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TITLE OF THE PROJECT

"**Micro Level Mapping of Morphological Changes in the Beaches Caused by Tsunami in between Cuddalore and Nagapattinam, Tamilnadu, East Coast of India**"

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Certificate

I Dr. R.KARIKALAN, declare that the work presented in this report is original and carried throughout independently by me during the complete tenure of major research project of UGC, New Delhi.

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I wish to express my thanks to all my friends who helped me a lot during the period of this project.

(R.KARIKALAN)

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1.1. General

Indian coastline is about 7500 km in length. Out of this, east coast contributes 2545 km. About 17% of India's population resides along the coastal zone, and coastal resources contribute a significant part of their livelihood. A series of gigantic waves triggered in a body of water by disturbance due to earthquake vertically displaces water column and leads to wall of water, hitting the shore with tremendous energy and leaving behind a trail of destructions. Such event has occurred on 26th December 2004, which one is among the worst coastal disorder in the world has faced so far. Magnitude of 9 is the 5th largest earth quake ever recorded in the history (Gupta, 2005). This has created series of massive ocean waves and caused devastating inundation in the south eastern coastline of India and eastern coastline of Srilanka.

The Indian coast is bestowed with a wide range of coastal ecosystems like mangroves, coral reefs, sea grasses, salt marshes and geomorphological features like lagoons, backwaters, and estuaries. In many areas, the coastal topography formed over the years provides significant protection from natural disturbances like cyclones and tsunamis (Ramachandran, 2006). But these natural barriers could diminish or even be lost if they are not managed properly. Pressure on the coastal environment arising from all kinds of human activities is generally high because of high population density; i.e., about 60% of the world's human population lives in the coastal areas.

Conversion of coastal sand dunes and plantations has intensified dramatically after the tsunami, driven largely by the belief that bio-shields mitigated tsunami inundation (Bhalla, 2007). Understanding of the coastal geomorphology helps the afforestation of the coastal areas using mangroves (Baskaran *et al.*, 2003). Even, coral reefs act as a barrier against wave action along the coastal areas and prevent coastal erosion.

In addition, coral reefs protect mangroves and sea-grass beds along the shore (Thanickachalam and Ramachandran, 2003). Chatenoux and Peduzzi (2007) reported that the areas covered by sea-grasses were less affected by tsunami waves. Coastal afforestation with casuarinas, screw pines, palms, bamboos, and mangroves can protect the coast from erosion and indeed protect other natural ecosystems (Gopalakrishnan, 2007).

The narrow coastal regions of India, both East and West coast, are the regions where Quaternary sedimentation largely has taken place. The Quaternary landforms of East coast of India commonly indicate features of emergence characteristics, while that of west coast are mostly subjected with features of submergence characteristics. A beach is a geological landform along the shoreline of a body of water. It usually consists of loose particles which are often composed of rock, such as sand, gravel, shingle, pebbles, or cobble stones.

The particles of which the beach is composed can sometimes have biological origins, such as shell waste or coralline algae fragments. Sand is a naturally occurring granular material composed of finely divided rock and mineral particles. While sediments brought by sea are being transported to the land, the beach sands form new environments creating a transition zone between the fluvial and marine environments. Greater attention is bestowed on research in beach environment during recent years and a wealth of information on biological, chemical, hydrographical and geological aspects of marine system have been gathered, and lengthy syntheses of the interaction between these subjects in several researches have been published.

These literatures clearly indicate that a given set of beach sands can never be identical in their environments of deposition. The interactions of so many variables and differences in the physicochemical, biological, meteorological and sedimentological conditions that exist in the different regions of our country make this problem more complicated, it is necessary to study each coastal region individually.

Beach sands are, one of the natural resources of the coastal zone of Tamil Nadu, calling for an intensive study on their distribution, modes of occurrence, and chemistry of the deposits available in the region. The deposits have a potential to contribute to the development of the industrial economy of the state (Indian Mineral Year Book, 1999). The deposits are confined to the surface in the coastal area with a uniform width, limited overburden and only minor variations. Sands of a specific grain size and composition concentrated in these locales are unique.

Quaternary is a subdivision of geological time which includes the present day (Pleistocene and Holocene). Climatic changes are the dominating characteristic of the Quaternary period. An evidence of major climatic changes is well documented during the Quaternary, as never before observed in geological history. Evidently, extreme climatic fluctuations occurred in the equatorial regions and temperate regions during this period caused extensive sea level fluctuations in the world oceans. During this period the cold climates resulted in the formation of glaciers which in turn, caused the retreat of sea levels and subsequent warm climates triggered the land ward migration of sea levels due to the melting of ice.

The four main glacial events of Quaternary epoch viz., Gunz, Riss, Mindel and Wurm have been identified in Alpine valley and they are correlated with North America by Nebraskan, Kansan, Iionian and Wisconsin stages. These four glacial stages are altered by interglacial periods and they together constitute the Ice Age. Worldwide studies indicate that the Last Glacial Maximum (LGM) reached high peak around 18,000 years. During this period, the shoreline all over the world retreated maximum of about 121 to 130m depth with reference to the present sea level (Milliman and Emery, 1968). Subsequently, the warm interglacial stage began around 18Ky B.P and shoreline advanced to present sea level. The landforms developed during the LGM and subsequent warm period since 18Ky BP are more or less remain unaffected both in onshore and offshore regions.

Sea level fluctuations were relatively more prominent during the Late Pleistocene-Holocene period and the evidences for these fluctuations were well preserved in the form of morphological features like terraces, ridges, pinnacles, etc., and the occurrence of relict sediments. It has been found on many continental shelves of the present day; oceans are blanketed by relict sediments of Late Pleistocene-Holocene period.

This phenomenon is normally not observed on the parts of the shelves where major rivers of the continents debouching into the sea because of the extensive in-flux of sediment to the sea. The relict environments in association with morphological features are commonly noticed in the parts of non- depositional areas. Relict sediments, in the broad range, are sediments that were deposited long ago in equilibrium with their environments; afterwards the environments changed so that the sediments no longer in equilibrium even though they remain unburied by later sediments. The chief cause of environmental change affecting present surface sediments of the continental shelves is the rise of sea level due to melting of glaciers during the past 18,000 years.

Along the coastal plains of west and east coasts of India, the records of high and low strand lines are found at different levels in the form of depositional or erosional features and each levels denotes a particular age. The height of strand-line positions reference to present sea levels varies from one area to other, possibly due to post formational tectonism.

The various geomorphic landforms formed in Quaternary period register the imprints of past geological processes. A widely varying nature of landforms and their disposition along the beaches and inland represents the successive phases of transgression and regression of sea level. The presence of palaeo-channels and Chenier or the study of fluvial processes can be of helped in identifying the palaeo-river courses or the migration of river pattern and inherent relation between sea level oscillations and channel shifting.

The advancement of scientific techniques has helped to study the Quaternary landforms through aerial photos and imagery. These tools provide an insight into the coastal evolution, sea level variations, possible neotectonic activities, by the typical uplift and alignment of landforms in a particular area.

In India, Quaternary studies have been given new impetus only in the early 80's, since the advent of aerial photos and remote sensing. In the study area, Loveson and Rajamanickam (1988) have observed the emergence of Southern Tamil Nadu Coast. Anbarasu (1994) has given a broad spectrum of evolution of coastal landforms of Northern Tamil Nadu.

Anbarasu and Rajamanickam (1997) have delineated the disposition of abandoned channels and they have identified a crustal flexure by Cymatogenic downwarping in the northern coast of Tamil Nadu, Anbarasu and Rajamanickam (1998) have studied Quaternary Sea Level Changes along the east coast. Karikalan (1996), Karikalan, et. al., (2001) have studied on the heavy mineral assemblages of different Quaternary landforms. Loveson and Rajamanickam (2001) have attempted the Quaternary Sea Level Changes (Glacial and inter glacial periods) shoreline displacement along the Coromandal coast of

India. Gnanaprakasam (2002) has adopted a GIS approach for studying the coastal landforms of the Parangipettai region.

1.2. Study Area

The area extends in between 10° 47' to 11° 47' N and 79° 43' to 79° 57' E. The boundary of study region is represented by Ponnaiyar river basin in the north and Uppanar river basin in the south (Fig.1.1).

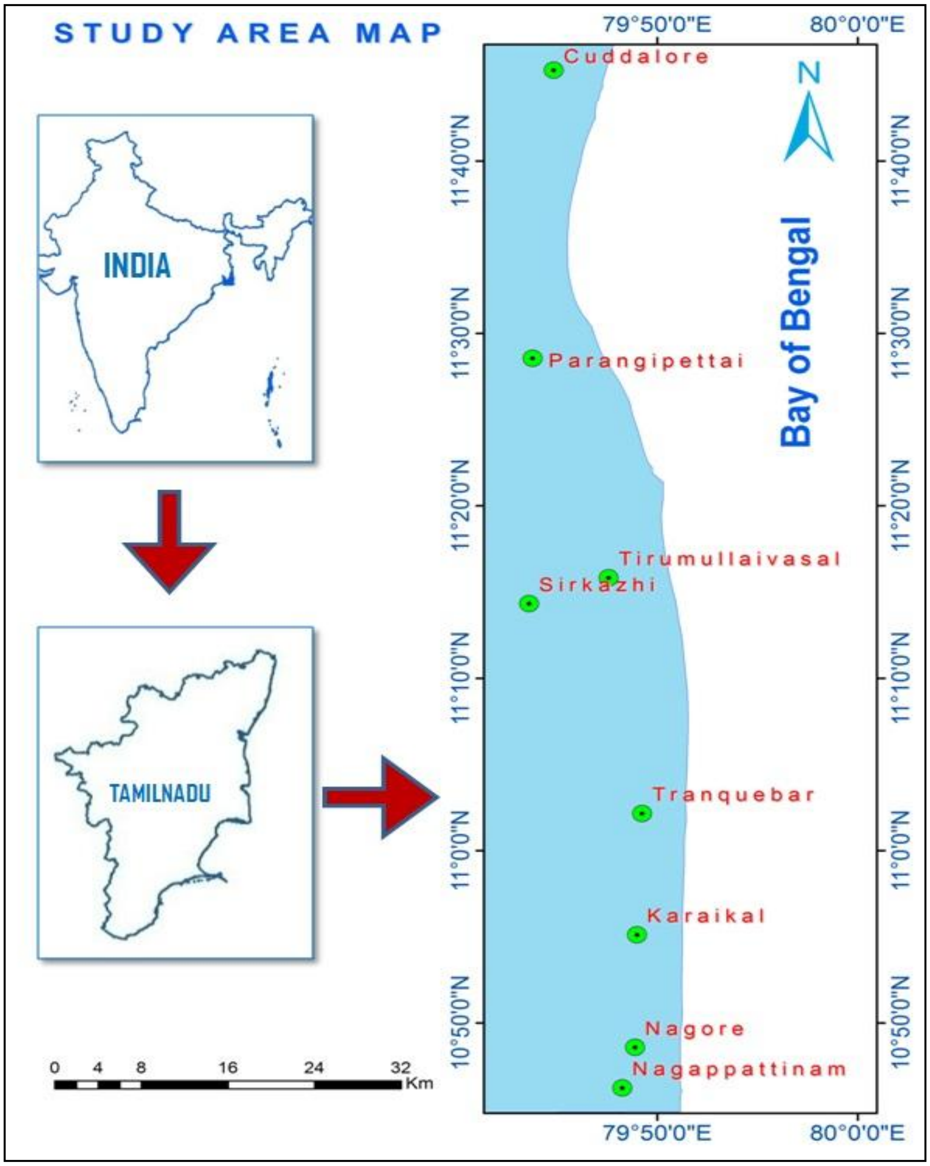

Fig.1.1.Study area of the region

The study region starts from the Cuddalore New Town in the western side while the eastern side of the basin is bordered by Bay of Bengal. It falls within the Survey of India Toposheets of 58 / M and 58/N in the scale of 2:50,000, and occupies in the Toposheets of 58 M/10,58 M/13,58 M/14,58 M/15,58 M/16,58 N/11,58 N/13 and 58N/15 in the scale of 1:50,000. The area is composed of Cuddalore, Chidambaram, Sirkazhi, Tarangampadi, Thiruvarur and Nagapattinam revenue districts and part of Karaikal, Puduchery union tertiary. The study area is well connected by roads from Cuddalore, Chidambaram, Sirkazhi, Tarangampadi, Thiruvarur, Thirumullaivasal, Nagapattinam, Karaikal, Puduchery Thanjavur, and many other places.

The area can also be reached by train from Virudhdhachalam to Cuddalore and Puduchery to Nagapattinam. There is a daily express train to Chennai via Mayiladuthurai and Ernakulam via Coimbatore. There are two triweekly trains from Mannargudi to Tirupati and Velankanni to Goa that pass via Nagapattinam. The nearby airport is Tiruchirappalli airport, located 145 km (90 mi) away from the town. Tourism plays a key economic role for the town, even though fishing is the major occupation. Nagapttinam is a base for heritage and historic points like Nagore, Velankanni, Sikkal, Kodiyakkarai, Vedaranyam, Mannargudi and Tharangambadi.

1.3. Origin of the research problem

A tsunami moves silently, but rapidly across the ocean and raise unexpectedly as destructive high wave energy along shallow coastal water, causing widespread devastation overland along the coast. The East Indian coast in Tamil Nadu is about 2000 km from the epicenter of the high magnitude earth quake, which triggered the 2004 tsunami. The wave appears to have hit the Cuddalore first, barely on one and half hour after the event. That makes the tsunami that hit the Indian coast to be an extremely fast one with a speed of about 900 km/hr. it started out from Sumatra coast in Indonesia and affected countries in the Indian Ocean regions, including India, SriLanka, and Thailand. It has claimed many lives. The death toll rate along the east coast of India is put more than 10,000, the worst affected area being Nagapattinam and Cuddalore Radhakrishnan, (2005).

Intensive industrial development along the coastal region has lead to worldwide concern on environmental and health impacts of contaminated effluent discharge (Vernet, 1991) apart from the changes in the landform and ecosystem. Developing economy is often heavily dependent on extractive or primary industry and many third-world countries face the difficult task of reconciling economic development with environmental and social protection. A legacy of unsustainable development is clearly accounted in the landform changes.

The geomorphic units not only act as a planning unit but also stand as a testimony for the process by which the land is currently subjected to. Thus a comprehensive need of data on various geomorphic units in conjunction with natural and anthropogenic influences in the coastal environment is an urgent need for various user communities, academicians, researchers and policy makers. Hence, this research project is focused on description and analysis of the various geomorphic units in micro level data compilation for the pre and post tsunami scenario of coastal regions in Cuddalore and Nagapatinam District.

1.4. Interdisciplinary relevance

The coast is a dynamic environment undergoing constant change. It is exposed to a wide range of natural coastal processes, including tidal and wind waves, storms and erosion and accretion. Coasts also face many environmental challenges relating to human-induced impacts, particularly associated with human development and settlement pressures. The coast is not simply a transitional zone but it is also the most productive ecosystem in the world (EEA, 2006). Coastal ecosystems play major roles in the prevention of shoreline erosion and provision of habitats for wildlife such as birds and fish. However, the coast is increasingly becoming a fragile vulnerable area whose environment suffers continuous degradation. Approximately 86% of Europe's coasts have been identified as 'at either high or moderate risk' from development related activities (Bryant *et al*., 1995)

In addition to the risk from natural coastal processes, and human development, and settlement, human induced-climate change and the associated accelerated sea level rise are also important threats to coast habitats. In order to protect coastal ecosystems and manage their natural resources efficiently, long-term coastal sustainable management plans based on the objective assessment of the impacts of threats to the coastline are needed.

1.5. Significance of the study

The planet Earth has enormous renewable and nonrenewable natural resources. But due to the rapidly exploding population, man is unscrupulously and haphazardly exploiting such natural resources, thus causing an irreversible depletion and damage to the environment. The proposal originates from the field evidences and articles that establish a link between land cover pattern changes especially the coastal landforms by natural (cyclonic effect and tsunami) and anthropogenic processes (industrialization, population etc) and its impact over the water resources in the coastal region. Particularly, the demand for water and land resources are expanded with the increase of human activities in coastal regions, which results in ecological and environmental concerns (Al-Adamat et al., 2003). Therefore, investigation on the impact of tsunami and human activities on landform changes and its consequences over the coastal system is important for both economic development and ecosystem protection in the proposed coastal regions.

1.6. Objectives

- To study the Coastal geomorphology changes in the Period of time in-between Pre – Tsunami 2000 and Post Tsunami 2005.
- To assess the post Tsunami (2004) over the land form changes amendment in the coastal region of the study area using 2006 remotely sensed data.
- To develop geospatial database on micro level geomorphic landforms using GIS.

1.7. Scope of the study

It is proposed to carry out Coastal geomorphological investigation over a length of 106 km of Cuddalore to Nagapattinam, Tamilnadu, and East coast India. The output will give regional morphology with maps and illustration. This types of study forms an essential part of environmental planning and coastal management especially for third world countries like India where population is concentrated along the coastal belt. Unfortunately for the most part of the world, including the developed countries, such reconnaissance maps are not available (Miles et al., 1973). It may be added, however, that such a type of study has been carried out along Maharashtra and Goa regions of the west coast of India by Wagle (1987).

The various coastal geomorphological landforms formed in Quaternary period register the imprints of earlier period geological processes. A generally varying nature of landforms and their disposition along the beaches and inland represent the successive phases of transgression and regression of sea level. The presence of palaeo-channels and Chenier or the study of fluvial processes can be of help to identify the palaeo-river courses or the migration of river pattern and inherent relation between sea level oscillations and channel shifting.

The advancement of scientific techniques has helped to study the Quaternary landforms through aerial photos and imagery. These tools provide an insight into the coastal evolution, sea level variations, possible neotectonic activities, by the typical uplift and alignment of landforms in a particular area. In addition to the interpretation of landforms from imagery and aerial photo, it is necessary to use conventional techniques like grain size and heavy mineral assemblage to study the depositional history, environment and provenance of sediments being distributed in these landforms. This will add more useful tell-tale evidences on the possible causes and the controlling factors of sediment distribution and deposition in a sedimentary basin. In this line, Anbarasu (1994) has made a detailed study on the nature of geomorphic landforms, their morphometry and coastal evolution of the study region.

1.8. Geology of the study area

1.8.1. Introduction

The study region is underlain by the various geological formations from the Archaeans through semi-consolidated formations of Mesozoic and Tertiary ages to the unconsolidated alluvial formations to Quaternary age. A generalized geological succession is presented in the Table 1.1 and the various formations are described briefly in the following paragraphs. Precambrian rocks, mainly Khondalite groups, Charnockites groups and Migmatites, cover over 75% of the state of Tamilnadu. Sedimentary rocks ranging in age from Gondwana to Quaternary are found along the Eastern coastal terrain regions. The study area contains sediments ranging in age from Gondwana to Quaternary (Fig.1.2). The sedimentary formations of various ages of the study area are underlain by Precambrian crystalline basement rocks. These basements have some characteristics features in the form of highs and lows as indicated by Bouguer gravity maps (Kailasam 1968 and Sastri & Raivarman 1968). These basement rocks exhibit ridges namely Kumbakonam ridge, Devakottai - Mannargudi ridge, Karaikal ridge and Thirupundi - Vedaranyam ridge and basins namely Ariyalur - Pondicherry sub basin, Thanjavur sub basin, Tranquebar sub basin, Ramnad - Palk strait sub basin and Thiruturaipoondi - Nagapattinam sub basin. The basement rocks are made up of Charnockites and associated rocks.

1.8.2. Cretaceous

The sedimentary formations of the study area are made up of cretaceous formations and largely with Tertiary and Quaternary Alluvial deposits. The cretaceous formations are not exposed in the study area, but the formations have been encountered in the sub surface lithology. Among the cretaceous formations the reefal limestone of Dalmiapuram is considered to be the oldest. They are hard, massive and coralline exposed in the Dalmiapuram and Maruvathur area of Tiruchirappalli district (these location are in the west of the study area) having a maximum thickness of 450 m. They overlie on irregular basement composed of boulder bed probably of Upper Gondwana formations. They are overlain by Late Cretaceous formations namely Uttatur formations. The Late Cretaceous sediments are exposed in the western part of Cauvery basin and are classified into Uttatur, Tiruchirappalli and Ariyalur formations with maximum thickness of 900m, 600m and 1500 m respectively.

The Uttatur formations rest unconformably on older basement rocks in some places and rest in reefal limestone in some other places and overlain by Tiruchirappalli formations. The Uttatur formations also consist of reefoidal limestone’s and minor sandstone with rich faunal assemblage. Conglomerates and Quartzite’s are also found to occur in the Uttatur rocks. These rocks are exposed in Tiruchirappalli area where they are overlying Gondwana and Dalmiapuram formations.

The subsurface equivalent of Uttatur formations is devoid of reefoidal elements. The Tiruchinapoly formations, unconformably overlying the Uttatur formation comprises conglomerate, pebbly sandstone as well as gritty calcareous sandstone with bands of claystone, gypsiceous claystone, sandy limestone, shell limestone and clayey limestone with abundant fauna. They are exposed in Ariyalur, Vridhachalam and Pondicherry areas. The Ariyalur formation is found to occur overlying Trichinapoly formation. They are exposed in Thanjavur, Ariyalur, Vridhachalam and Pondicherry areas. The rocks are mainly greenish grey, friae clayey sandstones, fossiliferous argillaceous limestones and sandstones.

The lower part of Ariyalur formation is highly fossiliferous while the upper is largely unfossiliferous. Equivalents to Ariyalur formation are represented by Patti limestone and Meppuliyur limestone in Vridhachalam area and Turuvai member in Pondicherry area. The cretaceous formations occur as a small patch west and Southwest of Vallam. These formations have a very thick lateritic cap, consisting of impure limestones and sand stones of silt, clay, calcareous and argillaceous variety. Near the coast, these formations are overlain by Cuddalore sand stones of Tertiary age.

1.8.3. Cenozoic – Tertiary

a) Paleocene

The Paleocene sequence unconformably overlies that of Late Cretaceous. It is locally designated as Niniyur stage and also Pondicherry formation. Generally, they comprise argillaceous limestone, variegated claystones, marlstones and bands of nodular limestone. The sediments of Paleocene age exposed in the eastern part of the Cauvery basin consist of marine shells, minor sandstones and limestone.

b) Eocene and Oligocene

The Eocene and Oligocene marine sequences are not exposed anywhere in Tamilnadu. However, they are very well-developed in the subsurface sequence. They comprise shale, sandstone and limestone. The Eocene sequence is largely clastic but in some places in the eastern part of the Cauvery basin, it comprises carbonates. The sequence is fossiliferous and has been classified into early, middle and late Eocene. Oligocene sediments are also found to occur only in sub-surface. They consist of sandstone, shale and minor limestones.

c) Miocene and Pliocene

Lower Miocene formations are represented by marine formations encountered only in sub rocks. These rocks show a development of arenaceous facies and shale facies with intercalations of limestone and sandstone. A maximum thickness of 1100m is estimated. The late Miocene to Pliocene rocks are represented by Cuddalore sandstone formation comprising reddish brown, highly ferruginous, gritty, friable, feldspathic, clayey sandstone with or without laterite capping. They are overlapping almost all types of rocks right from the Archaeans to Eocene. While the outcrops of Cuddalore sandstone formations are found to be of continental origin, the sub-surface sequence is of marine origin. Two large patches of Cuddalore sandstone are exposed in the study area one in the region west of Orathanadu and other in the area north of Coleroon River. The Cuddalore sandstone has developed high ground with flat top and is designated as upland.

1.8.4. Quaternary - Pleistocene and Holocene

Laterites occurring over Cuddalore sandstone constitute one of the important formations of Quaternary period. Deltaic sediments, beach sands, natural levees, channel fill deposits, lagoonal deposits, Aeolian sands, etc., are the characteristics deposits of Quaternary. Quaternary deposits of the study area are described in detail in the subsequent chapters. In coastal region, alluvial deposits of the river Cauvery lie over the tertiary sand stone. They consist of medium to fine sands, gravelly sands, clays and sandy clays. The thickness of these formations ranges from 30 meters to 400 meters.

Era	Period	Age	Formations	Lithology
	Quaternary Laterites	Recent	Alluvial and Laterites	Soils, alluvial and coastal sands, clays, kankar and laterites
Unconformity				
CAINO ZOIC		Mio-Pliocene	Cuddalore sandstones	Sandstones, argillaceous, pebble-bearing, sandstones, grits, sands with clays and lignite and pebble beds, Tertiary
Unconformity				
MESO ZOIC		Eocene	Gopurapuram	Black clays, or shales, grey color sand-stones, calcareous sandstones and Hale sand siliceous, limestone's with fossils
Unconformity				
	Upper Cretaceous			Fossiliferous siliceous limestone's, calcareous sandstones and marls
Unconformity				
AZOIC	Archaean			Gneisses, granites, charnockites, associated intrusive dolerites, pegmatitic and quartz veins

Table.1.1. Geological series of the Study Region

1.9. Physiography

The district of Cuddalore lies on the shores of the Bay of Bengal; it has an average elevation of 6 m (20 ft). The land is completely flat with large deposits of black and alluvial soil inland and coarse sand near the seashore. The sandstone deposits in the town are popular. The Ponnayar River runs north of the town, while Gadilam River runs across it. Cuddalore is situated at a distance of 200 km (120 mi) from the state capital Chennai and 18 km (11 mi) from Puducherry, the neighboring union territory. The nearest airport is at Chennai, 200 kilometers (120 mi) from Cuddalore.

The period from November to February in Cuddalore is pleasant, with a climate full of warm days and cool nights. The onset of summer is from March, with the mercury reaching its peak by the end of May and June. The average temperatures range from 37 °C (99 °F) in January to 22.5 °C (72.5 °F) in May and June. Summer rains are sparse and the first monsoon, the South-West monsoon, sets in June and continues till September. North-East monsoon sets in October and continues till January. The rainfall during South-West monsoon period is much lower than that of North-East monsoon. The average rainfall is 1,400 mm (55 in), most of which is contributed by the North-East monsoon. Cuddalore experiences a tropical wet and dry climate. In Tamil Nadu Cuddalore witnessing heavy rainfall in every northeast monsoon. There are daily express trains to Chennai, Tiruchirappalli, Karaikal, Tiruchendur and Mannargudi, weekly express trains to Rameswaram, Tirupati, Bhubaneswar, Mumbai, Karaikal and Pondicherry and triweekly trains to Madurai. There are passenger trains daily to Viluppuram, Mayiladuthurai, Bangalore, Karaikal, Vridachalam and Tiruchirappalli.

The nearest airport is in Pondicherry, approximately 25 km (16 mi) from Cuddalore, while the nearest international airport in Chennai International Airport, located 200 km (120 mi) from the town. The district of Nagapattinam lies on the shores of the Bay of Bengal, an area of 2,715 square kilometers (1,048 sq mi). The District capital, Nagapattinam lies on the eastern coast, 350 kilometers down south of the State capital Chennai and of Tiruchirappalli. It has an average elevation of 9 meters (30 ft) above the mean sea level. The district has a coastline of 187 kilometers (116 mi).

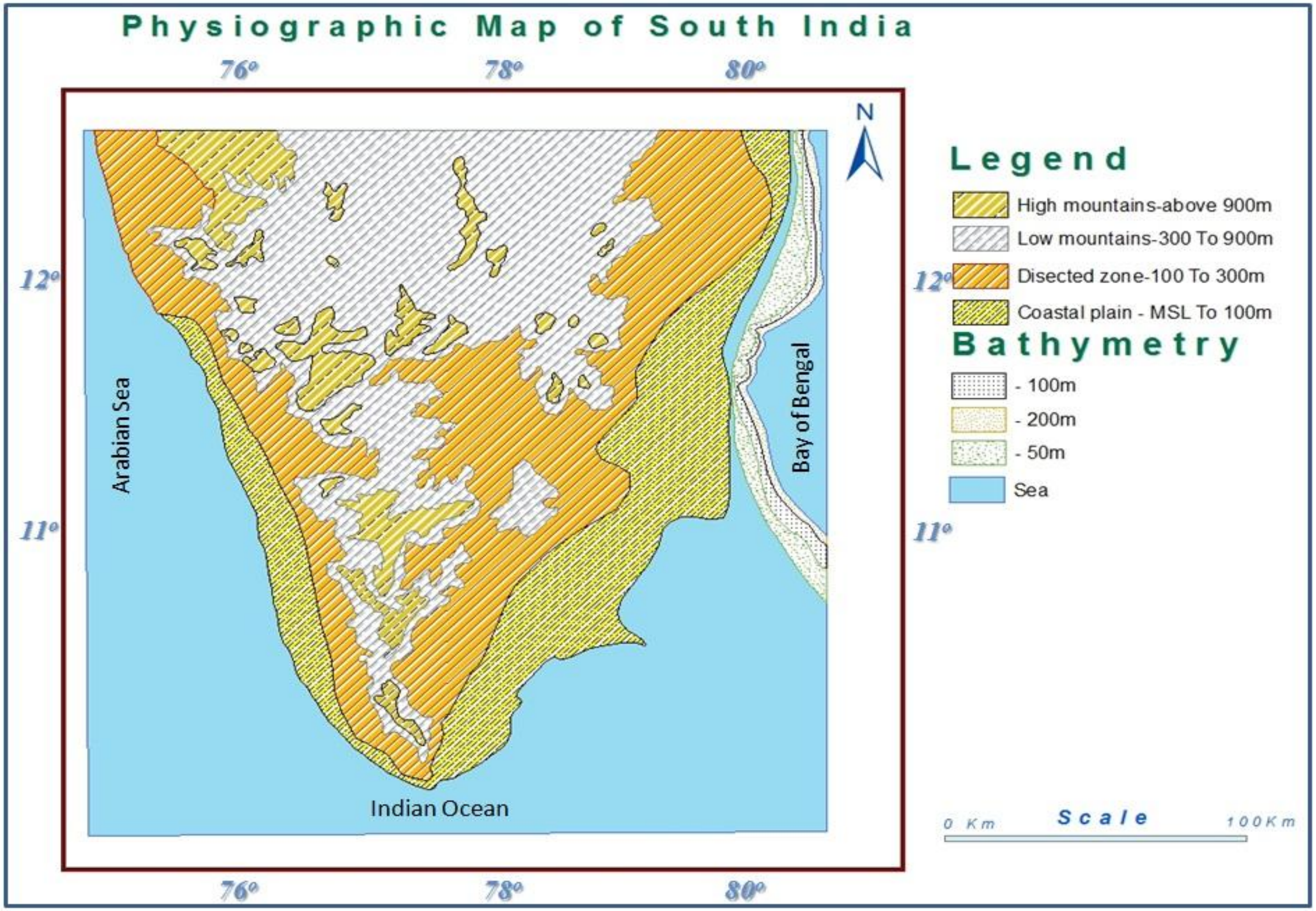

Fig.1.2. Physiographic Map of South India

1.9.1. Drainage

The Principal rivers in the study area are Ponnaiyar, Gadilam, Uppanar, Vellar, Coleroon, Cauvery, Arasalar and Thirumalarajanar. The Ponnaiyar (South Pennar) is a river in southern India. It rises on the hill of Nandidurga in Chikkaballapura District of Karnataka state, flowing south and then east for 400 km through Karnataka and Tamil Nadu, emptying into the Bay of Bengal at Cuddalore. Tirukkovilur is the largest city in the path of Ponnaiyar River.

The South Pennar River is known as Dakshina Pinakini in Kannada and Thenpennai in Tamil. It is also referred as Ponnaiyar. The Gadilam River (sometimes pronounced Kedilam) flows through the Cuddalore and villupuram districts of Tamil Nadu. It has a small water flow, drainage area and sand deposit. It is generally flooded during the monsoon season and raises the water table and feed tanks on its basin. Few famous temples like Thiruvathigai Veerataneshwar temple and Thiruvanthipuram Thevanathan perumal temple are located in its banks. It is also mentioned in the Medieval Bhakti literatures like Thevaram.

The Gadilam River flows through the town of Cuddalore and separates the Old Town from Thirupadiripuliyr. The Kollidam (referred to as Coleroon in Colonial English) is a river in southeastern India. The Kollidam is the northern distributaries of the Kaveri River as it flows through the delta of Thanjavur. It splits from the main branch of the Kaveri River at the island of Srirangam and flows eastward into the Bay of Bengal. The distribution system in Kollidam lies at Lower Anaicut which is an island of river Kollidam. Heavy floods in 2005 necessitated the flood prevention works along the Kollidam River by the Public Works Department (PWD). There is a daily express train to Chennai via Mayiladuthurai and Ernakulam via Coimbatore. There are two triweekly trains from Mannargudi to Tirupati and Velankanni to Goa that pass via Nagapattinam.

Among these, the Cauvery is the most dominant river. Its delta presents some extremely distinctive physical features and human habitats. Its irrigational developments are outstanding. It is not a large river when compared to other Indian rivers like the Ganges. It is only about 760 km long. It has a catchment of about 87900 sq.km. It takes its rise above the great Krishnarajasagar, only 19.2 km east of Mysore city and flows through the hilly terrain with manifestation of thick forest in the Mysore plateau. Just before joining with the Shimsha, its main left hand tributary the Cauvery crosses in a succession of falls giving rise to a total drop of 96 m by the time it reaches Sivasamudram (Karnataka State). From Sivasamudram, the river plunges and flows through a succession of wild gorges to 3km in Karnataka. Then, it makes a right angled bend with a vertical drop of 12 m creating the Hogenakal falls and flows in a south – North east direction into Tamil Nadu for about 32 km before reaching the 150 m contour level. From there, it runs through the plain. During that course, it is enriched with the addition of water from the tributaries like the Bhavani, the Moyar and the Noyal which are originating from Nilgris. At Srirangam, the river gets bifurcated.

The northern branch is known as Coleroon while the southern one is the Cauvery. From there onwards, it flows through the deltaic region, primarily of Thanjavur district. After running to 12.8km, it branches out into numerous small rivers before touching sixteenth km. These small branches spread to about 120 km wide in the delta. Many of them do not reach the sea. Instead, they empty the left-over water into minor tanks. The entire Cauvery basin represents a typical fan shaped delta. The major tributary of the Cauvery is the broad and braided channel system of the Coleroon River. The Vennar, the Arasalar, the Thirumalarajanar, the Upper, the Vellar, the Mulliyar are some of the other distributaries, supporting the minor river irrigation system. The drainage basin area of the Cauvery is 87.1thousand sq.km. Average relief of the drainage basin is 630 m. Average discharge is 664.32 m3 / sec.

The river Vellar is an ephemeral in nature and it generally, flows from NW to E but southeasterly at the lower reaches. The overall drainage pattern forms a sub-parallel to sub-dendritic pattern. Its tributaries on the western slopes of the Kalrayan hills in Attur taluk of Salem district. It maintains its course through Salem, Trichy and South Arcot districts. Vellar River is formed by the coalescence of two rivers, namely, the Vasishta Nadi and Sweta Nadi at about 6 km west of Toludur. The Sweta Nadi rises in the Kollimalai and drains the northern side of the Pachaimalai in Salem district. The Vasishta Nadi enters South Arcot district through the Attur pass just south of the Kalrayans and forms the boundary between the districts of South Arcot and Tiruchirapalli, for some twenty five km. Later, it joins with the Sweta Nadi. The unified streams' course proceeds for another 32 km. Then, the Sweta Nadi, which now comes to be called the Vellar, strikes north-eastwards and flows through the Vridhachalam taluk where it is joined by (about six km east of Srimushnam) a considerable tributary, the Manimukta nadi, the Gomukha nadi (cow's mouth river) and the Mayura nadi (Peacock river).

The Manimukta nadi consists of streams that drain the northern part of the eastern slopes of the Kalrayans. One more tributary named Chinnar river, originated from Pachaimalai hills also joined the Vellar (between the towns of Tittagudi and Pennadum). These rivers have cut for themselves deep clefts with often precipitous sides in the valleys, notably in the Tumbe valley down which the Manimukta nadi flows. After it is joined by the Manimukta nadi, the Vellar flows through the Chidambaram taluk and joins the sea immediately south of Parangipettai (Porto Novo). The Vellar receives little input from the south-west monsoon rains compared to the adequate input from north - east monsoon towards the latter part of the year. The Vellar River has an annual average maximum discharge of 75470 cusec water (P.W.D. Report, 1990). Its banks are often high and steep, and are influenced by the tides over a length of 12 to 15 km from its mouth at Parangipettai.

1.9.2. Climate

The study region enjoys humid-tropical climate and the average temperature of summer and winter are 32^{o}C and 25^{o}C, respectively. The relative humidity of the study area shows a fluctuation of 65-85 %. The higher rate of relative humidity is measured in NE monsoon period. In summer, the humidity is lower around 65 %. The wind speed is generally, found to be moderate in the study region and the velocity ranges from 7.4 to 12.6 km/hr. Wind speed is Maximum in May being 11.5 km/hr and minimum in October by 7.4 km/hr.

The climate in this area is generally uniform and is influenced by the adjoining sea. The recorded maximum and minimum temperatures are 37^o C and 30^o C in June and January respectively. The higher temperature recorded is 43^o C in the month of May. The normal maximum relative humidity is 87% and the minimum is 67%. The relative humidity during April-June is found to be longer than that of other months in the year. Southwesterly wind prevails over 33 percent of the days in a year while Northeasterly winds prevail over 32 percent of the days in a year. During the rest of the year the wind blows in other directions. The wind velocities vary from 6 km to 14 km per hour. The entire stretch of the coast experiences different seasons in a year such as i) South West monsoon (June, July, August and September), ii) North East monsoon (October, November and December), iii) Winter (January and May). This region has also been identified as cyclone prone zone.

1.9.3. Waves, Tides and currents

The change in seasonal cycles of monsoon influences the wave characteristics of the Bay of Bengal. The waves, approaching the shore in the direction N60°E and N45°W, with heights of 0.5 m to 3.5 m, and periods of 8 sec and 10 sec, are predominant. Tidal range along the coast mostly varies from 1 to 2 m. Two currents namely spring current in clockwise circulation and autumn current in anti-clockwise circulation are observed in the Bay of Bengal. Besides these, long shore littoral drifting currents dominantly occur from S to N. In general, the coast is wave dominated.

1.9.4. Rainfall

The weather cycle of the study area is constituted by SW monsoon (June - September), NE monsoon or retreating monsoon (October - December) and the hot weather season from mid-February to mid-June. The NE monsoon is closely associated with seasonal low pressure depressions. A higher amount of rainfall is recorded in that period. In the hot season, rainfall is scantily recorded. The total annual rainfall registered is 650 mm. The rainfall received in NE monsoon is more effective contributing about 48 % of the annual rainfall.

Table.1.2. Climate data for Nagapattinam, India

Climate data for Nagapattinam, India													
Month	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Year**
Average high °C (°F)	30.85	32.67	36.83	38.72	40.2	38.1	37.07	36.54	37.02	33.67	29.66	29.13	40.2
	-87.53	-90.81	-98.29	-101.7	-104.4	-100.6	-98.73	-97.77	-98.64	-92.61	-85.39	-84.43	-104.4
Average low °C (°F)	21.72	22.15	23.37	26.68	27.48	27.17	26.36	25.44	25.17	24.43	29.66	29.13	29.13
	-71.1	-71.87	-74.07	-80.02	-81.46	-80.91	-79.45	-77.79	-77.31	-75.97	-85.39	-84.43	-84.43
Average precipitation mm (inches)	12.2	12.4	—	2	26.5	—	39.5	39	25	85	32.15	46	319.75
	-0.48	-0.488		-0.08	-1.043		-1.555	-1.54	-0.98	-3.35	-1.2657	-1.81	-12.5886

Table.1.3. Climate data for Cuddalore, Tamil Nadu

Climate data for Cuddalore, Tamil Nadu													
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Average high °C (°F)	28.1	29.2	31.1	33.2	36.1	37	35.5	34.6	34	31.7	29.1	28	32.3
	-82.6	-84.6	-88	-91.8	-97	-98.6	-95.9	-94.3	-93.2	-89.1	-84.4	-82.4	-90.16
Average low °C (°F)	20.8	21.2	23	25.8	27.1	27	26.1	25.4	25.1	24.3	22.8	21.5	24.18
	-69.4	-70.2	-73.4	-78.4	-80.8	-80.6	-79	-77.7	-77.2	-75.7	-73	-70.7	-75.51
Average precipitation mm (inches)	30	13	11	16	46	38	85	144	121	247	329	172	1,252
	-1.18	-0.51	-0.43	-0.63	-1.81	-1.5	-3.35	-5.67	-4.76	-9.72	-12.95	-6.77	-49.28

1.9.5. Soil

As per Valdiya's (1987) soil classification of India, the soils in the east coast of Tamil Nadu mainly belong to oxisols i.e., the residual accumulation of inactive sediments. Laterites are distributed in the upper region. It enables to produce a type of soil known as laterosols i.e., the ultimate residue of clays and sandstones which have undergone to chemical weathering. The laterites also produce another type of soil, called as nitosols rich in Fe and Al content. A thin layer of inceptisols of a type of deltaic sediment is found in midstream region. The histol of (histos-tissue) found near Uppanar river areas composed of humus material. In the upper most part of the river areas, the Archaean hard rock's mainly made up of basic types, have given way to produce lime rich soils.

The soils of the district are classified as the black, red, ferruginous and arenaceous. They are again sub-divided into clays, loam and sands. Black soils are observed in the Chidambaram and Vridhachalam taluks. The sandy soils are confined only to considerable extent in the low strip areas facing the sea and confined to Cuddalore, Chidambaram and Tindivanam taluks. Younger alluvial soils are found as small patches along the river and stream courses in the district. The soils derived from the Cuddalore sandstones, laterites and lateritic gravels are of the red sandy type. Soils with deep reddish colour, developed over older geological formations are seen in forest and hilly areas.

1.9.6. Vegetation

Based on the nature of vegetation, study area vegetation can be classified into three types.

- Densely vegetated areas
- Sparsely vegetated areas
- Vegetation from cultivation

Dense vegetation can be known through the reserve forests of Kongarayapalayam, Kottalam and Asakalathur in upper part of Vellar. The coastal mangroves in the banks of Pichavaram area and the trees in lower reaches evidence the thick vegetation. In general, the trees distributed in these regions are Eucalyptus globulus arundinaceum, Retz, (Karuvela), Azadirachka indica, A.Juss (Neem tree), Ficcus carica (Fig tree), Bambusa arundinacea, Willd, (Bamboos) and Borassus flabellifer, Linn, (Palm trees).

In the habituated area and in the midst of cultivable lands, one can observe the trees like Tectona grandis (Teak), Adenanthera pavonia (Sandal), Bombusa arundinacea, Willd (Bamboo), Equisetifolia (Casurina), Anacardium occidentale (Cashewnut) and Mangifera indica (Mango trees). In addition to the paddy cultivation in this region, Saccharum officinarum, Linn. (Sugarcane), Ficus religiosa (ragi), Capsicum annuum (chillies), Allium cepa (Onion), Lycopersicon esceulentum (Tomatto), Lens essulents (Horse gram), Nigella sativa (Fitches), and Gossypium herbaceum (Cotton) are also cultivated. The cash crop like cultivation is also encouraged here under social forestry scheme and waste land development programme. Mass Cashewnut plantations in Kangiruppu reserve forest, Velankuppam, Mettukuppam forests, Erippalayam, Mavidaya Palayam, Narayankuppam, Kulandhaikuppam and Puduppalayam areas are noticed. Though the vegetation provides enough of food resources for the people dwelling inland, the people of coastal region mainly depend upon fishing, salt production, boating and shipping, handloom, pottery, carpentry, coir manufacturing, and salt pan for their livelihood.

Other areas, than the areas delineated as dense vegetation and cultivation from vegetation, are of sparsely vegetated. These areas comprising bushes, shrubs, grasses, thorny bushes, one or two large trees and sparsely grown smaller trees. Pichavaram regions represent one of the world's most beautiful mangrove formations. The common tree species one represented by Excecaria, Agallocha, Thespesia, Popularea, Prosopis Juliflora, Tamarix Dioca.

PREVIOUS STUDIES & EVIDENCES ON MAPPING

2.0 General

The coastal geomorphological research is one of the basic fields for coastal zone management. It has been given thrust after the development of wider usage of remote sensing techniques. Not only to have the better knowledge and understanding, but also to find out the gaps and delineate the new research activities in this specific field, a review has been done in the existing works.

2.1. Coastal Geomorphology

Coastal geomorphological studies were initiated in India only during 1960's. Chatterjee (1961) is the first published work on coastal landforms. He recognised seven landform levels along the coastal areas of India and correlated these levels with the Quaternary sea level oscillation. He also correlated these levels with that of Mediterranean region.

Pillai (1967) has studied the distribution and zonation of corals on the Palk Bay reefs by adopting the transect and Quadrant approach.

Meijerink (1971) conducted studies on Quaternary formations around Cauvery delta. He identified Quaternary lithological formations and named them as Orathanadu stage, Mulliyar stage, Vetter stage, Arasalar stage, Cauvery stage and Coleroon stage. Based on the geological and geomorphic studies he invoked that the sea has occupied -70m during the last glaciation period. He also observed sediments that were formed during Middle Holocene transgression (3000 - 6000 BP).

Ahmed (1972) in his booklet on "Coastal geomorphology of India" has given the regional geomorphological characteristics of east and west coast of India. Though he has narrated the regional characteristics of landforms, many of his observations were proved wrong by the studies conducted later. His classification of coastal configuration was also not correct on many aspects. But many of his observations cited below deserve to be appreciated. (i) The Pulicat lake was formed during the Middle Holocene transgression. (ii) Beach ridges are numerous along the coast which is parallel to NE and SW monsoon. (iii) Strand lines of coastal regions of India were correlated with Mediterranean Sea levels of Quaternary etc. Stoddart and Gobinathapillai (1972) studied corals around

Rameshwaram Island and reported 33 species. They also observed raised reefs in the island and suggested that the reefs have emerged due to local tectonic movement. Ahmed (1972) has described the geomorphic features and the evolution of the Indian coastline. Stoddart and Pillai (1972) have reported that raised reefs have resulted from a local uplift. Further, by Carbon dating, the age of reefs is estimated to be 4020+160 years B.P.

Meher-Homji (1973) has recognised three zones of mangrove species in Pichavaram lagoon area. By observing the distribution of species with respect to geomorphic condition, the evolutionary history of Pichavaram lagoon has been inferred. Babu (1973) inferred morpho - structures in the Krishna and Godavari deltas and observed that they possibly represent geomorphic expressions of buried structures.

Mergner and Scheer (1974) have found that the floral and faunal assemblage of reefs are derived from supra littoral to sub littoral zones.

Demongeot (1975) was also on the opinion of uplift of land responsible for the formation of marine terraces around Cuddalore and Pondicherry. Dwivedi et al., (1975), based on the study of intertidal micro fauna, classified the beaches of Tamilnadu area into two distinct categories, the sheltered and the open sea beaches. The beaches in the sheltered part have wider expanse, shallow gradient and weak wave action. On the other hand, open sea beaches have narrow intertidal expanse, steep gradient and strong wave action. Baskara Rao and Vaidyanathan (1975) have studied the coastal features between Visakhapatnam and Pudimadaka in Andhra Pradesh using aerial photo interpretation.

Anderson et al. (1976) have reported that package can be organized sectorally and successfully to address issues related to all sectors. Satellite imageries have been widely used in landuse planning along the Kumang river basin. Nageswara Rao and Subramanian (1976) have recognized five geomorphological units in the Araniyar - Korataliyar river basins. They are attributing the lowering of sea-level during last glaciation as cause to the development of canyons on the exposed continental shelf. From the presence of the raised marine deposit and paleo-channels, they suggest the role of neo-tectonic activity. Nageswara Rao and Subramanian (1976) have recognized five geomorphological units in the Araniyar - Korataliyar river basins. They are attributing the lowering of sea-level during last glaciation as cause to the development of canyons on the exposed continental shelf. From the presence of the raised marine deposit and palaeo-channels, they suggest the role of neo-tectonic activity.

Prasad (1978) has also suggested that neotectonic activity is the reason for the occurrence of lignite bed at a depth of 72m around Pondicherry and the submerged forest at Valimukam and the occurrence shell bed at higher elevation near Porto Nova. Vaidyanathan (1981) was also in the opinion of emergence of the region while giving reason for the coral terraces in Rameshwaram Island. He also identified places which were in the coastal belt during the historical past but found for inland today giving evidences the progradation of the coast.

Thin sections, TEM, SEM analysis carried out by Gardner (1981) indicated that the ‘Teri’ sands (Tamil = sandy waste) of Ramanathapuram have formed out of in situ weathering of coastal dune sands. It is postulated that the garnet was a major sources for hematite which has reddened the sands. These dune sands are dated to 21000 + 2160 years BP by 14 C dating analysis of shells collected within it.

While tracing the evolution of Cauvery delta, Sambasiva Rao (1982) has recognised the following (i) the delta has a mean gradient of 1 in 4400, (ii) twelve sets of abandoned river channels, (iii) three strandlines at 15 km, 25 km, and 4 km inland indicated by series of beach ridges. Arunachal Pradesh (Raghavaswamy 1982).

Barwis (1983) has surveyed the Pleistocene shoreline deposition and sea level history at Swatklip, South Africa. Narasima Rao et al. (1983) have surveyed the studies on wave indicated shoreline sediment transport on beaches and related phenomena.

Silas et al., (1985) have emphasized the need for establishing a “Marine National Park” in the south east coast of India. Swaminathan (1985) based on his study of littoral regime along the coast of Madras, has deciphered that the introduction of any artificial structure in the littoral regime will result in erosion on the downdraft side and deposition on the updrift side.

Fontugue and Duplessy (1986), while studying the effect of glacial and interglacial epochs during Quaternary, observed not only the strong fluctuation in sea-level and intermittent exposure of the continental shelf to sub-aerial processes as in other parts of the world, but also the appreciable perturbation in rainfall patterns. He has also reported that during last glacial maximum the southwest monsoon had disappeared from the Indian landscape. Fontugne and Duplessey (1986) have also reported that during last glacial maximum, the south west monsoon had disappeared from the Indian landscape.

While discussing neotectonic activity in India, Dhou dial (1987) demarcated seven zones of Quaternary tectonic domains with distinctive geologic, seismic, neotectonic and geothermal gradient characteristics. He has suggested that easterly and northerly structural trends are active in coastal and offshore areas during Quaternary. Merh (1987) while compiling sea-level studies of Indian region agreed to the view that the level rose higher than the present level by 6-10m during Holocene transgression. He attributed the glacioeustatic combined with glacio-isostatic rise of sea level by 6-10 m for this Holocene transgression. While discussing neotectonic activity in India, Dhoundial (1987) has suggested that easterly and northerly structural trends are active in coastal and offshore areas during Quaternary. Tissot (1987) carried out palynological analysis of sediments cored in the estuaries of the Cauvery and stated that they must have been 2000 years old. Based on the palynological evidence, the evolution of Pichavaram lagoon has been described. It has been concluded that successive developments of seaward sand barriers enclosing the lagoon were favorable for the growth of mangroves.

Bruckner (1988) has synthesized the geomorphological and sedimentological characters of parts of Tamilnadu, Andhra Pradesh and the Andaman islands for understanding sea levels from Jurassic to Recent. He has invoked late Quaternary transgression around 1, 25,000 years BP during last interglacial period and Holocene transgression between 6000 and 4000 years BP along the coast of Tamilnadu. Loveson and Rajamanickam (1988) have visualized the active progradation along the southern Tamilnadu coast from the occurrence of number of spits and beach ridges. They have divided geomorphically the coastline into four zones viz., moderately cliffed coral shoreline, gently sloped sandy shoreline, cliffed sandstone shoreline and impermeable crystalline shoreline. Ramasamy et al. (1988) have made detailed studies on scientific designing of salt-pan along the Madras coast, Tamilnadu. Kaliasundaram et al., (1988) have identified the places of erosion and accretion along the coast of Tamilnadu based on the analysis of data collected from 30 locations for the period from 1978 to 1988. They identified erosion or accretion by measuring the distance between the berm and the reference pillar erected for this purpose in all 30 locations. They haveconclbuded that 18 stations are of erosive and 12 stations are of accretive nature.

Bruckner (1989) while studying the late Quaternary shorelines of India, has inferred that the 1, 25,000 years old strandline about 4 m above present sea-level to be the outcome of the subsidence or stability of the coast rather than emergence for this. He has proposed a rise in sea level of 1 m above present MSL during Holocene transgression.

Vaidyanathan (1990), while discussing the morphology of deltas of east coast modern deltas, has indicated that the growth of Cauvery delta is mainly towards east and southeast portion. The occurrence of very few features of marine action in Cauvery delta is compared with the delta of Mahanadi. He has also inferred structural control for straight N-S coastline of the area. Remote sensing application in the field of coastal geomorphology has been attempted by Loveson et. al., (1990), Nagarathnam et. al., (1990), Srinivasan and Srinivasan (1990), Subramanyam et al., (1990). Broad geomorphic classification, strandline identification and coral reef growth rate inference are some of the studies attempted using remote sensing techniques. Rajamanickam and Loveson (1990), based on 14C results of the coral samples collected around Rameshwaram area, have inferred that a transgression around 5000 years BP must have resulted in the Ariyankadu coral terrace. The successive regressions left two more terraces and they have been dated 3670 ± 65 years BP and 2630 ± 50 years BP. Rajamanickam and Loveson (1990) have reported for the first time in the east coast of India, the results of radio carbon dating of samples taken around the Rameshwaram Island. Srinivasan and Srinivasan (1990) have attempted to infer the coastal geomorphology of the entire Tamil Nadu, through remote sensing applications without field checks. They have classified the Tamil Nadu coast into 8 blocks. Rajamanickam et al. (1990) have observed the features of emergence and submergence respectively along the southern and northern parts of Tamil Nadu. They have also postulated that the landward migration of offshore sediments combined with terrestrial sediments accelerates the progradation along Palk Strait region. Bhave (1990) has recorded the reactivation of basement ridges in the Cauvery basin by the Geophysical studies.

Kaliyanasundaram et al. (1991) have observed the coastal erosions and accretions along the Tamil Nadu coast. Ramasamy (1991) has studied in the morphology of the river deltas of Tamil Nadu, on the nature of the river delta, fluvial activity, marine influence over their growth and the Pleistocene tectonic movements. Mitra and Agarwal (1991) have recorded number of lineaments along Cauvery delta. Based on the morphostructures occurring around Mannargudi they have delineated promising areas for hydro carbon entrapment. They have also suggested the areas south of Chidambaram for the hydrocarbon study based on the morpho structural analysis. Rajamanickam (1991) observed the features of emergence and submergence respectively along the southern and northern parts of Tamilnadu. He has postulated that the landward migration of offshore sediments combined with terrestrial sediments accelerates the progradation along Palk Strait region. He has also invoked upwarping along Tuticorin area. Ramasamy (1991), based on interpretation of satellite imagery, has propounded his inference that it is the Cauvery river that has successively migrated south right from north of Madras to its present course.

Usha and Subramanian (1992) have studied the wind wave relationship for Bay of Bengal. Chavadi et al. (1992) have inferred beach morphology study along Ramangundi beach of North Karnataka coast (West coast of India). Pathan (1992) has developed flow charts for assessment of land suitability. A few attempts have also been made to develop a methodology for urban landuse zone.

Varadharaj (1993) has attributed a rise in sea level, resulting due to the close of river and lagoon mouths with sandy barrier bars and it leads to the poor quality of water in many pockets of Madras city. Based on the borehole data of Central Ground Water Board, the depositional environments around Madras city from Gondwana to Quaternary are discussed. Anbarasu and Rajamanickam (1993) have reported preliminary investigation of Holocene sea level variation along the coast of Tamil Nadu. Chokalingam and Rajamanickam (1993) have studied the coastal geomorphology of the region between Devipattinam and Mandapam, Tamil Nadu. Loveson and Rajamanickam (1993) have undertaken detailed studies on Neo-tectonics and the evolution of Quaternary landforms in southern Tamil Nadu, India. Rajaram et al. (1993) has made a detailed study on the Geomorphology and Quaternary Geology of Rameshwaram Island in India. Krishnamurthy (1993) has explained the role of mangroves of the Tamil Nadu coast and the sea grass and algal vegetation associated with them. Vaidyanathan (1993), while summarizing the geologic and geomorphic history of east coast of India, observes the dating of samples collected from different horizon along east coast invariably indicates Holocene age, though some dates point to upper Pleistocene. He has also observed tectonic effect on coastal region evidenced by abrupt changes in the course of river, the anomalous orientation of coastline and the juxtaposition of different lithological units within the Quaternary. Loveson (1993) has attempted to recognize the regional tectonism of the southern Tamil Nadu coast. Muralidharan (1993) has explained the erosional and depositional landforms and evolution of Thiruchendur coast, Tamil Nadu, India. Radhakrishna (1993) has summarised the sequence of events of land and corresponding effects on the east and west coasts of India.

Anbarasu (1994) has concluded that along the northern coast of Tamil Nadu, sea has transgressed and regressed two times during Quaternary and it is in the third regressive phase at present.

Hashimi et. al., (1995) prepared a sea level curve compiling all the available dates on the west coast of India. They have concluded that sea level was at low - 100m depth - around 14500 years BP and a rise to 80m depth around 12000 years BP showing a rate of more or less 10meters per 1000 years which was followed by a still stand for about 2000 years. From 10000 to 7000 years the sea level rose at a high rate of 20 m per 1000 years. Minor fluctuations of sea level are noticed after 7000 years BP.

Karikalan (1996) has concluded in the northern coast of the Tamil Nadu, around Porto Novo, respectively and they have identified various geomorphic features like beach ridge, Chenier, mudflat, palaeo-channel and mangrove swamps. Indira et al., (1996) have concluded that sea level variations reflect the dynamics of the nonlinear atmosphere-ocean-cryosphere-lithosphere system, using the data from Indian tide gauge stations during the past several decades has been done using the Iterated Function System (IFS) technique. The long term behavior of sea level changes can be modeled by a nonlinear dynamical system having a small number of variables. Chaurasia et al. (1996) has analysed multi-sensor remote sensing data to map the existing temporal changes in land use pattern. Ghosh et al., (1996) have developed classification technique for land use changes analysis in relation to elevation, slope aspect and bio-climatic classes. Land deterioration over the two mapping periods has been identified and strategies have been suggested to mitigate the problem. Singh (1996) has reported on human impact assessment on management of forest in Andaman Islands.

Anbarasu, K. and Rajamanickam, G. V. (1997) Abandoned channels of rivers- An evidence for neotectonism. Ramaiyan et. al., (1997) studied shoreline movement at 30 sites for the period from 1978 to 1996 based on the coastal monitoring data collected in the institute of Hydraulics and Hydrology, Poondi, Tamilnadu. They have identified places of accretion, erosion, stable and oscillation sites. Baskaran and Rajamanickam (1997) have given a detailed study of geomorphic features along the coast of Nagapattinam and the signatures of changes in sea level. Vaz and Banerjee (1997) have estimated that the net sediments accumulation in the Pulicat lagoon is at the rate of 1mm per annum along the western half to 2.5mm per annum at its eastern margin based on the dating of lagoonal sequence with bivalve rich layers. Based on the C14 datesthe evolution of Pulicat lagoon since 5000 BC has been traced.

Ramalingam and Renganathan (1998) have studied on the coastal geomorphology and its evolution of in Agniar basin, Tamil Nadu. Loveson and Rajamanickam (1998) have studied on the geomorphic Evolution of Rameshwaram Island, South India. Badawe et al. (1998) have noticed drainage network analysis and geomorphic evolution of the Kera river basin, Islampur, Satara district, Maharashtra. Ramesh (1998) has studied the geomorphic evolution of Northern Chennai coast, Tamil Nadu, India. Mohapatra et al. (1998) have noticed the influence of river mouth processes of Vasishta Godavari River. Srinivasan et al. (1998) have reported on the problems and perspectives of the prograding coast at Adirampattinam, Kodiakkarai area, Tamil Nadu. Ramasamy et al. (1998) have identified the recent shoreline changes of Rameshwaram Island, an appraisal through GIS, Tamil Nadu, and India. Rhodes (1998) has noticed on features of a sudden rise of sea level on a neotectonically positive coastline. Kasse (1998) has made detailed study on Early-Pleistocene inshore tidal deposits in the southern Netherlands and Northern Belgium and estimated paleotidal range. Katupotha (1998) has brought out the Coast and shelf evolution of Sri Lanka in the Quaternary. Sukhtankar (1998) has studied the Evolution history of the West coast of India. He has also reported about on the Quaternary coastal evolution case. Zhaoxitao (1998) has explained sea level changes in China and, their trends and impacts. Chakraborti (1998) has inferred coastal evolution of the coastal plain around Digha, West Bengal, India. Ramasamy and Ramesh (1998) have made detailed study using remote sensing techniques for the neotectonic scenario of central Tamil Nadu coast, India. Ray (1998) has made detailed study on the evolution of saline lakes of Rajasthan, India. Meera (1998) has studied on the structural landforms and geomorphic processes of Kalimachak river basin (a sub-basin of Narmada) in Madhya Pradesh. Devendra Pal and Sah (1998) have made detailed study on the late Quaternary climatic changes and their effects on landform development in Kanga Valley. Reddy et al. (1998) have made a detailed study on geomorphic classification system using landsat imagery. Angusamy and Rajamanickam (1998) have studied the wave refraction pattern of Soutern Tamil Nadu coast and identified the zone of wave convergence and divergence.

Anbarasu et.al. (1999) have traced the evolution of landforms between Pondicherry and Chidambaram considering marine, fluvial and tectonic processes. Based on the grain size studies they reclassified the older beach ridges as Chenier's due to the abundance of fluvial sediments init. The impact of Quaternary sea level oscillation on the fluvial system has also been recorded. Based on the Quaternary sea level evidences and the interrelation between paleo channels and river courses, various stages of development of landforms between Chidambaram and Pondicherry have been pictured out. Shanthi Devi and Rajamanickam (1999) have done detailed study on Beach, Beach ridge morphology of the coast between Adirampattinam to Nagapattinam, South coast of India. Uma Shabitha (1999) has studied on coastal geomorphic landforms (erosional, depositional and other landforms) and their evolution between Devipattinam and Sethupavachattram coast. Revathi (1999) has given a detailed account of geomorphic features (Beach, beach ridges, swales, sand dunes and palaeo-landforms) along the coast between Nagapattinam and Porto Novo area. A detailed investigation of Cauvery delta has been carried out through remote sensing approach by Krishnasamy and Natarajan (1999). Edwin Chandrasekaran (1999) has studied on the physio chemical studies on river Cauvery in three different seasons at Tiruchirapalli area. Anandhavalli Mahadevan (1999) has attempted to infer the environmental status of river Vaigai. Shahul Hameed (1999) has reported on the natural radioactivity in Cauvery River. Ajmalkhan (1999) has surveyed the present status of Vellar estuary.

Anjum Farooqui and Vaz (2000) based on palynological studies, inferred climatic fluctuation and sea level changes during Holocene around Pulicat lagoon. They have concluded that the middle Holocene sea level rise reached its maximum around 6650 years BP at Sulurpet. Chockalingam et.al., 2000) A study on the evolution of coastal landforms between Mandapam and Devipattinam, East coast of India. Shanthi Devi,R. and Rajamanickam.G.V. (2000) Distribution of coastal landforms between the coast of Adirampattinam and Nagapattinam, Tamil Nadu. Hanamgond (2000) has studied the small scale beach morphological changes during premonsoon and post monsoon season at Acre beach, West coast of India.

Hanamgond (2000) has reported on micro -time scale beach morphology (erosion, and accretion) and sediment movements along Arge beach, Uttar Kannada coast (India). Ramasamy (2000) has reported that the remote sensing and has a tool for identifying the evolution of southern Tamil Nadu coast, India. Banerjee (2000) studied sea level indicators of Holocene high stand along the east coast of India from Cape Comorin to Rameshwaram. He has observed that the Holocene high stand reached above 3 meters LTL at 7.3 ka and a second pulse of relative sea level rise between 5.2 and 4.2 ka along the Northern coast of Mandapam and Rameshwaram. The little ice age witnessed a minor relative sea level fall along east coast. This was followed by a rise of sea level during the last few centuries. Thrivikramaji (2000) has reported the geomorphology features like coastal high lands (backshore cliff and head lands) and evolution of Kerala coast. Baskaran et al. (2000) have studied the landform (beach, tidal flat and lagoon) processes around Marakkanam, Tamil Nadu. Chandramohan (2000) has surveyed the beach erosion near Danish fort of Tranquebar, Tamil Nadu.

The study by Chandramohan et. al., (2001) shows an average yearly deposition of sediments to a thickness of 0.01 m at Gulf of Mannar, 0.006 m at Palk Bay and 0.003 m at Sand heads. Chokalinkam et al. (2001) have suggested evolution of Quaternary landforms (beach, beach ridges, sand dunes) between Devipattinam and Rameshwaram, east coast of India. Subash Chandra Das (2001) has identified the coastal morphological changes and it’s relation to the development works (tidal and fluvial processes) along the coast of Bangladesh. Mani (2001) has attempted a detailed study on the protective measures of creeks through numerical approach from Ennore, Madras, and Tamil Nadu.

Arunachalam (2001) has shown the coastal changes in and around Bombay region. Ganesh Prusty and Dash (2001) have accounted the spatio-temporal analysis of the migration behavior of Nasi sand bars, Gahirmatha coast, India using IRS satellite images. Natarajan (2001) has explained the geomorphological setting and the origin of landforms of Tamil Nadu, based on remote sensing approach. Ruma Bhowmik (2001) has identified the changing characteristics of the rivers of Daksin Dinzapur, West Bengal, India. Ramanathan et al. (2001) have brought out detailed account on the landuse changes in and around Neyveli open cast mining region, Tamil Nadu, India.

Balasubramanian et al. (2001) have studied that the sea level rise (submerged) in the coastal Tamil land during the Cankam age. Rajamanickam et al. (2001) have documented the Quaternary sea level changes (glacial and interglacial periods) shoreline displacement on the southern Coromandal coast of India. Sunando Bandyopadhyay (2001) has reported on coastal changes from the perspective of long-term evolution of Hugli estuary, West Bengal, India. Mohana Rao et al. (2001) have reported the signatures of late Quaternary sea level changes and neo-tectonic activity over Visakhapatnam, Gopalpur shelf, East coast of India. Prasad (2001) has done a detailed study on sea level trends and consequent impact on shoreline changes along Kanyakumari to mouth of Hooghly, East coast of India. Loveson and Rajamanickam (2001) have brought out the evidence of Quaternary sea level changes and shoreline displacement on the southeastern Coromandal coast of India. Kasinatha Pandian et al. (2001) have noticed on the erosion and accretion problems on coastal landforms of Ennore coast, North of Chennai city. Vasudevan et al. (2001) have reported on the coastal tectonics and its control over the distribution of geomorphic units in the coast of central Tamil Nadu.

Anbarasu and Rajamanickam (2002) have concluded that the erosion being taking place around Pondicherry is neither man induced nor wave powered, but it is an effect of crustal flexure caused by cymatogenic down warping. The down warping has lead to the landward migration of shoreline and submergence of beach ridges in the area. The crustal flexure culminates around Cuddalore. Kumaraswamy (2002) has related on sea level changes and salt-water intrusion along the coastal Tamil Nadu, India. Arumugam et al. (2002) have reported that coastal tectonic and its control over the distribution of geomorphic units in the coast of central Tamil Nadu, East coast of India.

Thanikachalam and Ramachandran (2003) have studied shoreline and coral reef eco system changes in the Gulf of Mannar region based on the remote sensing studies. They have observed various places of erosion and accretion along the region.

Singarasubramanian (2005) A preliminary report on coastal sediment characteristics after Tsunami event along the central Tamil Nadu, east coast of India. In Book: Sumatra Tsunami on 26th December 2004,

Abbas Hameed et. al., (2006) dated cores collected from tidal flats and estuaries in the region around Cuddalore. The dates of these sample range from 2700 to 9000 years BP. Based the dates they have surmised that the sea level around Marakkanam rose slowly from 8200 years BP to 2700 years BP. Singarasubramanian. Mukesh et.al., (2006) Sediment characteristics of the M9 tsunami event between Rameswaram and Thoothukudi, Gulf of Mannar, Southeast coast of India. Ramasamy et. al., (2006) have dated sediments of a few abandoned channels of different rivers of Tamilnadu. The dates of these channels range from 2300 years BP to 8000 years BP. The paleo channels occurring north of Chennai were dated to 8000 years BP and those of Thanjavur region were dated to 2300 years BP.

Rajesh et. al., (2007) have concluded that the silica sands occurring in the paleo barriers around Marakkanam were deposited under back barrier environment during the Quaternary sea level high periods. The source rock for the silica sands was Mio-Pleistocene Cuddalore sandstone. Vaz et. al., (2007), based on the study of bathymetry of the shelf near Dhanushkodi using side scan sonar, identified raised region in the shallow off shore region. They attributed neotectonic movement for such raise. They measured the throw of Dhanushkodi fault as five meters.

Vaz et. al., (2008) have dated palaeo high sea level evidence around Mandapam based on the 14C dating. Based on the 14C dating of beach rocks of Mandapam they have inferred high strandline position during Mid Holocene period at 2m above MSL between 5650 and 6110 years BP. They have also assigned both the neotectonic movements and sea level changes as the causes for high strand.

Sathiyanarayanan Sridhar et. al., (2009) have studied shore line oscillation in the regions around Nagapattinam, Poompuhar and Tarangambadi using Remote sensing techniques and identified places of accretion and erosion. Singarasubramanian.S.R., Mukesh, (2009) Geomorphological and Sedimentological changes during and after the December-2004 Indian Ocean Tsunami near the Vellar river and the M.G.R. island area of the central Tamilnadu coast.

Alexander Kunz et. al., (2010) have dated by OSL method the dunes occurring between Port Nova and Cuddalore. Though they related Quaternary interglacial sea level rise with the origin of beach ridges, they did not rule out the subsidence of the area. They have also concluded that the stabilization of dune surface has been taking place since 3500 years BP.

Singarasubramanian, (2011) Geomorphic and Sedimentological Changes in the East Coast of Tamilnadu by Indian Ocean Tsunami-2004.

Kongeswaran and Karikalan (2015) Studies on Remote sensing and Geographical Information System Applications on Coastal Geomorphological Landforms from Portonova to Coleroon River Mouth, South Arcot, Tamilnadu, East coast of India. Karikalan and Kongeswaran (2015) Morphological Changes Caused by Post-Tsunami in the Region of Nagapattinam Coast, Tamilnadu, East Coast of India.

Kongeswaran and Karikalan (2017) A Study of Coastal Geomorphological features Changes In Part of East Coast from Cuddalore to Nagapattinam, Tamil Nadu using Remote Sensing & GIS Techniques.

MATERIALS AND METHODOLOGY

3.0 General

Mapping of coastal landforms is primary to understanding of evolution of any coastal area. The south-west coast of Tamil Nadu comprises of various landforms that are experiencing morphodynamic changes in shape, size and distribution due to various coastal hydrodynamic factors including human interferences. The depositional landforms like beaches and fore dunes are maintaining stable morphological structures along coastal stretches prevailing with constructive wave action coastal stretches prevailing with constructive wave action. Quantifying volumetric change of sediment load in a particular area provides insight into the erosional or depositional processes taking place over a period of time. The coastal landforms and vegetation cover along the coast has been significantly altered in terms of morphological settings has been significantly altered in terms of morphological settings after the Tsunami occurred on 26th, December 2004. However, the coastal landforms have gradually disappeared in the down-drift side of the coastal structures such as groins, revetments, seawall and jetties due to interference to the littoral sediment flow along the coast

The research involved three main steps. In the first step, classification of satellite data for Coastal Geomorphology and change detection analysis in the Coastal Geomorphology. The second step concentrated on the classification and change detection analysis in the land use land cover types. The third step concentrated on the shoreline changes. Analysis of satellite data includes registration, classification and change detection using post classification comparison. Spatial data analysis is done by using Arc GIS software.

3.1 Data preparation

Acquired satellite data is reregistered using image to map registration technique. Then each image was cropped to study area using Area of Interest cropping method. These three cropped images were re-projected to a common projection; Universal Transverse Mercator (UTM) with (World Geocoded System 84) WGS 84 datum and Zone 44 North.

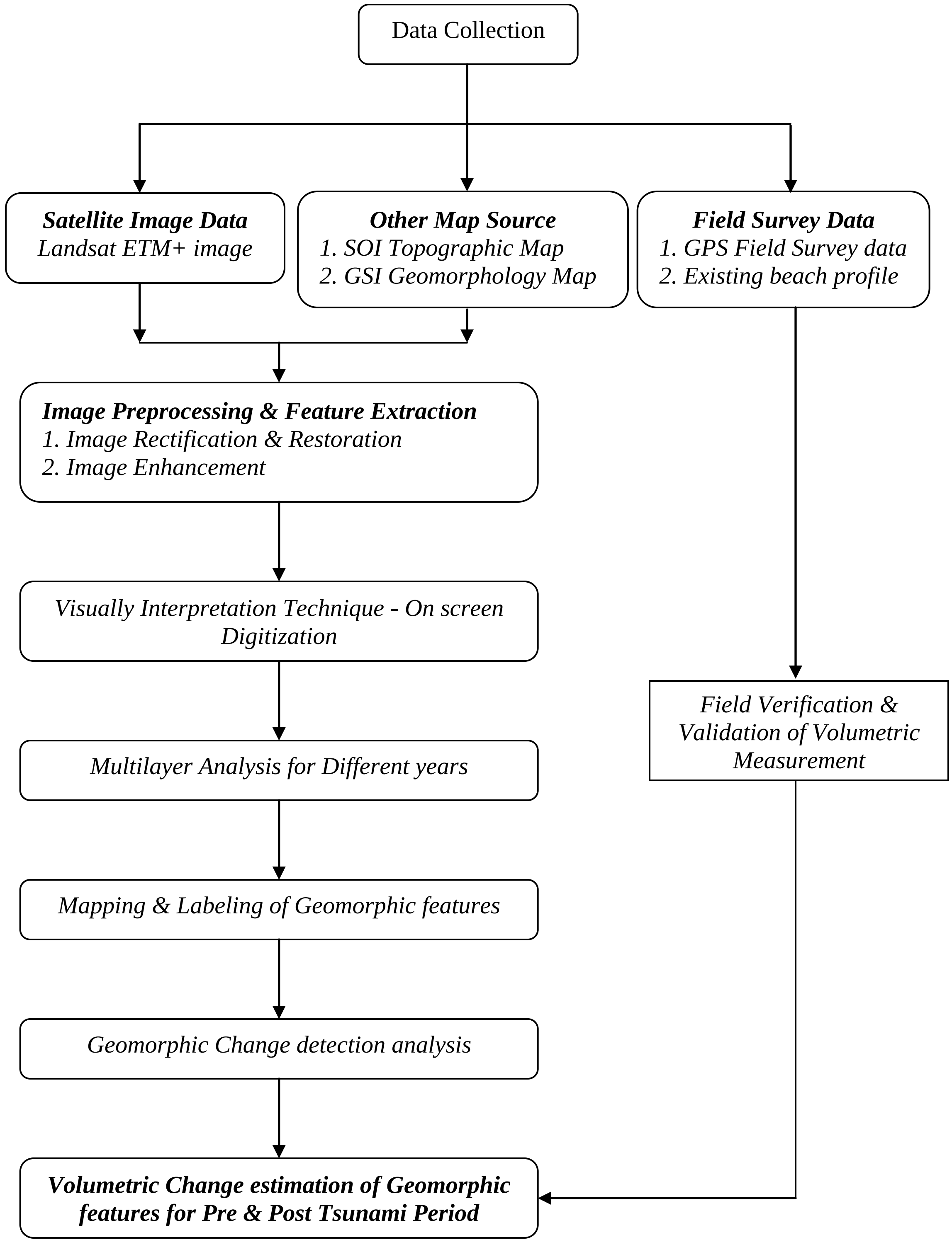

Fig.3.1 Methodology Flowchart

3.2. Change detection

Change detection analysis encompasses a broad range of methods used to identify, describe and quantity differences between images of the same scene at different times or under different conditions. Number of the tools can be used independently or in combination as part of a change detection analysis. Change detection menu after a straight forward approach to measuring changes between a pair of images that represent initial stage and final stage. The change detection statistics for classification images average used for the compute difference map for image.

3.3. Data products used

The data products for the study used both Satellite data and Survey of India Toposheets. Satellite images (Landsat data1980, 1990, 2000, 2005, 2015 and IRS data 2010) were interpreted for pre field geomorphological mapping. All the discernable coastal landforms were marked on the map with their geographical extent. A detailed field work was carried out with the base maps to observe the characteristics of coastal landforms and relation of landforms with each other. After field observations the Satellite images were again interpreted for preparation of final geomorphological map incorporating all the details collected from the field work. Later the final geomorphological maps were drawn under a GIS environment using Arc GIS 9.3. For this, geo reference of latitudes and longitudes were done with the help of survey of India Toposheets of 58 M/10,58 M/13,58 M/14,58 M/15,58 M/16,58 N/11,58 N/13 and 58N/15. Those geo reference points were transferred to the geomorphological maps prepared. Then all the landforms and their boundaries were digitized to make various layers of individual landforms. Though the maps were prepared in 1:50, 000 scales, to get a comprehensive bird’s eye view of the area all the maps were compiled to get a single map of the study area.

During the field work, beach measurements, the field photos were taken and its location was noted using GPS. These locations were transferred to the GIS environment. As coastal evolution is a combined effect of fluvial, fluvial marine, marine and tectonic processes, data pertaining to these processes were recorded during the field work. Since many landforms depicting Quaternary sea level changes are observed in the region, Archaeological, Lithological and Geomorphological indicators for sea level changes were searched and recorded. As the deltaic plain has been traversed with number of abandoned channels, all the abandoned channels and the related landforms were recorded to understand the changes in the regime of sedimentation and the shifting of delta lobes. As many underlying fractures have been reported in the region tectonic details of the area were also collected. By compiling marine, fluvial and tectonic evidences the Quaternary coastal evolution was determined.

3.4. Data acquisition

The representative satellite image is chosen by identifying the path and row of the study area from satellite reference map. Satellite imagery for the present study was obtained from the National Remote Sensing Centre and Landsat imageries USGS. The salient technical details of the satellite imagery are given below

The long-term coastal studies Cuddalore to Nagapattinam coast is studied for a period of 5 years from 2000-2005. Coastal Geomorphology, Landuse landcover and Shoreline change evaluations are based on comparing six historical shorelines extracted from different satellite imageries. Multi-temporal satellite data of Landsat (ETM) data’s were downloaded freely from the website www.landsat.org & http://glovis.usgs.gov for the period 2000 and 2005. The details regarding satellite and their acquisition dates are listed in table below.

Table 3.1. Details of the satellite data and their acquisition dates

Satellite data/Sensor	Year of pass	Spatial Resolution	Producer	Product Scale
LANDSAT (ETM+)	2000	30m	USGS	1: 50,000
LANDSAT (ETM+)	2005	30m	USGS	1: 50,000

3.5. Software used

The image enhancement technique is carried out for satellite images for better visualization. The maps were drawn through on-screen digitaization using visual interpretation technique in ArcGIS software.

3.6. Preparation Preliminary Map

Preparation of base map and drainage map from the Survey of India Toposheet (1:50.000). Maps are updated with the remote sensed data to assess the geomorphologic features. Digitization of the thematic layers using Arc GIS (9.3 version), software package. GIS based analysis is carried out to asses the Geomorphology.

3.6.1. Techniques

The techniques used in this study are mainly based on the Remote Sensing and Geographic Information System. Based on these the information drawn is given below.

a) Base map creation using Arc GIS (9.3 Version)
    - Digitization
    - Error rectification
    - Geo-coding
    - Projection
    - Labeling
    - Layout

b) Image processing methods to delineate the geomorphologic features by using ENVI (4.6 version) software.
    - Data processing
    - Feature identification
    - Classification

c) Supervised classification to make clear map from the imagery
    - Featured identification
    - Application of supervised classification

d) Data base created using Excel it has been linked with the maps
    - Primary data collection from various sources

- ➢ Data input
- ➢ Error rectification
- ➢ Data link

e) Final preparation of geomorphology map of the study area

- ➢ Base map
- ➢ Comparison map
- ➢ Overlay map
- ➢ Query method map

3.6.2. Field Check

Confirmation of mapped geomorphic features in the field itself is a way of reassessing the accuracy of interpretation. The data generated during the field check is an important database, in addition to remote sensing data. Ground data is, generally an amalgamation of collection, verification and measurement of landforms. Ground truth accuracy depends upon the extent of doubtful areas, the number of area verified, the sampling and surveying procedure adopted depending on the terrain conditions, the accessibility to the study region and accuracy requirements. The field traverse is made to cover maximum doubtful area.

The field equipments like measuring tape, camera, field note, pen, pencil, eraser, hammer study area Toposheets and more the preliminary map are taken to the field. All the doubtful areas are marked in Toposheet to know their geographical location and accessibility by using Garmin GPS (Global Positioning System) readings taken with respect to two permanent objects, shown in the Toposheet. Such readings of front bearing have been plotted in the base map after converting into backward bearing. Using those readings lines were drawn. The intersection point of those lines was marked as the location for sampling station. While traversing along the beaches, the nature and type coastal features are taken note of. In marine terraces, the aerial extent, height and their nature and composition are recorded. The height of terrace is fixed with reference to mean sea level. Details regarding beach rock outcrops, lithological variations, grain size of the beach, ripple marks, nature and height of sand dunes, narrowness and slope of wave approaching directions, nature of river mouth, and also shoreline indicators like older beach ridges are thoroughly traced and noted down. From the cuttings, unweathered rocks have been chiseled for deciphering their depositional environment. At places of geomorphic importance typical landforms created by manmade action, are corrected in the field itself in the preliminary map or pre field interpretation map.

3.6.3. Final Map

The post ground truth corrections and modifications are transferred from preliminary map to base map. This map represents the coastal geomorphologic features of the study area. This map is updated with field information with utmost precaution, to ensure maximum accuracy and reliable information after repeated rechecking and cross checking. In this map, the different features are delineated and classified and details of legend are prepared.

3.7. Data input in GIS

3.7.1. Data base generation

The development and assessment of geology, geomorphology ecology, land cover, natural resources need précised maps. The specific purposes maps are often referred as "thematic" maps because they contain f\information about a single object or theme, to make the thematic data easy to understand. The namely sensed data provides more reliable information on the different themes. Hence in the present study various thematic maps were prepared by visual interpretation of geo-code satellite imagery, SOI Toposheet. All the thematic maps are prepared in 1: 50,000 scale.

3.7.2. Preparation of vector layer

This layer was prepared after the visual interpretation the traced map are scanned and get in the form of raster data format that data into ArcGIS software and follow the below steps for reaching our goals

3.7.3. Georeferencing

Geographic georeferencing which is sometime simply called georeferencing, handling spatial information requires the establish meant of a spatial reference system to which all spatial measurement must relate to concept of representing the physical shape of earth by means of a mathematical surface and realization of this concept by the definition of the geoids and the ellipsoid are fundamental to georeferencing.

3.7.4. Shape file creation

This is a file creating individual layers are separately this can be created in ArcGIS as layers, which are projected from file, from the study area coordinates, from this projected file based on the type of feature need we are creating that shapefile.

Ex: If it is a point feature the shapefile must be a point format. If it is a poly line feature the shapefile must be a poly line format. If it is a polygon feature the shapefile must be a polygon format.

3.7.5. Digitization

A digitizer is an electronic or electromagnetic device consisting of a tablet upon which the map or document can be placed. The most common types currently used for mapping and high quality graphics are either the electrical orthogonal fine wire or the electrical wave phase type. The principle aim of the digitizer is to input quickly and accurately the co-ordinates of point and bounding line. The digitizer is used to encode the polygons by digitizing the arcs (boundaries). These sets of arcs can be easily converted in to a raster from at any resolution required.

3.7.6. Error correction

After digitization any map we want to correct that map from the errors, the errors may be hanging nodes or over shoots or silver polygon.

3.7.7. Layout preparation

A layout is a map that lets you display views, charts, tables, imported graphics primitives. The layout is used to prepare these graphics for output arc map. A layout defines what data will be used for output and how they will be displayed. A layout can be dynamic because it allows you to make specific graphics live. When a graphics is live, it replaces the current of the data.

3.7.8. Synthesis

By using Arc GIS software the raster maps converted in to vector layers by following the some few steps such georeferencing, digitization, shape file creation, error correction and according to user layout preparation are the steps for vector layer preparation.

3.8. Data base generation

The development and assessment of geology, geomorphology, and land cover, natural resources need summarize maps. The specific purposes maps are often referred as "thematic" maps because they contain information about a single object or theme, to make the thematic data easy to understand. The namely sensed data provides more reliable information on the different themes. Hence in the present study various thematic maps were prepared by visual interpretation of geo-code satellite imagery, SOI Toposheet. All the thematic maps are prepared in 1: 50,000 scale.

3.9. General methodology for preparation of thematic maps using SOI Toposheets

The survey of India Toposheet No 58 M/10, 58 M/13, 58 M/14, 58 M/15, 58 M/16, 58 N/11, 58 N/13 and 58N/15 has been used. From the SOI Toposheet the following basic thematic maps prepared.

- Base Map
- Drainage Map

3.9.1. Base map

Base map were prepared using SOI Toposheet, the following details were included; settlements, major roads, Railway line, major land marks and reserved forest boundary etc. All these details extracted from SOI Toposheet and the prepared map scanned using A0 colour scanner input into ARCGIS for on-screen vector conversion. Based on the features different layer of data were formed, then these layers were geo-referenced so as to overlay one over the other (Fig. 3.1).

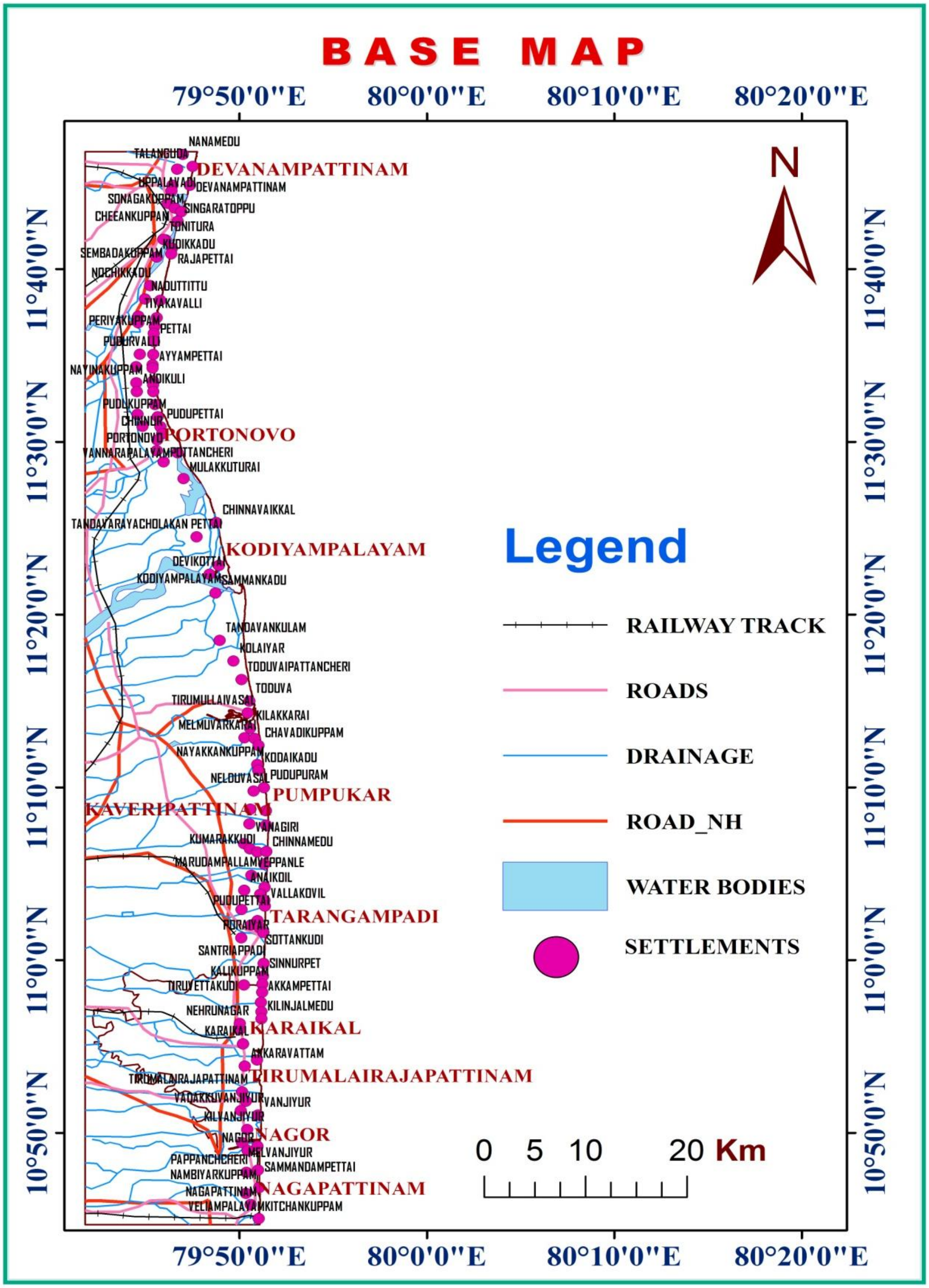

Fig.3.2.Base map

3.9.2. Drainage map

A drainage system that develops on a regional surface is controlled by the slope of the surface, the types, and attitudes of the underlying cracks.(Fig.3.2) Drainage patterns which are visible on aerial photographs and satellite images. Drainage depends mainly on the type, distribution, attitude, attitude of the surface rocks, lines of weakness etc.

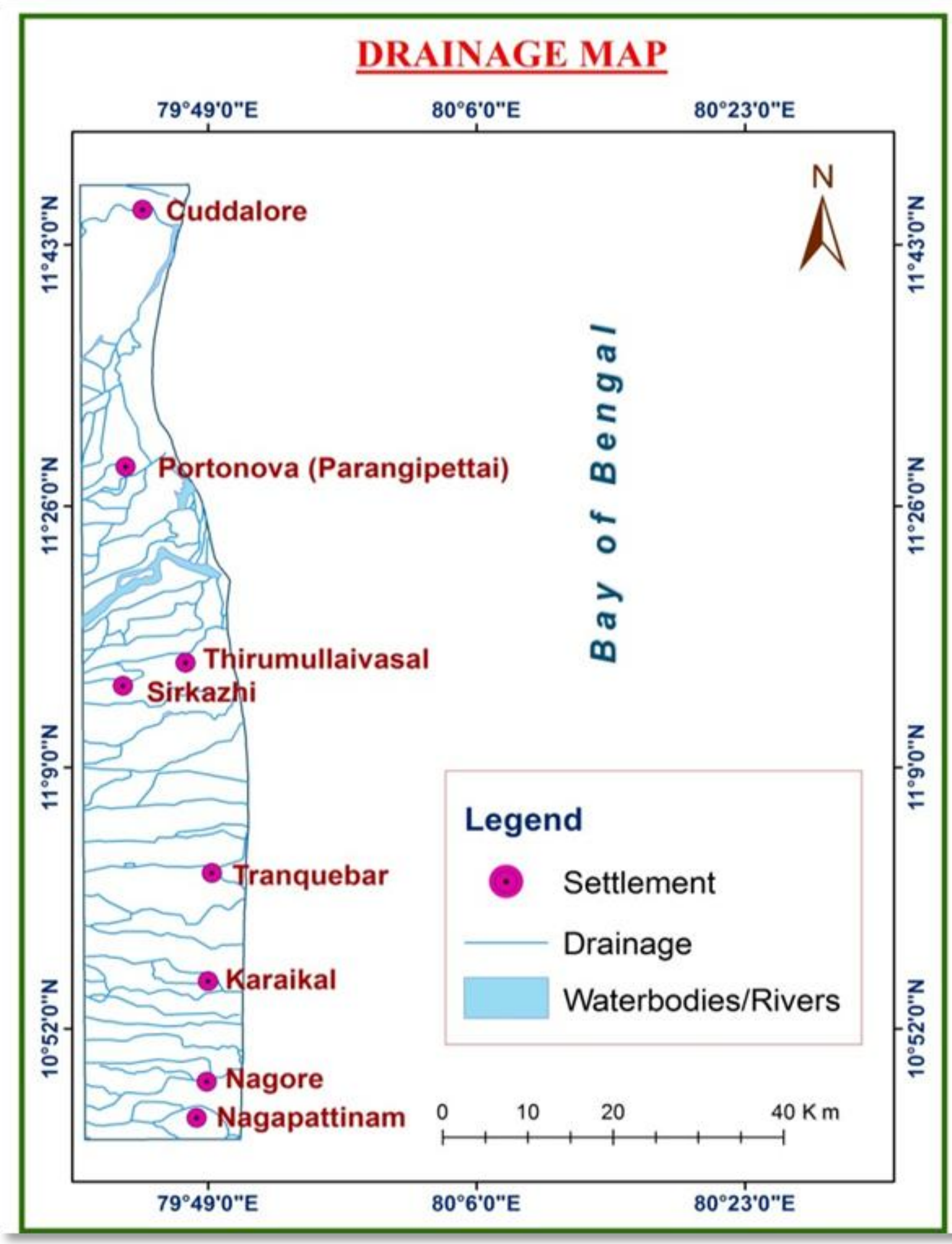

Fig.3.3. Drainage map

3.10. General methodology for preparation of thematic maps using satellite data

The various thematic maps are generated:

- Pre Tsunami - Coastal Geomorphology Map 2000
- Post Tsunami - Coastal Geomorphology Map 2005

COASTAL GEOMORPHOLOGY MAPPING

4.0 General

The study of Coastal Geomorphological landforms can provide a proper understanding of coastal process, which can lead a better coastal zonal management. To begin with, different coastal landforms were picked out from Satellite imageries. In the year 2000 to 2005 Landsat data's were used for interpreting the various Coastal Geomorphological features. Satellite data's were digitally processed through Arc GIS Software. The processed outputs were used for demarcate various geomorphic features for the years in between 2000 to 2005. The digitization works has helps to identify varies depositional and erosional coastal geomorphological landforms in the study area.

All Coastal landforms explicitly indicate the type of natural processes involved in its formation and distribution. Depositional landforms dominate the region except low beach cliff observed in a few places, which are product of erosion. The landforms noticed in the study region can be classified as given in the following tables.

Table 4.1.Classification of coastal landforms of the study area

Process	Erosional	Depositional
Marine	Beach cliff	Beaches, Beach ridges-Paleo and Younger, Paleo-lagoonal plains, Mud flats
Fluvio-Marine	-	Deltas, Point bars, Sand bars
Fluvial	-	Abandoned river channels
Aeolian	-	Dunes
Biogenic	Mangroves swamps, Salt marshes	
Others	Lagoons, Tidal Creeks	
Plantation	Cuddalore sandstone uplands	Pediment high land

The present study area is predominantly covered by the Cauvery delta in the south fluvial systems are Ponnaiyar, Gadilam and Uppanar. The north fluvial systems are Vellar, Coleroon, Uppanar, Arasalar, Tirumalarajanar, Vettar. The coastal zone, in general, is constituted by various fluvial, fluvio-marine and marine landforms (Babu

1975, Ramasmy, 1991; Rajamanickam, 1996; Mohan, 2000; Anbarasu, 2002). However, finer resolution geomorphic interpretation was carried out in the present study with the critical eye to evaluate the responses of the geosystems. The interpreted geomorphic features (Ahmed, 1972) from the digitally processed satellite data and the followed up field traverses are

- ✓ Cuddalore sandstone upland
- ✓ Flood plain
- ✓ Sand bar
- ✓ Point Bar
- ✓ River Island
- ✓ Rivers / Streams
- ✓ Delta plain
- ✓ Paleo - Beach Ridges
- ✓ Paleo Swales
- ✓ Paleo - Lagoonal plains
- ✓ Swales
- ✓ Lagoon
- ✓ Mangrove Swamps
- ✓ Mudflats / Salt Pans
- ✓ Beach Ridges
- ✓ Beaches
- ✓ Bay Mouth Bars / Spits
- ✓ Water bodies

Water bodiesThough, the above geomorphic features are generally observed in the whole study area, certain features were found entire study area (for example: well defined drainage systems and rivers).The different year wise Satellite data were used and geomorphic features which were mapped in detail are briefly discussed below.

4.1. Cuddalore sandstone upland

Cuddalore sandstone is a Mio-Pliocene formation found to occur in Tamilnadu in detached patches from Marakkanam (Northern Tamilnadu) to Sivaganga (southern Tamilnadu), in the western margin of Cauvery sedimentary basin, and also in the area north of Madras which extends into the adjoining Andhra Pradesh state. These Cuddalore sandstones develop uplands invariably in all their locations with/without laterite capping. These uplands are formed by differential erosion due the occurrence of laterite capping which is more resistant to erosion than the adjoining formations. The laterites are resistant to erosion because they become hard like a brick, when exposed to rain and sun alternately. For this reason Buchanan (1807) coined the term “laterite”. In the study area, Cuddalore sandstone uplands are found to occur in two regions, one around the area west of Orathanadu and other in the area north of Coleroon River around Udaiyarpalayam. The height ranges from 10 m to 80 m. The removal of laterite from these uplands during anthropic activity makes this upland subject to fast erosion and as a result, deep gullies and bad land topography have been developed in some places. The top portion of this upland is, generally, horizontal to gently slope towards east. Many geologists call it as table land. The Cuddalore sandstone is buff to red coloured due to the laterite cover. It contains mixture of sediments of silts, sand and boulders. It is the host rocks for lignite deposits occurring in Neyveli and Jayamkondam region. Total area covered by the Cuddalore sand stone uplands is 1875 sq.km. In this study area, this landform occupies in Pre – Tsunami 2000, 1.55% and Post – Tsunami 2005 1.17%.

4.2. Flood plain

A floodplain or flood plain is an area of land adjacent to a stream or river that stretches from the banks of its channel to the base of the enclosing valley walls and experiences flooding during periods of high discharge. The soils usually consist of levees, silts, and sands deposited during floods. Levees are the heaviest materials (usually pebble-size) and they fall in first; silts and sands are finer materials. In this study area,floodplain landform Pre –Tsunami 2000, (32.43%) and Post – Tsunami 2005, (28.15%)

4.3. Sand bar

In oceanography, geomorphology, and earth sciences, a shoal is a natural submerged ridge, bank, or bar that consists of, or is covered by, sand or other unconsolidated material, and rises from the bed of a body of water to near the surface.

Often it refers to those submerged ridges, banks, or bars that rise near enough to the surface of a body of water as to constitute a danger to navigation. Shoals are also known as sandbanks, sandbars, or gravel bars. Two or more shoals that are either separated by shared troughs or interconnected by past and or present sedimentary and hydrographic processes are referred to as a shoal complex. The term shoal is also used in a number of ways that can be either similar or quite different from how it is used in the geologic, geomorphic, and oceanographic literature. Sometimes, this terms refers to either (1) any relatively shallow place in a stream, lake, sea, or other body of water; (2) a rocky area on the sea floor within an area mapped for navigation purposes; (3) a growth of vegetation on the bottom of a deep lake that occurs at any depth; (4) and as a verb for the process of proceeding from a greater to a lesser depth of water. Point bar is a wedge of sand occurring within the river course and induce braiding of river channels. Points bars are usually occur in the loop like portion of the river course are in the place where the energy of the water is very low and deposition is very high. Point bars are noticed along the Coleroon river course at many places from Kollidam to mouth of the river. In this study area, this landform occupies in Pre – Tsunami 2000, 12.42% and Post – Tsunami 2005 0.57%.

4.4. Point Bar

Point bar is a wedge of sand occurring within the river course and induce braiding of river channels. Points bars are usually occur in the loop like portion of the river course are in the place where the energy of the water is very low and deposition is very high. Point bars are noticed along the Coleroon river course at many places from Kollidam to mouth of the river. In this study area, this landform occupies in Pre – Tsunami 2000, 0.25% and Post – Tsunami 2005 0.01%.

4.5. River Island

A river island or river archipelago is any landmass or fluvial landform within a river. The term "towhead" implies a little islet or sandbar within a river (most often the Mississippi River) having a grouping or thicket of trees, and is often used in the Midwestern United States. Many rivers, if wide enough, can house considerably large islands. The term "towhead" was popularised by Mark Twain's Adventures of Huckleberry Finn. In England, a river island in the Thames is referred to as an "ait" (or "eyot"). The present study area is predominantly covered by the Cauvery delta. The Number of major and minor rivers are present the study area flowing and meeting the Bay of Bengal viz; Ponnaiyar river in the north to Vettar river of Nagapattinam in the south. In the northern sector, the rivers like Ponnaiyar, Gadilam and Coleroon. The Coleroon river having River Island. In this study area, this landform occupies in Pre – Tsunami 2000, 4.55% and Post – Tsunami 2005 0.26%.

4.6. River/streams

The Number of major and minor rivers are present the study area flowing and meeting the Bay of Bengal viz; Ponnaiyar river in the north to Vettar river of Nagapattinam in the south. In the northern sector, the rivers like Ponnaiyar, Gadilam and Coleroon are comparatively bigger with broader river bed and at places with floodplains too. In the southern sector, almost all the rivers are thin and rectilinearly flowing in E-W direction. These rivers/ streams are said to be controlled by prominent E-W lineaments/faults (Elliot et al.1998). Further, in the southern sector, in their upstream, these rivers/streams are misfit over the left out traces of Cauvery drainage system, which had earlier flown in this area and migrated northerly to reach the present Coleroon tract (Ramasamy, 1991). Cauvery is a nomenclature used for the river right from the place of origin (Kodagu) to the place of confluence at Poompuhar. But from Kallanai geomorphologically the river Coleroon is the original continuation of the river Cauvery. The designated river Cauvery from Kallanai to Poompuhar is only a tributary. All the rivers mentioned above are tributaries of the river Cauvery. Along the many abandoned channels of the river Cauvery also a lean flow of water is noticed.

4.7. Deltaic plain

The vast flats occurring in between the landward beach ridges are obviously the palaeo swales as these occur in between the beach ridges. These palaeo swales are completely overprinted by the vast spread of deltaic sediments and are under intensive canal irrigation in Cauvery delta. In this study area, this landform occupies in Pre – Tsunami 2000, 25.12% and Post – Tsunami 2005 32.69%.

4.8. Paleo - Beach Ridges

The older ridges contain yellow colour bleached sand and occur along the land ward margin of the beach ridge plain. The direction of older beach ridges changes from NE-SW direction to EW in the study area. The older beach ridges are stabilized and flatted by the terrestrial processes. The sands are bleached and yellowish in colour. The sands are fine in nature and well sorted. The comparison of the alignment of configuration of these older ridges with respect to the present day shoreline helps to trace the direction of Progradation of delta and evolution of the coast. Paleo - beach ridges are observed in the area of Chidambaram and Thirumullaivasal in the north as discontinuous patches. Prominent older ridges are observed around the study area.

These Paleo - beach ridges and also the intervening palaeo swales are mostly used for agricultural practices, settlements and also casuarinas are planted here and there. Again, the Paleo - beach ridges which have a width of 3-4km in Cuddalore area, got branched off into a number of actuate beach ridges to a width of 30-40km in between Perumal eri in the north and up to Karaikal in the south with intervening vast flats. Again along Nagore - Nagapattinam, these Paleo - beach ridges have almost pinched off. These Paleo - beach ridges have been cut and leveled in most of the places for cultivation. This landform occurs continuously throughout the total length of the study area Pre-Tsunami 2000,(4.02%) and Post – Tsunami 2005, (6.90%)

4.9. Paleo Swales

The N-S trending sub parallel linear depressions found amidst the long and linear sand ridges and occurring at a little higher elevation from the MSL in a zone of 3-8 km adjacent to the shoreline are interpreted as palaeo swales. The clayey sub stratum while indicates its marine origin, the absence of linkage with sea and lack of tidal activities indicate that these would have lost their linkages with the sea in the recent past. Hence, these are interpreted as palaeo swales. In this study area, this landform occupies in Pre – Tsunami 2000, 0.04% and Post – Tsunami 2005 0.57%.

4.10. Paleo - Lagoonal plains

Paleo - lagoonal plains are observed bordering the older beach ridges in the Portonova North region (Fig 2.4). They are originally swales developed between older beach ridges and had been flooded by sea water for long time to form clay and silt deposits. The paleo lagoonal plains are bordered by deltaic plain in the land ward side and by younger beach ridges in the sea ward side. The paleo lagoonal plain contains mainly clay and silts of marine origin. The shells of marine animals like Cardium spp, Cardita spp, Murex spp etc are found to occur. The sediments of older beach ridges lie over the paleo Lagoonal plains. The paleo lagoonal plains are nothing but mudflat developed when the older beach ridges were formed. To distinguish them from the mudflats formed during the formation of younger beach ridges, they are named as paleo lagoonal plains. In this study area represents, this landform occupy Pre –Tsunami 2000, (1.51%) and Post –Tsunami 2005, (0.1%).

4.11. Swales

A swale is a low tract of land, especially one that is moist or marshy. The term can refer to a natural landscape feature or a human-created one. Artificial swales are often infiltration basins designed to manage water runoff, filter pollutants, and increase rainwater infiltration. The swale concept has also been popularized as a rainwater harvesting and soil conservation strategy by Bill Mollison, Geoff Lawton and other advocates of permaculture. In this context it usually refers to a water-harvesting ditch on contour. Another term used is contour bund.

Swales as used in permaculture are designed to slow and capture runoff by spreading it horizontally across the landscape (along an elevation contour line), facilitating runoff infiltration into the soil. This type of swale is created by digging a ditch on contour and piling the dirt on the downhill side of the ditch to create a berm. In arid climates, vegetation (existing or planted) along the swale can benefit from the concentration of runoff. Trees and shrubs along the swale can provide shade which decreases water evaporation; however they increase transpiration, so their net effect on the hydrologic cycle is probably to reduce infiltration.

The term swale or "beach swale" is also used to describe long, narrow, usually shallow troughs between ridges or sandbars on a beach, which run parallel to the shoreline. In this study area, this landform Occupies in Pre – Tsunami 2000, 0.19% and Post – Tsunami 2005 8.14%.

4.12. Lagoon

A lagoon is a shallow body of water separated from a larger body of water by barrier islands or reefs. Lagoons are commonly divided into coastal lagoons and atoll lagoons. They have also been identified as occurring on mixed-sand and gravel coastlines. There is an overlap between bodies of water classified as coastal lagoons and bodies of water classified as estuaries. Lagoons are common coastal features around many parts of the world. Lagoons can also be man-made and used for wastewater treatment, as is the case for e.g. aerated lagoons and anaerobic lagoons. Lagoon occupies in Pre –Tsunami 2000, 0.03% and Post – Tsunami 2005, 0.04% in the study area.

4.13. Mangrove Swamps

A mangrove is a shrub or small tree that grows in coastal saline or brackish water. The term is also used for tropical coastal vegetation consisting of such species. Mangroves occur worldwide in the tropics and subtropics.

The mangrove vegetation growing irregularly around Pichavaram lagoon (Plate 4) consists of *Rhizophora Spp, Avicennia marina, Bruguiera cylindria, Aegiceras corniculata, Ceriops decandra*, etc., (Meher - Homji, 1973). About 8 sq km area is under mangrove vegetation.

The geomorphic setting of Pichavaram lagoon, with Coleroon in the south and Vellar in the north and a connecting tidal channel between these two rivers with a lagoon, has favoured the development of mangrove swamps. Tissot (1987), based on pollen study conducted in sediments cored in Pichavaram lagoon, has concluded that the development of successive seaward sand barrier enclosing the lagoon has been responsible for the development of favorable environment for the growth of mangroves.

The Pichavaram backwater has rich growth of Mangroves as also colorfully seen in the satellite FCC data with thick red colour.In this study area, a mangrove swamps landform in Pre – Tsunami 2000, (0.50%) and Post – Tsunami 2005, (0.35%).

4.14. Mudflats/ Saltpans

Mudflats also known as tidal flats are coastal wetlands that form when mud is deposited by tides or rivers. They are found in sheltered areas such as bays, bayous, lagoons, and estuaries. Mudflats may be viewed geologically as exposed layers of bay mud, resulting from deposition of estuarine silts, clays and marine animal detritus. Most of the sediment within a mudflat is within the intertidal zone, and thus the flat is submerged and exposed approximately twice daily.

In the past tidal flats were considered unhealthy, economically unimportant areas and were often dredged and developed into agricultural land. Several especially shallow mudflat areas, such as the Wadden Sea, are now popular among those practicing the sport of mudflat hiking. On the Baltic Sea coast of Germany in places, mudflats are exposed not by tidal action, but by wind-action driving water away from the shallows into the sea. These wind-affected mudflats are called wind watts in German.

Fringing the creeks, river mouths, swales and backwaters, the mudflats and saltpans are found. The normally occur under the grip of the tidal activities. In some pockets, these mudflats/saltpans are also found directly exposed to shoreline too.

` Natural salt pans or salt flats are flat expanses of ground covered with salt and other minerals, usually shining white under the Sun. They are found in deserts, and are natural formations (unlike salt evaporation ponds, which are artificial).

A salt pan forms by evaporation of a water pool such as a lake or pond. This happens in climates where the rate of water evaporation exceeds the rate of precipitation, that is, in a desert. If the water cannot drain into the ground, it remains on the surface until it evaporates, leaving behind minerals precipitated from the salt ions dissolved in the water. Over thousands of years, the minerals (usually salts) accumulate on the surface. These minerals reflect the Sun's rays and often appear as white areas.

Salt pans can be dangerous. The crust of salt can conceal a quagmire of mud that can engulf a truck. The Qattara Depression in the eastern Sahara desert contains many such traps which served as strategic barriers during World War II.

Fringing the creeks, river mouths, swale and backwaters, the mudflats and saltpans are found. These normally occur under the grip of the tidal activities. In backwater, the mudflats are developed to a wider spread. In addition, in some pockets, these mudflats / saltpans are also found directly exposed to shoreline too. The mud flat is of local nature extending up to 1 km E-W and up to 2 km N-S. The thickness of the clay and silt goes up to 5 m. Pre –Tsunami 2000, (2.92%) and Post – Tsunami 2005. (1.58%).

4.15. Beach Ridges

A beach ridge is a wave-swept or wave-deposited ridge running parallel to a shoreline. It is commonly composed of sand as well as sediment worked from underlying beach material. The movement of sediment by wave action is called littoral transport. Movement of material parallel to the shoreline is called longshore transport. Movement perpendicular to the shore is called on-offshore transport. A beach ridge may be capped by, or associated with, sand dunes. The height of a beach ridge is affected by wave size and energy. A fall in water level (or an uplift of land) can isolate a beach ridge from the body of water that created it. Isolated beach ridges may be found along dry lakes in the western United States and inland of the Great Lakes of North America, where they formed at the end of the last ice age when lake levels were much higher due to glacial melting and obstructed outflow caused by glacial ice. Some isolated beach ridges are found in parts of Scandinavia, where glacial melting relieved pressure on land masses and resulted in subsequent crustal lifting or post-glacial rebound. A rise in water level can submerge beach ridges created at an earlier stage, causing them to erode and become less distinct. Beach ridges can become routes for roads and trails.

Beach ridges are the long and linear sub parallel swarms of sand ridges occurring parallel to the coast for several kilometers both continuously. These represent the ancient shoreline along which the littoral currents and the waves have dumped the sediments and built the beaches. These have become stabilised as long and linear sand ridges called beach ridges during the process of sea level recession. in the northern sector, around

Cuddalore, such beach ridges are found to a width of 7-8km and these have been classified into two, as seaward beach ridges and landward beach ridges, the former occurring as bundles close to the coast with thin intervening palaeo swales and the later appear to be comparatively thin but separated by wide and flat palaeo swales. These seaward beach ridges gradually become wider in the south and in between Cuddalore (old town) and Karaikal, these occur as a number of collinear beach ridges intervened by palaeo swales. But again these seaward beach ridges have become thinner along Nagore-Nagapattinam. Similar to beaches, beach ridges are converted to the beach ridge plain. Pre-Tsunami 12.43% and Post – Tsunami 10.95%, these landforms are covered along the entire stretch of the coast of the study area.

4.16. Beaches

A beach is a landform along a body of water. It usually consists of loose particles, which are often composed of rock, such as sand, gravel, shingle, pebbles, or cobblestones. The particles comprising a beach are occasionally biological in origin, such as mollusc shells or coralline algae. Some beaches have man-made infrastructure, such as lifeguard posts, changing rooms, and showers. They may also have hospitality venues (such as resorts, camps, hotels, and restaurants) nearby. Wild beaches, also known as undeveloped or undiscovered beaches, are not developed in this manner. Wild beaches can be valued for their untouched beauty and preserved nature. Beaches typically occur in areas along the coast where wave or current action deposits and reworks sediments.

I the entire study area, the beach is very thinly developed to a breadth of 100-300m only. These don't have much vegetation except some scrubs at places, as also evidently seen from the bright tone in satellite imagery. This landform occurs continuously throughout the total length of the study area ranging in width from 100m to 500m Pre – Tsunami 2000 (1.34%) and Post – Tsunami 2005 (0.96%).

4.17. Bay Mouth Bars / Spits

A bay mouth bar is a depositional feature as a result of longshore drift. It is a spit that completely closes access to a bay, thus sealing it off from the main body of water. It is different from a barrier island separating a lagoon because it closes the bay off completely, not partially. These bars usually consist of accumulated gravel and sand carried by the current of longshore drift and deposited at a less turbulent part of the current. Thus, they most commonly occur across artificial bay and river entrances due to the loss of kinetic energy in the current after wave refraction.

A spit or sandspit is a deposition bar or beach landform off coasts or lake shores. It develops in places where re-entrance occurs, such as at a cove's headlands, by the process of longshore drift by longshore currents. The drift occurs due to waves meeting the beach at an oblique angle, moving sediment down the beach in a zigzag pattern. This is complemented by longshore currents, which further transport sediment through the water alongside the beach. These currents are caused by the same waves that cause the drift.

The bay mouth bars are found in almost all the rivers. This indicates that these rivers are dynamically weak, thus facilitating me littoral currents to dump the sediments and build the sandbars at these mouths. The Bay Mouth Bars / Spits are significant changes and conversions over the study years.

The entire bay mouth bars and spits100% of them have been totally washed off by the Tsunami. When Tsunami hit the coast, these bay mouth bars and spits seem to have meekly surrendered to the tidal energy and thereby allowed the tidal water to get into the rivers and creeks. Similarly, the barely opened river and creek mouths also facilitated the Tsunami waves to gush freely into their respective courses. On the contrary, wherever obstruction or concrete walls are constructed at their mouths or even abutments along the banks at their mouths were present the Tsunami has smashed the adjacent lands and settlements. The Uppanar river mouths of Nagapattinam region provide excellent examples for these observations. In this study area, this landform occupies in Pre – Tsunami 2000, 0.06% and Post – Tsunami 2005 0.25%.

4.18. Water bodies

A body of water or waterbody (often spelled water body) is any significant accumulation of water, generally on a planet's surface. The term most often refers to oceans, seas, and lakes, but it includes smaller pools of water such as ponds, wetlands, or more rarely, puddles. A body of water does not have to be still or contained; Rivers, streams, canals, and other geographical features where water moves from one place to another are also considered bodies of water.

Most are naturally occurring geographical features, but some are artificial. There are types that can be either. For example, most reservoirs are created by engineering dams, but some natural lakes are used as reservoirs. Similarly, most harbors are naturally occurring bays, but some harbors have been created through construction.

Bodies of water that are navigable are known as waterways. Some bodies of water collect and move water, such as rivers and streams, and others primarily hold water, such as lakes and oceans. The term body of water can also refer to a reservoir of water held by a plant, technically known as a phytotelma. Bodies of water are affected by gravity which is what creates the tidal effects on Earth. In this study area, this landform occupies in Pre – Tsunami 2000, 0.36% and Post – Tsunami 2005 1.42%.

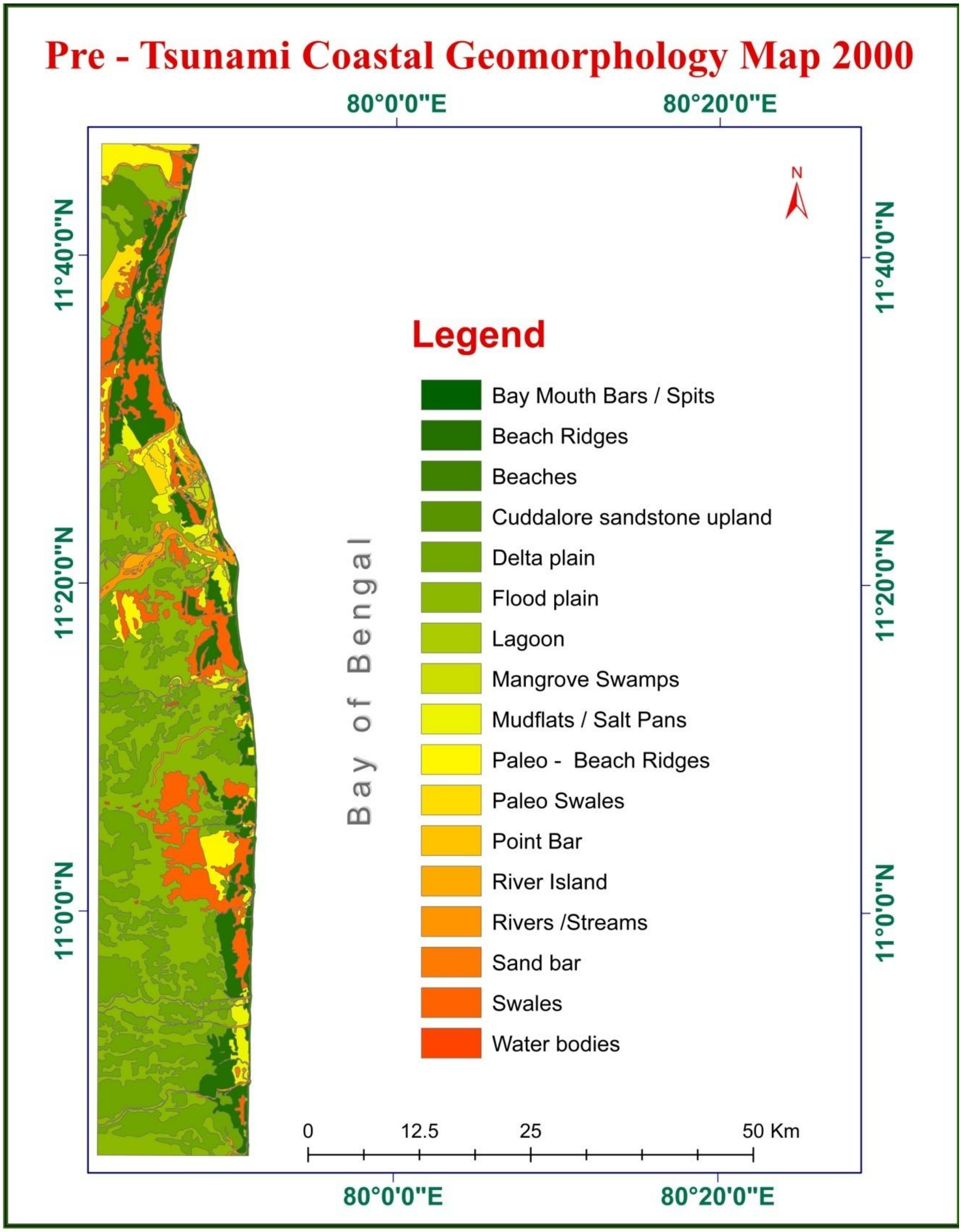

Fig.4.1. Pre-Tsunami Coastal Geomorphology map 2000

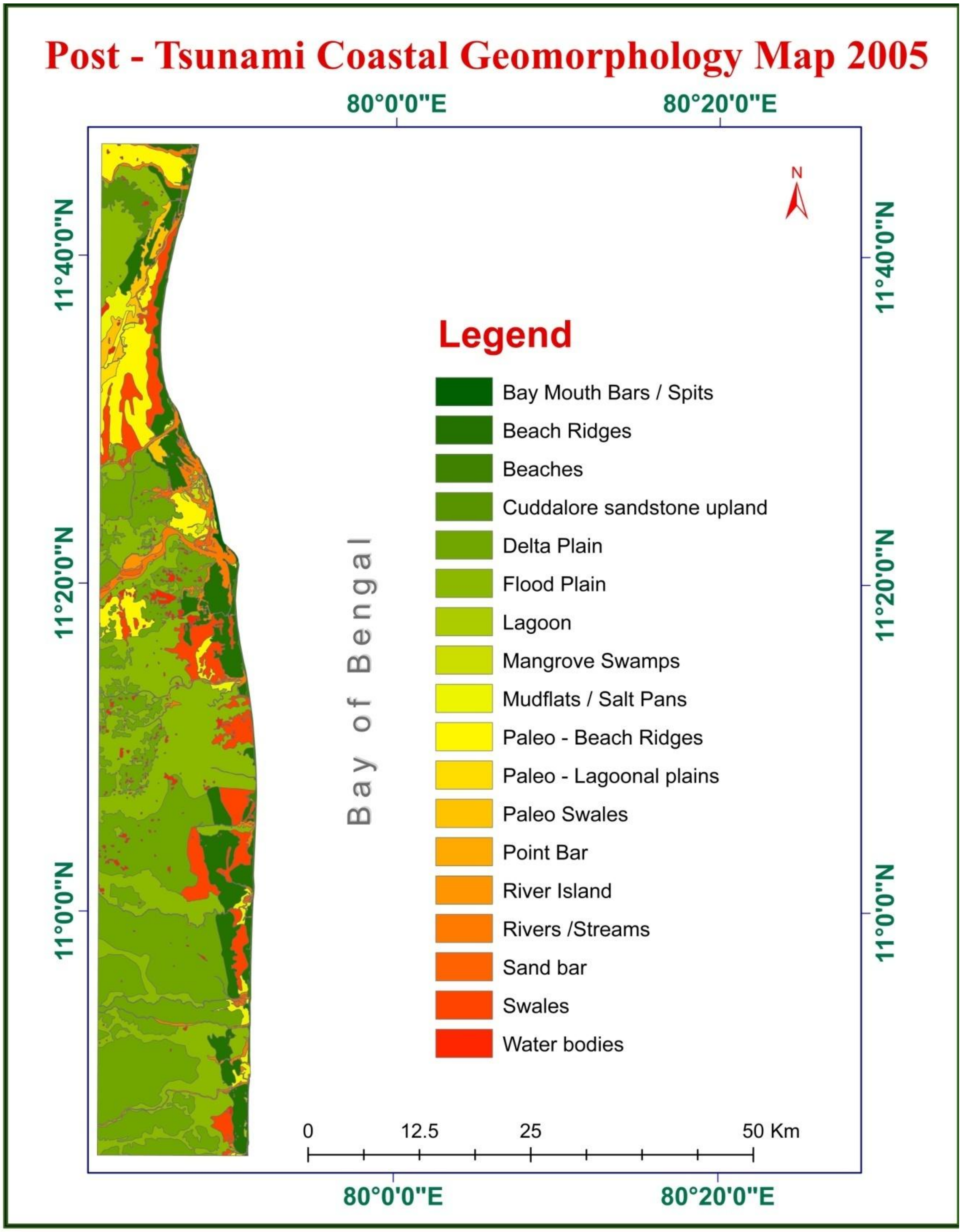

Fig.4.2. Post - Tsunami Coastal Geomorphology map 2005

Table 4.2. Area statistics of Coastal Geomorphology classes for the study periods

Coastal Geomorphology	Pre – Tsunami (Year 2000)		Post – Tsunami (Year 2005)	
	Area (Sq.Km)	Percentage (%)	Area (Sq.Km)	Percentage (%)
Bay Mouth Bars / Spits	0.90	0.06	3.96	0.25
Beach Ridges	197.45	12.43	173.09	10.95
Beaches	21.26	1.34	15.12	0.96
Cuddalore sandstone upland	24.56	1.55	18.57	1.17
Deltaic plain	398.94	25.12	516.94	32.69
Flood plain	515.08	32.43	445.15	28.15
Lagoon	0.46	0.03	0.61	0.04
Mangrove Swamps	8.01	0.50	5.56	0.35
Mudflats / Salt Pans	46.42	2.92	24.93	1.58
Paleo - Beach Ridges	63.85	4.02	109.08	6.90
Paleo - Lagoonal plains	23.97	1.51	3.25	0.21
Paleo Swales	0.56	0.04	24.89	1.57
Point Bar	4.01	0.25	0.11	0.01
River Island	72.24	4.55	4.09	0.26
Rivers / Streams	4.33	0.27	75.83	4.80
Sand bar	197.23	12.42	8.95	0.57
Swales	3.08	0.19	128.79	8.14
Water bodies	5.77	0.36	22.48	1.42

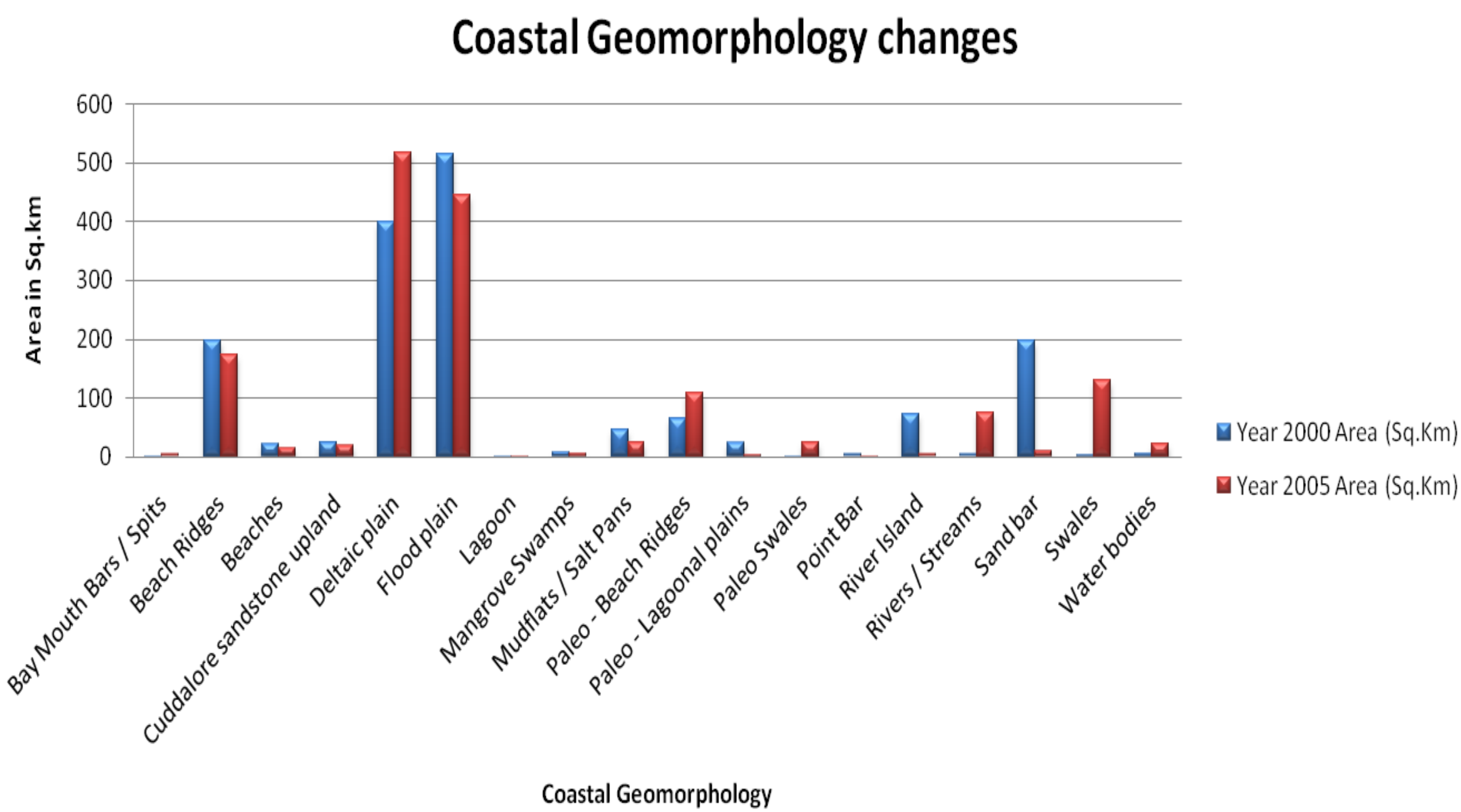

Fig.4.3. Area statistics of Coastal Geomorphology classes for the study periods

Table 4.3. Coastal Geomorphology changes in the study periods (% area)

Coastal Geomorphology	2000 to 2005
Bay Mouth Bars / Spits	0.19
Beach Ridges	-1.49
Beaches	-0.38
Cuddalore sandstone upland	-0.37
Delta plain	7.57
Flood plain	-4.28
Lagoon	0.01
Mangrove Swamps	-0.15
Mudflats / Salt Pans	-1.35
Paleo - Beach Ridges	2.88
Paleo - Lagoonal plains	-1.3
Paleo Swales	1.54
Point Bar	-0.25
River Island	-4.29
Rivers / Streams	4.52
Sand bar	-11.85
Swales	7.95
Water bodies	1.06

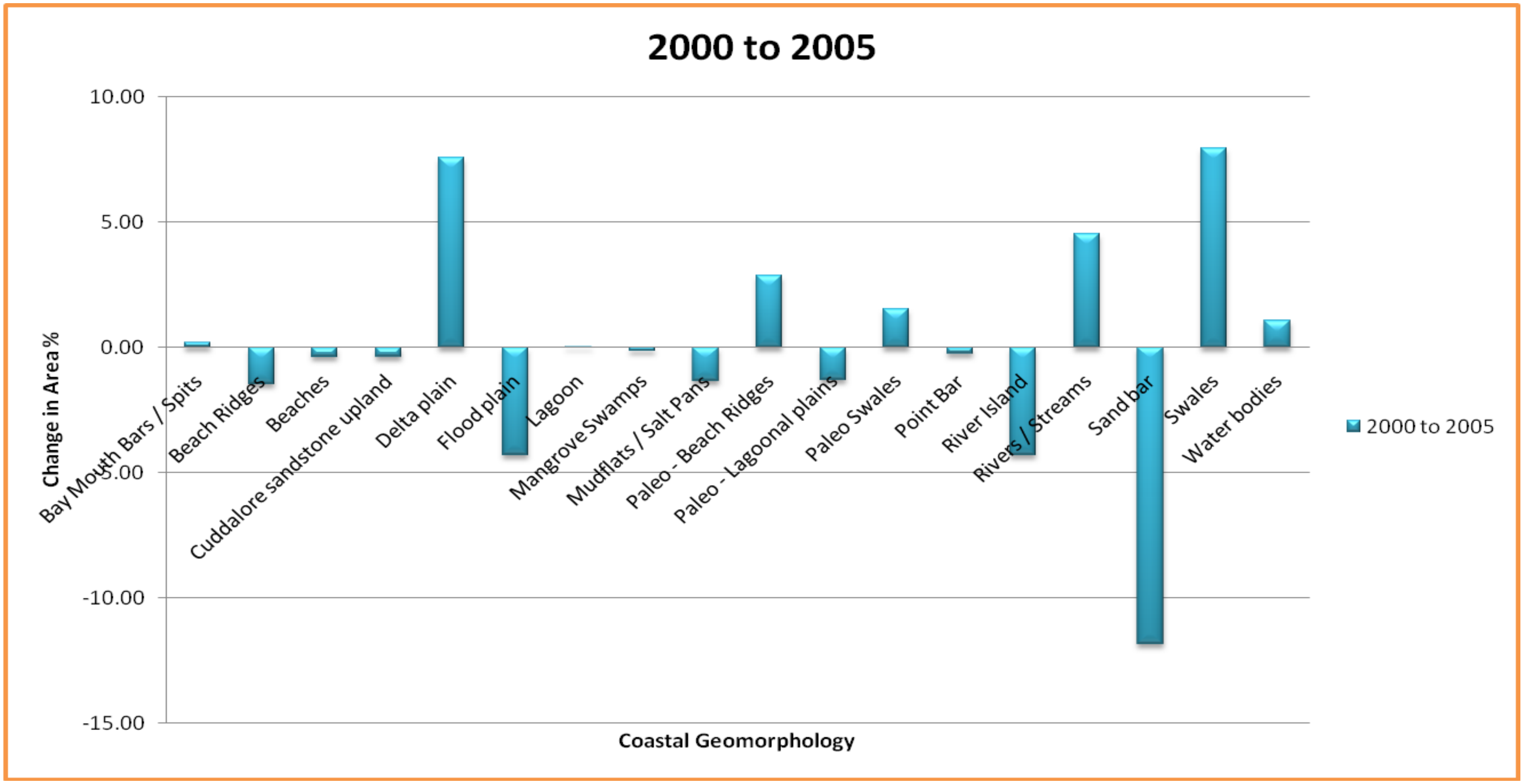

Fig.4.4. Coastal Geomorphology Changes (2000 to 2005)

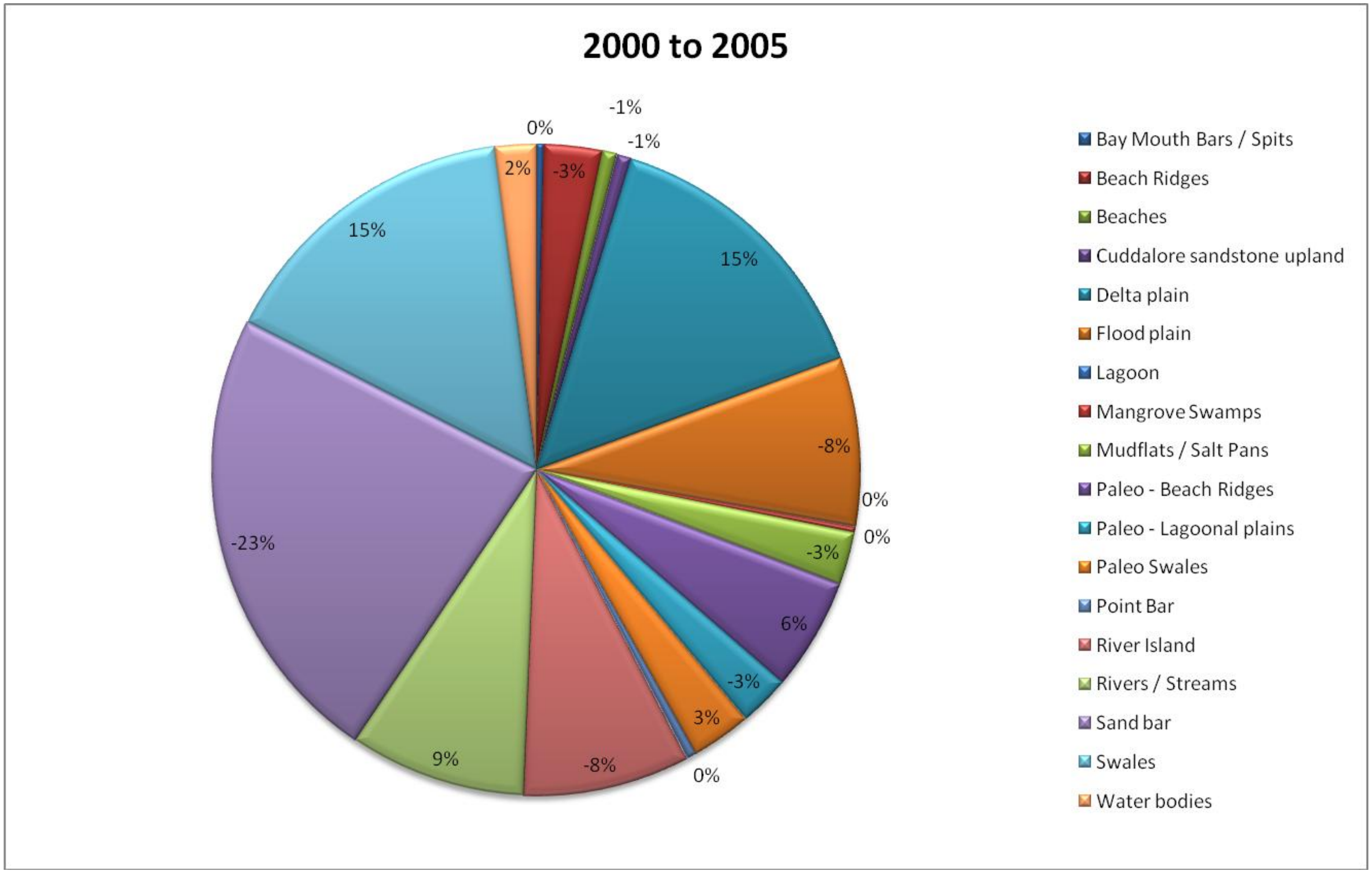

Fig.4.5. Coastal Geomorphology Changes (2000 to 2005)

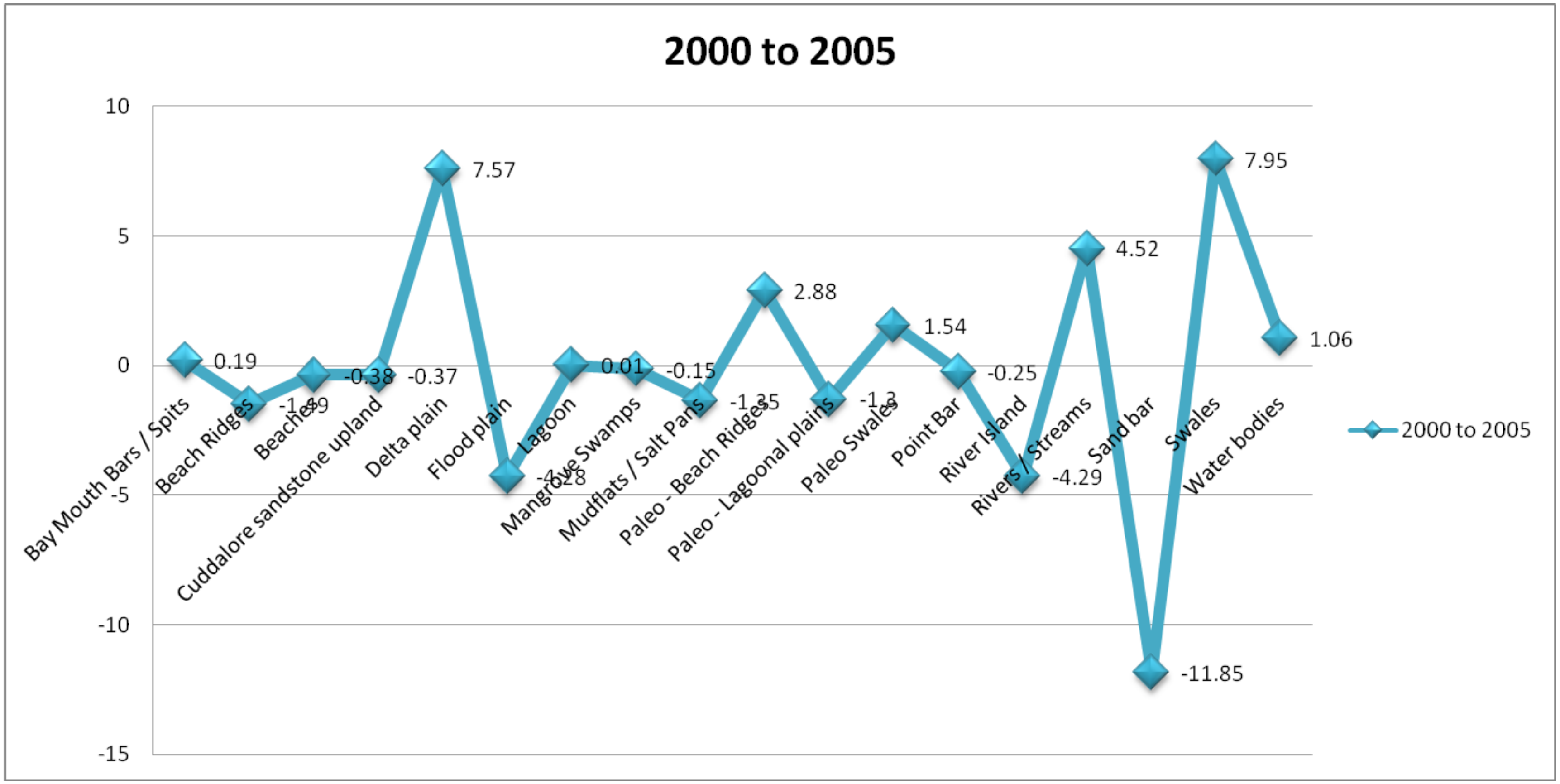

Fig.4.6. Coastal Geomorphology Changes (2000 to 2005)

TSUNAMI IMPACTS

Tsunami is a series of massive ocean waves, caused by submarine earthquakes that set off waves with long wavelengths in water and the most destructive tsunamis are caused by subduction zone earthquakes, landslides, volcanic eruptions, nuclear explosions, and even impacts of objects from outer space (such as meteorites, asteroids, and comets). “Tsunami devastated inundation in the southeastern coastline of India and the eastern coastline of Sri Lanka is known in geological parlance as tsunami. The tsunami is reported to have encroached 500m to 2km at various places according to the flatness of several beaches (GSI, 2005). A tsunami which causes damage far away from its source is sometimes called a "teletsunami", and is much more likely to be produced by vertical motion of the seabed than by horizontal motion (Lorca, 2005). The term tsunami is a Japanese word which means harbour waves (tsun means harbour and nami means wave) (Bryant, 2001). Land cover change plays a vital role in regional, social and economic development and global environmental changes. It contributes significantly to earth—atmosphere interactions. Biodiversity loss is a major factor in sustainable development and human response to global change, and is important in integrated modeling and assessment of environmental issues in general. Scientists, researchers and planners have paid much attention to the issues of land cover change over the past decade.

Table 5.1 People affected by South East Asian Tsunami (December 2004)

Country	Deaths (No)		Injured (No)	Missing (No)	Displaced (No)
	Confirmed	Estimated			
Indonesia	1,73,981	2,20,000	~100,000	6,245	4,00,000-7,00,000
Sri Lanka	38,195	38,195	15,686	23,000+	~573,000
India	10,744	16,413	—	5,669	380,000
Thailand	5,305	11,000	8,457	4,499	—
Somalia	~150	298	—	—	5,000
Myanmar	59	290	45	7,000	3,200
Malaysia	68	74	299	—	—
Maldives	82	108	—	26	12,000 – 22,000
Seychelles	3	3	—	—	—
Tanzania	10	10+	—	—	—
Bangladesh	2	2	—	—	—
South Africa	2	2	—	—	—
Kenya	1	2	2	—	—
Yemen	1	1	—	—	—
Madagascar	—	—	—	—	~1,000
Total	228,601	~288,608	~125,000	~40,000	~1.5 million

Source : Wikipedia, 2005

~ = Approximately

A number of studies have been carried out using various methodologies and algorithms to derive land cover and change information from different sets of remotely sensed data. Natural disasters are inevitable, and the Japanese Islands are prone to all type of natural disaster such as flood, drought, typhoon, earthquakes and forest fires. Disasters can be classified in several ways. Possible sub-divisions are: 1) Natural Disasters, 2) Human made disasters, and 3) Human induced disasters. Another sub-division is related to the main controlling factors leading to a disaster. These may be meteorological, geomorphological/ geological, ecological, technological, global environmental and extra terrestrial. Some disasters strike within a short period with devastating outcomes; others have a slow onset period with equally or even more serious repercussions. The tsunami affected countries in Southeast Asia and beyond included Thailand, Sri Lanka, India, Indonesia, Malaysia, Somalia, Myanmar, Maldives etc. In India the most affected areas are Tamil Nadu, Andhra Pradesh, Union Territory of Pondicherry and Andaman and Nicobar Islands. Table 6.1 gives statistical details in South East Asia (Wikipedia, 2005).

5.1 Tsunami impact in India

In India the death toll is estimated to be more than 9500 people in the states of Tamil Nadu, Pondicherry, Andhra Pradesh, Kerala and Andaman and Nicobar Islands. Table 5.2 gives the details of state wise Indian Scenario (Wikipedia 2005).

Table 5.2 Tsunami Losses – Indian Scenario

Details	Andhra Pradesh	Kerala	Tamil Nadu	Pondicherry	Total
Coastal Length Affected in km	985	250	1,000	25	2260
Penetration of water into main land in km	0.50-2.0	1-2	1-1.5	0.30-3.0	
Villages affected (Nos)	301	187	376	33	894
Average height of the tidal wave (m)	5	3-5	7-10	10	
Population Affected (in lakh)	2.11	24.70	8.90	0.43	36.14
Dwelling Units	1,557	17,381	1,28,394	10,061	154089
Cattle cast	195	-	9,559	506	10068
Cropped area (ha)	790	-	10,245	792	4248
Boats damaged (Nos)	1,362	10,065	45,920	6,678	64,025

Source : Wikipedia 2005

India usually experiences several cyclones each year, which impact different areas. As a result, the government has a well organized procedure for dealing with natural disasters. The difference between responding to the aftermath of a cyclone and the recent tsunami was the size of the area and number of persons, buildings that were affected. The occurrence of tsunamis in India is a rare one and it is reported to have occurred only in 1881, 1883, 1941 and 1945 (Wikipedia, 2005). The details of previous tsunamis are given in Table 6.3. This study has been carried out to identify the impact of December 26, 2004 tsunami on the study area, using satellite data and GIS Technologies.

Table 5.3 Details of Previous Tsunamis in India

Date	Cause	Impact	Source
31st December, 1881	Earthquake beneath Car Nicobar (7.9 Richter scale)	Entire east coast of India and Andaman & Nicobar Islands; tsunamis of 1m height waves were recorded at Chennai.	Bilham 1881
August, 1883	Explosion of the Krakatoa Volcano in Indonesia	East coast of India, tsunamis of height 2m were recorded at Chennai.	Bapat 1883
26th June, 1941	Earthquake in the Andaman archipelago. (8.1 Richter scale)	East coast of India was affected but no estimates of height of the tsunami is available	Bapat 1941
27th November, 1945	Earthquake at a distance of about 100km south of Karachi (8.5 Richter scale)	West coast of India from north to Karwar was affected; 12m tsunami was felt	Bapat 1945

Source: Wikipedia 2005

5.2 Tsunami impacts in Tamilnadu

Tamil Nadu alone accounts for 7923 deaths. In Tamil Nadu average height of tsunami waves was 7 to 10 m affecting 362 villages with 1, 12,748 dwelling units covering a population of 6.9 lakhs. In Tamil Nadu, the worst affected areas are Nagapattinam, Cuddalore, Chennai and Kanyakumari. Apart from this, portion of areas in other district also got affected. In Table 5.4. Details of impact of tsunami in Tamil Nadu and Pondicherry have been given. At present around 8000 people have died and extensive damages have occurred to many boats and catamaran in the coastal area. Most of the roads, bridges have been washed away by the recent tsunami.

Numbers of settlements have been washed away in the Chennai, Nagapattinam, Cuddalore, and Kanniyakumari districts. Most of the communication lines were snapped and wells in area have been affected by the intrusion of Seawater. The tsunami created extensive damage. Tsunami waves penetrated inland up to 2 kms causing very extensive damage in Nagapattinam, moderate in Pondicherry (penetrated inland up to 1 km) and not much effect in Tuticorin coast due to the intrusion of seawater. So it is the need of the hour to assess the exact damage caused due to the recent tsunami (Table 6.4).

Table 5.4 Impact of Tsunami in Tamil Nadu and Pondicherry

Sl. No.	Loss	Tamil Nadu	Pondicherry
1.	Villages affected (No)	362	33
2.	Population affected lakhs)	6.91 lakh	43,000
3.	Dwelling Houses affected (No)	1,12,748	10,061
4.	Cattle lost (No)	5,477	506
5.	Cropped area hit	2,589 ha	792 ha
6.	**Damage estimated (in Rs.)**	**2,730.70 Cr.**	**512.00 Cr.**

Source: Ministry of Home Affairs (2005)

Run-up is a measurement of the height of the water onshore observed above a reference sea level. As the tsunami wave travels from the deep-water, continental slope region to the near-shore region, tsunami run-up occurs. Table 5.5 shows pictorial run up along the coast of Tamil Nadu. The tsunami wave heights vary between 2.5 to 5.2 m. in these regions. The combination of high run up, low topography and dense development apparently accounted for the large loss of life and property. The surge water elevations, together with surge water depths appear to be important parameters in tsunami hazard analysis (GSI, 2005).

Table 5.5 Details of run up survey along the coast of Tamil Nadu

Location	Lat/Long Degree/Mintues/ Seconds	Run up elevation (m)
Pulicut	13° 23' 04" 80° 19' 98"	3.2
Pattinapakkam	13° 11' 26" 80° 26' 72"	2.7
Kovalam	12° 47' 45" 80° 15' 00"	4.3
Kalpakkam	12° 30' 37" 80° 09' 68"	4.1
Periakalapet	12° 01' 54" 79° 51' 88"	3.9
Puttupatinam	11° 51' 61" 79° 48' 92"	2.6
Devanampattinam	11° 44' 57" 79° 43' 23"	2.5
Parangipettai	11° 30' 96" 79° 45' 94"	2.8
Tarangambadi	11° 01' 62" 79° 51' 35"	4.4
Nagapattinam	10° 45' 78" 79° 50' 92"	5.2
Pondicherry	11° 50' 00" 79° 45' 00"	2.6

Source: Survey of India 2005

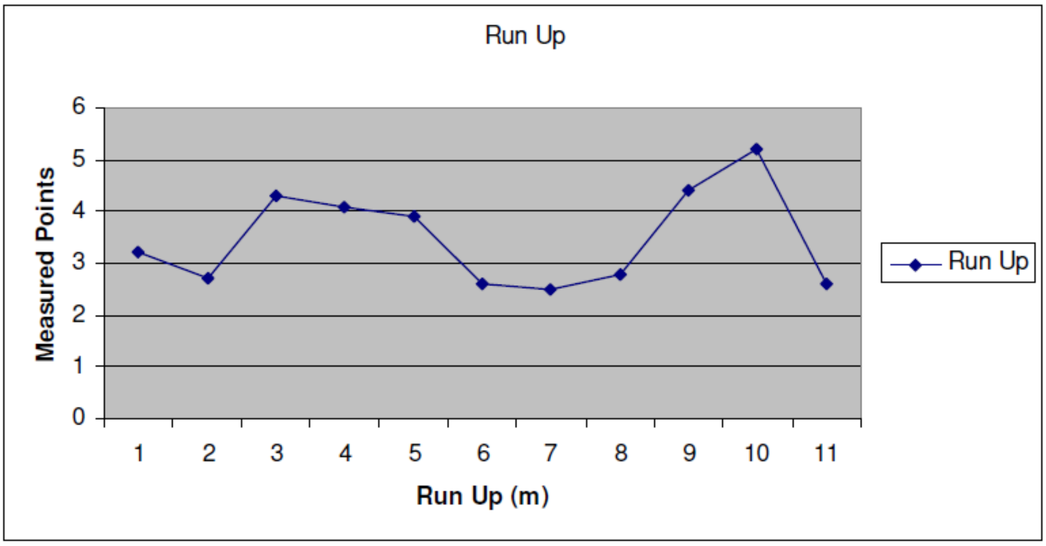

Fig.5.1 Run Up Measurement (Source: Survey of India 2005)

5.3 Tsunami Impact in the Study Area

All three areas under study were found to be affected by the tsunami. Nagapattinam is one of the hardest hit cities on India's east coast. There is extensive damage throughout the coastal portions of the city, and damage up to the river valley in south of the town centre. In the north of the city, there is moderate to extensive damage to houses along the northern edge of the town, with the greatest damage to buildings closest to the ocean. The lighthouse near the mouth of the river harbor is intact, but the buildings around it have suffered moderate damage, and the area has been heavily eroded. The tank farm at the mouth of the river appears undamaged. The two barriers at the mouth of the river on each side have been damaged. The northern barrier has sustained heavy damage near the shore. The impact of Tsunami was very less in the northern sector from Pondicherry to Marakkanam as these shores is characterized by somewhat high relief marked by series of sand dunes with vegetation. The southern sector from Pondicherry to Cuddalore was affected much because of gently sloping nature of the coast, the presence of many river mouths, creeks estuaries and lack of sand dunes.

5.4 Results and Discussion – Nagapattinam and Cuddalore

5.4.1 Visual discrimination of Satellite data

In Nagapattinam coast, there are dense households from the coast up to 1.5 km. Tsunami has devastated the Nagapattinam area with the death toll of above 6065 people (Table 5.1) and damaging as many as 40,000 houses (social work department,

2005) (Table 5.2). Complete and partial destruction of buildings in Akkaraipettai, Velankanni, Seruthur, and Pratabaramapuram are the affected villages in Nagapattinam of Nagapattinam district (Figure 5.4). The worst affected Nagapattinam (Light house transect) showed longer penetration of seawater (750m) up to an elevation of 3.9 m due to the gentle slope of coastal land combined with the effect of Tsunami wave. Presence of creeks like Velakanni canal in Vadakkupoyyur facilitated the seawater inundation of 1.95 km to an elevation of 5.6m, respectively. In Velankanni village, the lands interrupted by streets and buildings and open beach led to the penetration of sea water up to 950 m with the maximum run up level of 4.3m. Coastal lands with heavy plantation and sand dunes in Therkupoyyur and Pratabaramapuram villages showed a sea water intrusion level of 250m and 282m and up to the elevation level of 4.6 and 3.3m respectively.

6. Results and Discussion

The Chapter 4th deals with coastal geomorphology of the study area. A brief report of regional geomorphology has been given in order to provide the geomorphological set up of the region. Coastal Geomorphology has been described in three sections namely 1. Distribution 2. Description and 3. Change deduction of land forms. Under the distribution, the geographical display of land forms has been described. Under the description, individual land form characteristics have been detailed. Under the Change deduction, individual land form characteristics have been detailed. The land forms noticed in the study area are Bay Mouth Bars / Spits, Beach Ridges, Beaches, Cuddalore sandstone upland, Deltaic plain, Flood plain, Lagoon, Mangrove Swamps, Mudflats / Salt Pans, Paleo - Beach Ridges, Paleo - Lagoonal plains, Paleo Swales, Point Bar, River Island, Rivers / Streams, Sand bar, Swales, Water bodies etc.

The delta plain contains mostly silt and clay in the subsurface and is covered by out wash plain on the surface. Beach ridges are divided in two typically one Paleo - beach ridges; second one is Younger beach ridges. Paleo - beach ridges and Younger beach ridges prominently well-developed between Cuddalore and Nagapattinam. The width of beach ridge plain decreases towards both the north of Nagapattinam and north of Portonova and only a few narrow ridges are noticed here. Swales are present in between the beach ridges. The swales occurring between the older beach ridges are designated as paleo lagoonal plains and swales observed in the Paleo – beach ridges side of younger beach ridges are designated. Paleo lagoonal plains occur bordering the Paleo - beach ridges and mudflats occur bordering younger beach ridges. The river of Cauvery has migrated from Kattumavadi in the south to the present Coleroon in the north. Thick Mangrove vegetation is noticed around the Pitchavarm lagoon. Another lagoon occurs at Nagore south, Pudupettai, Chinnakuda, Nambiarkuppam etc. All the features mentioned above are bordered in the west by Cauvery deltaic alluvial plain that extends inland up to 70 km, where it is bordered by hinterland features. In the northwest and middle west part of the study area, Cuddalore sand stone (Mio-Pliocene age) uplands occur. These uplands are bordered in the west again by hinterland features. In general, following major changes in Coastal Geomorphology were observed in the Bay Mouth Bars / Spits, Beach Ridges, Beaches, Cuddalore sandstone upland, Deltaic plain, Flood plain, Lagoon, Mangrove Swamps, Mudflats / Salt Pans, Paleo - Beach Ridges, Paleo - Lagoonal plains, Paleo Swales, Point Bar, River Island, Rivers / Streams, Sand bar, Swales, Water bodies during change study periods.

The study areas landforms were increased and decreased between 1980 and 2015 for each five year time intervals (Table 4.2, 4.3 and Figure. 4.1, 4.2, 4.3, 4.4, 4.5, 4.6 and 4.7). The Vellar River and to the north and south by the Muzhukkuthurai lagoon. A vegetated coastal dune with a length of about 1.5 km protected the island. Tsunami waves ranging in height from 4 to 6 meters breached the dunes, caused erosion and carried debris of destroyed coastal buildings westward to more than 50 m inland. The tsunami run up was up to 1.3 m. Very fine sand with a thickness of one meter filled the Muzhukkuthurai lagoon in the west. Heavy erosion resulted in a steep beach gradient. Sediments transported from the SE and the SSE direction resulted in greater accretion along the intertidal region. The sediment layer exhibited trampled and load structures, indicating deposition by the flooding and receding motion of the water, moving at high velocity. The sediments ranged from fine to medium in size and were well sorted.

The fore dunes offered coastal protection by reducing tsunami wave velocities and by refracting wave paths. However, they were completely eroded. The waves not only altered the geomorphic features and adjoining areas but also brought voluminous sediments from the shelf and the coast. The Tsunami sand bars developed in the south with orientation perpendicularly to the coast. This is evidence of changes in local coastal morphology and wave direction caused by the Tsunami. Small-elevated land surfaces could also be seen near the mouth of the Vellar River immediately after tsunami, but slowly these became flatter and merged. Complete closure of both the Vellar estuary and the Muzhukkuthurai lagoon inlet were evidence of post Tsunami sedimentation. Also, reworked dune sediments were deposited in the Muzhukkuthrai lagoon west of the M.G.R. Island. In the canal, the thickness of the tsunami deposit was about one meter. These changes were evidence of the ferocity of tsunami waves. Near the coast, the thickness of the tsunami deposits varied from 5 to 15 cm. The erosional features were more prominent in the small island. Tsunami waves had eroded the profile of the beaches to a depth of about 120 cm. Tsunami deposits had a buff coloration and could be easily differentiated from normal tidal dune sediments. Trampled structures were prominent over the planar beds. This was indicative that the sediments were deposited under conditions of high water velocity and turbulence.

The presence of the fine sands indicates deposition from suspension. Tsunami deposits were well to very well sort in character. Sands which are normally deposited on portions of beaches within the breaking wave zone wash continuously thin sheets of sediments which invariably lack admixtures of fine-grained sediments (Friedman and Sanders, 1978). The shelf region normally contains well-sorted river sediments deposited by rivers during the ice age, when the coastal areas emerged. Though the wave action is considered to be responsible for sorting the sediments on the beaches, the dominance of well-sorted sediments is attributed to improvement of uniformity in grain size by the removal of both coarser and finer fractions by strong wave energy. Well to very well sorted sediments in the study region indicated sudden winnowing or back and forth motion by the depositing agent. Friedman (1961) has attributed that such winnowing action is the reason for positive skewness of beach sands and that such action removes the fine grained particles leading to a back of tail of fine-grained material. Also, predominant positive skewness in size of sediments indicates unidirectional transport (channel flow) or deposition in sheltered, low energy environment (Brambati, 1969). The sediment characteristics in the study area indicated scouring which changed the local bathymetry from 20 to 30 m, i.e. the low energy marine environment where waves cannot interact with seabed sediments. The leptokurtic nature of sediments indicated fluctuation in energy conditions of the depositing medium.

7. Conclusion

The 26th December, 2004 tsunami event along the Tamilnadu coast brought lot of geomorphic and sedimentological changes. In the study area the tsunami resulted in the breaching of sand dunes, the filling of lagoon, erosion and the loss of numerous lives. It can be concluded from the study that stabilized dunes with vegetation offer some protection to the coast from natural marine disasters like cyclone surges, tsunamis or extreme storm waves. Also that the Vellar river and the Muzhukkuthurai lagoon reduced tsunami inundation and extent of destruction in the inland region. Thus, the coastal morphologies played an important role in protecting the coast and the coastal communities. The particle size analysis in the study area indicates that the sediments that were deposited by the waves of the tsunami inland ranged from fine to medium, well-sorted sands. These deposits showed typical color and textural variations from the normal tidal sediments. Near the estuary they were superimposed over the pre-existing dark carbonaceous estuarine clays. Overall, the deposits exhibited trampled structures over the planar beds which indicate that the tsunami deposition of sediments occurred under high wave velocity conditions.

The study has revealed that the central coastal parts of Tamil Nadu, namely Cuddalore – Nagapattinam districts, which were worst affected by the recent tsunami, expose a combination of landforms of tectonic, fluvial, fluvio – marine and marine processes. These different landforms have responded differently to the recent tsunami viz: as facilitators, carriers, accommodators, absorbers, barriers etc. on the basis of the same, different eco – friendly, cost effective and result oriented methods are suggested to mitigate the effects of tsunamis.

The present study shows that satellite remote sensing based land cover mapping is very effective for Coastal Geomorphology changes. The high resolution satellite data such as IRS LISS III data and Landsat ETM are excellent source to provide information accurately. From this study, it has been observed that important coastal landforms types like Bay Mouth Bars / Spits, Beach Ridges, Beaches, Cuddalore sandstone upland, Deltaic plain, Flood plain, Lagoon, Mangrove Swamps, Mudflats / Salt Pans, Paleo - Beach Ridges, Paleo - Lagoonal plains, Paleo Swales, Point Bar, River Island, Rivers / Streams, Sand bar, Swales, Water bodies drastically reduced. The Coastal landforms management plan need to protect the important of coastal zone. It is use for before extinction. Thus, the present study clearly reveals that various geosystems especially the tectonic and geomorphic features have played a vital role in Tsunami inundation and hence long term mitigation measures will have to be carved out on the basis such geosystems. It should be admitted here that one important parameter that definitely has they approach the shoreline and cause inundation and damage, is the nature of the slope of the near continental shelf in relation to the sea levels above it. If data on these parameters is also obtained in the near future (Physical oceanographic studies), that would further help in planning appropriate strategies at different sections of the coast.

References

Agarwal,R.P. and Mitra,D. (1991) Geomorphology of Cauvery basin Tamil Nadu, based on interpretation of Indian Remote Sensing Satellite (IRS) data. Jour. Indian Soc. Remote Sensing, No.19, pp.263-267.

Ahmed,E. (1972) Coastal Geomorphology of India. Orient Longman. New Delhi, 222p.

Anbarasu, K. and Rajamanickam, C.V. (2002) Coastal erosion around Pondicherry and Ennore along the East Coast of India. Jour.Geol.Soc.India, v.60(5), pp.519-526.

Babu,P.V.L.P (1975) A study of Cyclic Erosion Surfaces and Sedimentary Unconformities in the Cauvery Basin, South India. Jour. Geol. Soc. India, v.16, pp. 349-359.

Ballukraya, P.N. (2005) Tsunami of 26th December 2004: observation at Chennai and east coast of India. Jour. Geol. Soc. India, v.65(3), pp.368-369.

Elliiot,C.I., Joyce, E.B., Bishop, I., Ramasamy, SM. and Kumanan, C.J. (1998) Lineaments of Southeastern India and their relationship to Drainage Pattern and Groundwater Flow. Proc. Vol. on Int. Association of Hydrogeologists, University of Melbourne, Feb. 8 – 13, pp.131-135.

Geosystem Responses to December 26, 2004 Tsunami 291

Jayanthi, N. and Sen Sharma, A.K. (1988) A catalogue of storm surges in India. Prepublished scientific report. India Meteorological Department, Madras, P.21.

Le Pichon. (1968) Sea Floor spreading and continental drift. Jour. Geophys. Res., v.73, pp.3661-3697.

Mohan,P.M., Shephard,k., Angusamy,N., Suresh Gandhi, M. and Victor Rajamanickam,G.(2000) Evolution of Quaternary Sediments along the coast between Vedaranniyam and Rameshwaram, Tamil Nadu. Jour. Geol. Soc. India, V.56(3), pp.271-283.

Narasimhan,T.N. (1990) Palaeochannels of the Palar river west of Madras city: Possible implications for vertical movement. Jour. Geol. Soc. India, v.36, pp.471-474.

Narayana, A.C., Tatavarti. R. and Mudrika Shakdwipe (2005) Tsunami of 26 December 2004: Observations on Kerala coast. Jour. Geol. Soc. India, v.65(3), pp.239-246.

Prasad, K.N. (1978) Studies on the Quaternary Geological formation of Peninsular India. Third Regional conference On Geology and Mineral Resources Of Southeast Asia, Bangkok, Thailand, pp.4423-426.

Radhakrishna, B.P. (1992) Cauvery – its geological past, Jour. Geol. Soc. India, v.40(1), pp.1-12.

Radhakrishna, B.P. (2005) O, horrible! most horrible! – Devastating Tsunami Strikes Coastline of India on 26th December 2004. Jour. Geol. Soc. India, v.65, no.2, pp.129-134.

Rajamanickam, G.V. (1996) A synoptic view of Quaternary sediments and their importance to natural resources. Proceedings of first Regional GEOSAS Workshop on Quaternary Geology of South Asia, Dept. of Geology, Anna University, Chennai, pp.257-276.

Ramasamy SM, 2006. Remote Sensing and Active tectonics of South India. International Jour. Remote Sensing, Taylor and Francis, London, Vol.27, No.20, pp. 4397-4431.

Ramasamy, SM. (1989) Morpho – Tectonic Evolution of East and West Coasts of Indian Peninsular. Geol. Surv. India Spec. Publ., No.24. pp.333-339.

Ramasamy, SM. (1991) Remote Sensing of River Migration in Tamil Nadu. NNRMS Bulletin, Vol.B-(14), pp.25-28.

Ramasamy, SM. And Balaji, S. (1995) Remote Sening and Pleistocene Tectonics of Southern Indian Peninsula. Int. Jour. Rem. Sen., Taylors and Francis, London, v.16(13), pp.2375-2391.

Ramasamy, SM. and Kumanan, C.J. (2000) Eyed Drainages Observed in IRS Imagery in Tamil Nadu and their Geological Significance. Intl. Jour. Remote Sensing, V.21(3), pp.475-481.

Ramsamy SM, 1999. Tectonic and Geomorphic Evolution of West coast along Mangalore-Cape Comorin sector, India. Indian Jour. Geomorphology, Vol. 4, No. 1&2, pp.115-126.

Reprinted from Journal Geological Society of India, Vol.68,pp-967-983,2006
Reprinted from Journal Geological Society of India, Vol.68,pp-967-983,2006
Subrahmanya, K.R. (1994) Post Gondwana tectonics of the Indian Peninsula. Curr. Sci., v.67(7), pp.527-530.

Vaidyanadhan, R. and Ghosh, R.N. (1993) Quaternary of the east coast of India. Curr. Sci., v.64, pp.804-816.

Valdiya, K.S. (1998). Late Quaternary movements and landscapes rejuvenation in southeastern Karnataka and adjoining Tamil Nadu in southern Indian shield. Jour. Geol. Soc. India, v.51 (3), pp.139-166.

Vemban, N.A., Subramanian, K.S., Gopalakrishnan, K. and Venkata Rao, V. (1977) Major Faults / Dislocations / lineaments of Tamil Nadu. Geol. Surv. IndiaMisc. Publ. no.31, pp.53-56.