.

They have also very much helpful to economic activities such as, fisheries industry, tourism and coir industry etc. But these resources were badly influenced by 2004 tsunami. There were a lot of changes in coastal landforms. The main theme of this study is to identify these changes and the influences of these changes and investigating and analyzing of the causes for these changes.

9.0 Conclusions

According to this study the conclusions and suggestions as mentioned below.

(I). The southwest coastal landscape has been created with Variety of coastal landforms, originated from processes of marine, fluvial, flurio-marine, winds and denudation. But 75% of them have been damaged by the 2004 tsunami. The beaches and its allied features such as, bay, lagoons, and estuaries were the mostly damaged land forms of the coastal lowlands.

(II). A part from the damages, a lots of changes of landforms could be identified. The changes were broadening, narrowing and blocking of rivers and lagoon outfalls, broadening and sedimentation of marshlands and lagoons. 80% of the lagoons and estuaries in the area were under influenced of these changes.

(III). The study area consists of various kinds of ecosystems such as, lagoons, estuaries, corals, mangroves and sea grass beds. Most of them were severely damaged and very extensive damage has occurred on coastal vegetation, river and lagoon outfalls. Mangroves are highly damaged at some places on river mouths, estuaries. But some places are moderate or low. The vegetation distributed in some places caused to minimize tsunami damage and this research revealed that the importance of the shore

vegetation as a buffer against tsunami waves. Extensive damage has occurred on coral reefs, especially through sand, mud and debris depositions.

(IV). In addition to the above mentioned influences there are some environmental problems created by tsunami. They are sea erosion, coastal pollution, and sedimentation of the coastal wetlands. 80% of surface water bodies and wells have been polluted because of spoiled water. About 300 inland coral pits were sediment and broaden filling with this water. The capacities of the lagoons and estuaries have been reduced because of the debris brought by tsunami and it has influenced the fishing industry. It has also been caused to reduce the number of fish population and other aquatic living beings that depended on above mentioned features.

(V). The spatial changes of damage of the area can be different from place to place, influenced by various geographical factors such as coastal location, shape, relief, soil, drainage, coastal engineering structures and vegetation. According to that the highest damaged area was from Hikkaduwa to Ambalangoda and it was the straight coastline with plain.

(VI). A part from the physical factors, some human activities have affected to increase the damages and changes of coastal environment. They are coral mining, sand mining, destruction of coastal vegetation and they have mostly impacted on areas such as Ahangama, Akurala, Seenigama and Telwatta.

Although badly impacts on landforms and ecosystems can be identified in the area, most of them have become into normal level. With the influence of the nature. That is about 77% of landforms and ecosystems especially on coral reefs, beach rocks, mangroves and beaches.

10.0 Suggestions

- (i) Making special attention of planners and policy makers to minimize the future tsunami impacts by implementing coastal resource management plans.
- (ii) Beginning of integrated community based management planning for conservation of coastal landforms and ecosystems.
- (iii) Conservation of land forms and ecosystems that can be on high risk.
- (iv) Construction of strong coastal engineering structures in the high risky areas of coastal erosion.
- (v) Construction / Growing of greenbelt parallel to the coastline for the coast conservation and minimization of disaster damage.
- (vi) Protection of special coastal features such as sea cliffs, headland areas, mangroves, estuaries and lagoons to reduce the impacts of future tsunami.
- (vii) Limitation and control the human constructions within the coastal zone and prevention of the damage by reconstructions on ecosystems which were not damaged and recovering to normal situation.
- (viii) Reintroduction of coastal zone at the minimum of loom from the coastline towards the land.
- (ix) Awareness programs for students and community.

11.0 Problems

According to this research granted on 3rd May 2006, I am unable to fulfill all of the project work up to now, because the funds for the second year were not received yet, as the short of funds being faced by your institute. Therefore, I have prepared this report on the basis of just finished research work only.

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