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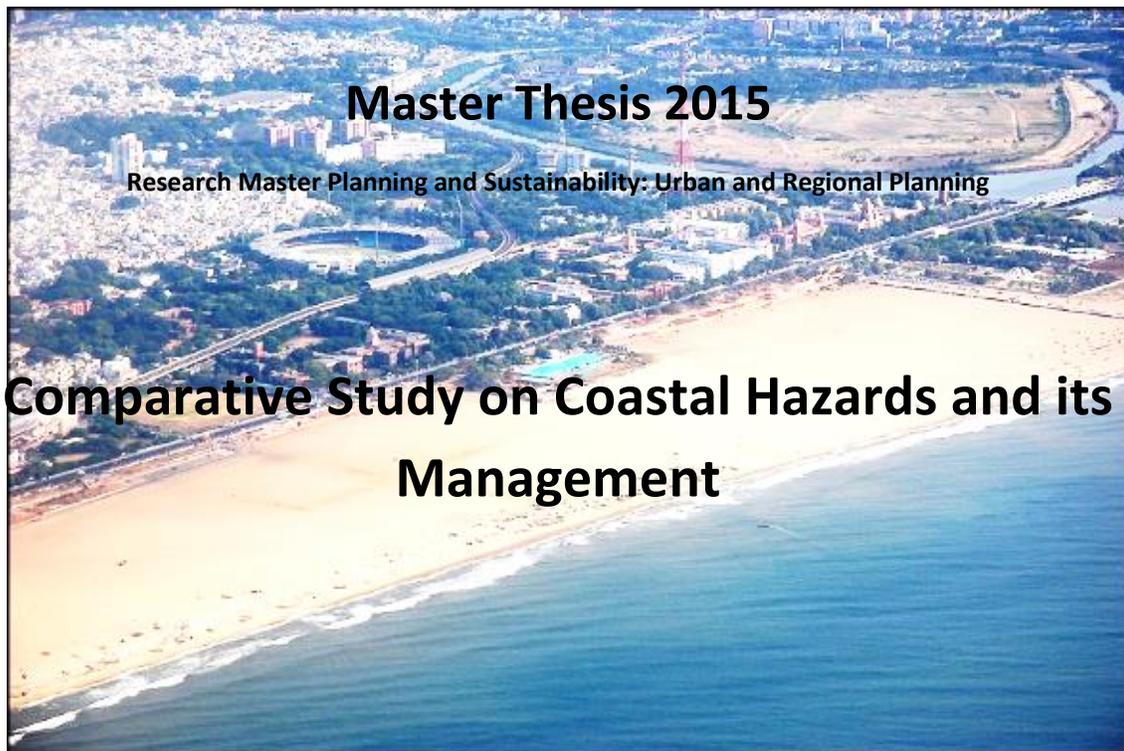
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LIST OF SYMBOLS AND ABBREVIATIONS

CMDA	Chennai Metropolitan Development Authority
CRZ	Coastal Regulation Zone
DRR	Disaster Risk Reduction
EIA	Environmental Impact Assessment
GIS	Geographic Information System
HFA	Hyogo Framework for Actions
HTL	High Tide Line
ICMAM	Integrated Coastal and Marine Area Management
ICMAM-PD	Integrated Coastal and Marine Area Management Project Directorate
ICZM	Integrated Coastal Zone Management
LTL	Low Tide Line
MoEF	Ministry of Environment and Forest
MoES	Ministry of Earth Sciences
MPA	Marine Protected Areas
MSL	Mean Sea Level
SLR	Sea Level Rise

CHAPTER 1

INTRODUCTION

Coast, the boundary between land and sea is directly or indirectly influencing the humans. Coastline is the line where the land and sea come in contact and this cannot be fixed as it varies from place to place depending on various factors. Hence the term coastal zone is used to refer the area adjacent to sea. This coastal zone provides a variety of functions which attracts population. More than half of the world's population live in coastal zones. The high level of bio-diversity it offers makes people dependent on it for various uses. Due to its vibrant natural beauty, recreational opportunities and economic benefits like tourism, fishing, shipping, etc., it offers coastal zones are treasured world over. These coastal areas are major contributors of global economy in many countries with wide beaches attracting large number of tourist.

However with the wide range of benefits they provide, coastal zone also comes with vulnerabilities which puts human life and other infrastructure and properties to risks. This is due to the dynamic nature of the coast. The unstable coast is dominated by winds from sea and sea level changes. They face a lot of environmental challenges including those influenced by human activities.

Although living along a coast has many advantages, it also comes with a unique set of hazards that can threaten lives, property, and economies. Natural disasters and shoreline erosion are two of the main threats that coastal communities face. Such communities are particularly vulnerable to hurricanes and tsunamis, and as more people move to the coast, the potential of such events causing catastrophic loss of life and property damage also rises. Shoreline erosion, a worldwide phenomenon that is often exacerbated by coastal storms, is also increasing due to a number of factors, including sea level rise and loss of wetland buffer areas.

These economically sensitive areas must be protected for the human well-being and other habitats dependent on it. Also it is necessary to protect the increasing population at the coast which are under risk. The sea level rise and climate change adds

additional pressure on these coastal zones and hence management measures are in emergency need. When these areas are not protected, the world would face its worst consequences from the various hazards such as flooding, erosion, storms, tsunamis, etc.

CHAPTER 2

THEORETICAL FOCUS

2.1. SEA LEVEL RISE

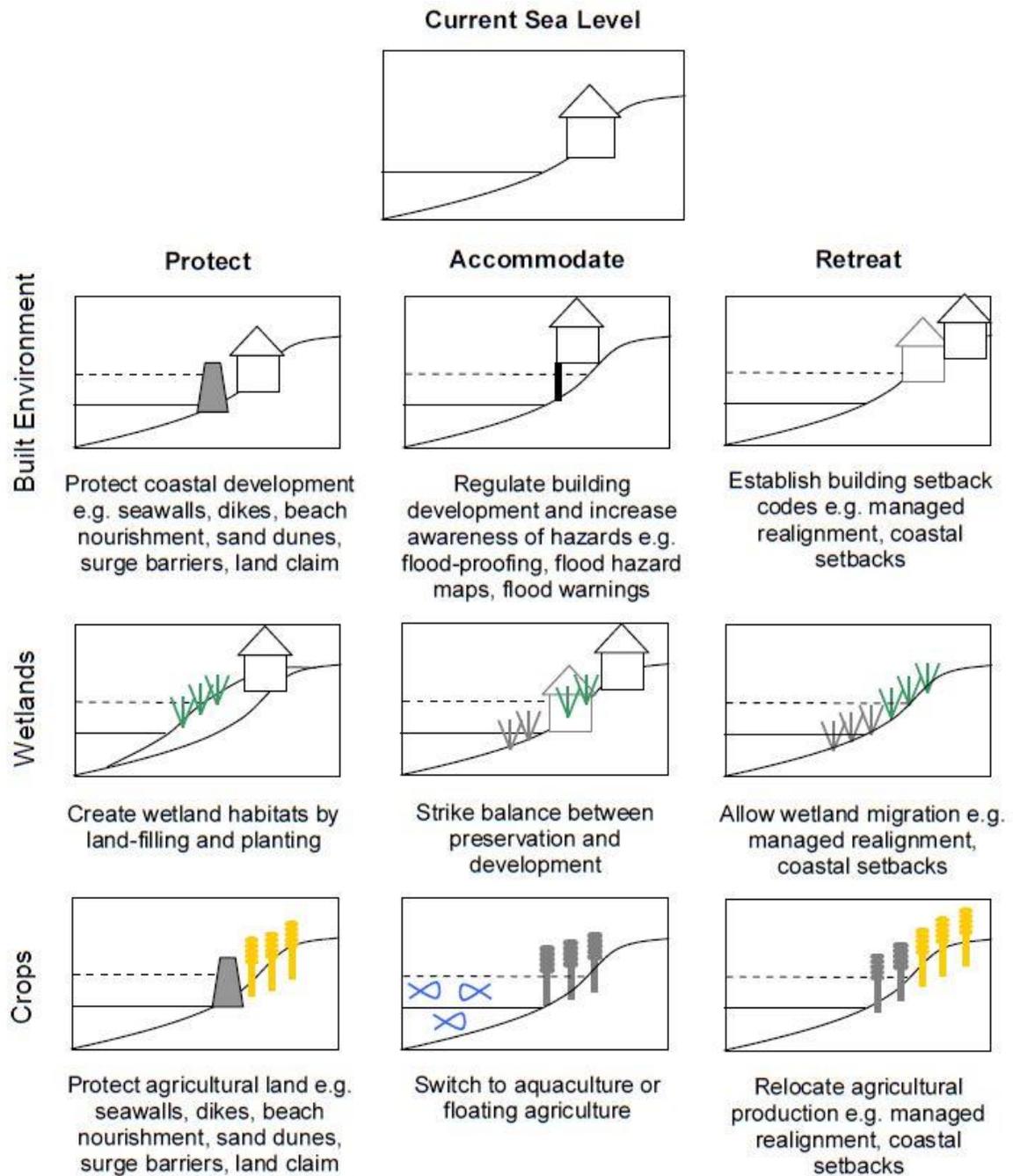
Sea Level Rise (SLR) refers to the increase in the Mean Sea Level (MSL). The rise in sea level is caused due to two main reasons namely:

- Thermal expansion of water due to the increase in temperature
- The huge volume of melting ice caps in the polar region

Sea level rise is largely influenced by climate change and global warming. The effects of hazards such as floods, earthquake, tsunami, etc., can be seen immediately while the effect of sea level rise is gradual and takes a long time to realize. The impact of sea level rise on the coastal zone cause loss to the habitats by inundating the wetlands nearby, flooding, salt water intrusion, etc. the rising sea level can exacerbate the process of coastal erosion and cause risks to low lying areas to a greater extend. This sea level rise is not uniform due to variations in oceanic process and the variability in the warming of climate. This may result in the increase in sea level above mean sea level or it can even decrease below mean sea level.

Even if the level remains unchanged, the result of sea level rise will be devastating with increased intensity of storm events and accelerate coastal erosion by promoting offshore sediment transport. The flooding caused due to increase in sea level will threaten the availability of drinking water to greater extend. Land subsidence is another important negative effect due to sea level rise in delta regions.

The adaptation to the rising sea level can be better explained in the following figure 1.1.



The dashed line represents future SLR. Grey houses and vegetation indicate their previous locations prior to relocation or natural migration

Fig.1.1. Adaptation to Sea Level Rise (Source: Technologies for Climate Change Adaptation)

2.2. CLIMATE CHANGE

The effects of climate change are being felt especially in coastal areas. The change in climate drives the change in temperature and the precipitation rate. It also change the pattern of storms and ocean currents. Due to climate change the flow in the rivers are likely to change. The variation in climate expose coastal areas to risk and threatens the biodiversity and ecosystem of the region. Sea level rise, coastal erosion, flooding, increased cyclones, changes in the species are some other effects of climate change. The coastal cities will face submergence due to climate change and the accompanying sea level rise. Similarly the sectors such as water resource, fisheries and tourism will have a bad influence due to climate change.

Impacts of climate change

Storms: climate change increase the wave heights and also intensify the storms reaching the coast. Particularly the storms in the tropical region accompanies greater devastating effect.

Ecosystem: the resilience of the ecosystem is reduced due to the climate change.

Economy: the increasing surface temperature along the coast makes the coastal areas unsuitable for tourist for recreation which in turn affects the economy of the areas depending on coastal areas for its economy.

Water quality: the quality of water is altered due to the climate change. This will be as a result of increased algal blooms

Coral reefs: coral reefs requires particular temperature for its growth and if the temperature of the water increases, the algae which live in the coral reefs die. When these algae are dead, the coral reefs are affected as they feed on these algae for their nutrition.

Mangroves: Mangroves have both positive and negative effect due to climate change. The increase in temperature increase the dissolved carbon di oxide and helps the growth of

mangroves. But at the same time the salt water intrusion and increased coastal erosion puts mangroves to risk.

2.3. COASTAL CLASSIFICATION

The coast can be classified into different categories based on the phenomenon under which it is classified. The general phenomenon considered in the classification of the coast are

1. Process
2. Materials
3. Forms
4. Age or stage of development
5. Environments (e.g. ecological regions, land systems, morphodynamic zones)

The most common system of classification of coast based on relative sea level rise is shown in the following table.

Table 2.1. Classification of coast based on sea level rise (Source: Coastal Classification: Systematic Approaches to Consider in the Development of a Comprehensive Scheme)

I. Submergence coasts
A. Ria coasts
B. Fjord coasts
II. Emergence coasts (with barriers) coastal plain shoreline
III. Neutral coasts
A. Delta coasts
B. Alluvial plain coasts
C. Outwash plain coasts
D. Volcano coasts
E. Coral-reef coasts
F. Fault coasts
IV. Compound coasts—any combination of the above types

Submergent/ Emergent coast: The coasts which emphasized relative movement of land and sea due to submergence or emergence.

Neutral Coast: This comprises of coast which are not mainly due to submergence or emergence.

Compound Coast: Coasts which shows the features of one or more other three main categories.

2.4. COASTAL HAZARDS

Coastal hazards in general can be divided into two based on the control of individuals. The one which have some control, e.g. the people agreeing not to live in vulnerable areas. The later in which people don't have control, e.g. tectonic failure or landslides.

This hazards can be broadly classified into the following types as described in the table below.

Table 2.2. Classification of coastal hazards

Classification	Cause	Hazards
Surface hazards including hydrological and physiographic (short term/ long term)	Natural/ human activities	High tide flooding, spring tide and equinoctial flooding; flash flooding, erosion of soft cliffs by slumping, land claim, removal of wetlands for urban and agricultural area, natural cliff failure, undercutting of hard cliffs
Climatological hazards (short term/ long term)	Natural/ human activities	Storm surges, cyclones, tropical storms, hurricanes,

		offshore surges, fluvial and pluvial flooding, ocean acidification, sea level rise, storminess, ingress of seawater/ saline intrusion
Tectonic hazards (Short term/ long term)	Natural	Natural tsunamis, seismic slippages, natural isostatic rebound
Anthropogenic hazards (Acute/ chronic)	Macrobial/ microbial/ technological/ chemical	Anthropogenic Sewage pathogens, Anthropogenic Alien, introduced and invasive species, bloom-forming species, Anthropogenic Infrastructure, coastal defenses, Anthropogenic Removal of space, removal of biological populations (fish, shellfish, etc.); seabed extraction and oil/ gas/ coal extraction leading to subsidence, Anthropogenic Pollution from one-off spillages, oil spills, Anthropogenic Diffuse pollution, litter/ garbage, nutrients from land run-off, constant land based discharges, aerial inputs

Coastal population are often vulnerable to coastal hazards such as tsunamis, floods and tropical cyclones. Many of them lose their homes, property and livelihoods and suffer from food insecurity. The polluted coastal environment become vulnerable to numerous water borne diseases and malnutrition.

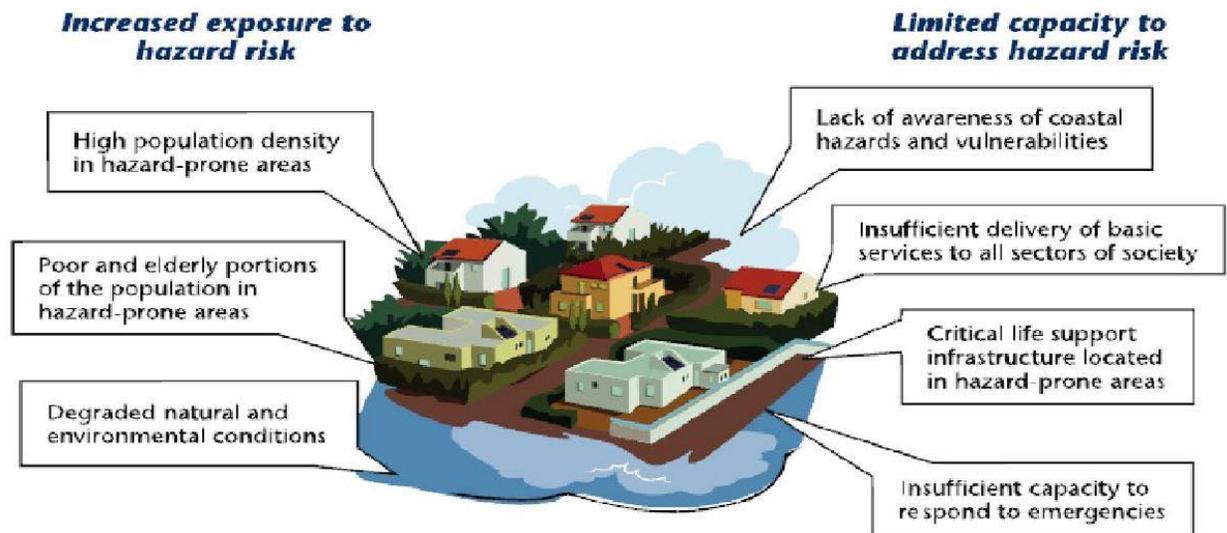


Fig.2.1. Factors contributing to the vulnerability of coastal population (How Resilient is your Coastal Community? A guide for evaluating coastal community resilience to tsunamis and other hazards, U.S IOTWS)

Causes of Coastal Hazards

Some of the causes that are responsible for the hazards in the coastal areas are explained briefly here.

Unsustainable Fishing:

Fishing has diminished due to habitat degradation, over fishing, trawling and bycatch. Another important reason for reduction is climate change. In contrast coastal fish farming is increasing as the demand for food and fresh water availability is increasing. This has led to the uncontrolled fishing and prohibition of fishing in certain

areas resulted in illegal fishing. Earlier intensive fishing was done only in concentrated areas and now it encompasses to all fisheries. Bycatch, the capture of unintended species in the name of fishing has disturbed the ecosystem offshore.

Reclamation of land:

The rapid urbanization and the attraction of people towards the coastal zone have made the land demand. As a result of this the coastal zones are reclaimed for the construction of residences in many developing and developed countries. For example, the consequence of increased land reclamation on coastal areas has put China's coastal and marine ecosystems into severe pressure.

Pollution and Waste:

Marine pollution from land based sources such as agricultural runoff, untreated sewage and debris from industries, discharge of pesticides and nutrients, spilling of oil while transporting petroleum through tankers, etc., are being a serious problem in coastal areas. The cause and effect, the mitigation and the management of non- point sources are in an international agreement as it is related to institutional/ industrial issue. Being an institutional issue, governments are unable to enact or enforce needed regulation to reduce or remove the problem.

Ports and Harbours:

The construction of ports and harbours affect the long shore drift over a period of time. This long shore drift in term affects the sedimentation pattern which lead to accretion or erosion in the sites. These effects are in long term basis and in short term, these ports and harbours are responsible for shoreline evolution.

Loss of biodiversity:

The degradation of ecosystem and loss of biodiversity in turn loss the ecological function and this makes the marine area less resilient and so its capacity minimizes to withstand additional stresses.

Coastal Hazards

Among the earlier mentioned hazards, some of the hazards are discussed in brief/detailed manner.

STORM SURGE

Storm surge which causes flooding is the most destructive form of storm in tropical areas. This is caused when the high winds and low atmospheric pressure combine beneath a storm resulting in increase in sea level rise.

One such example is the Hurricane Katrina which brought highest storm surge that was ever recorded in the US. It is said that the water raised 30 feet in some location. This massive storm with huge volume of water was responsible for the devastation of the coastal property and loss of lives.

SHORELINE CHANGE

Shoreline changes are induced by erosion or accretion of coastal areas by natural process taking place over a range of time scale. In the long term basis, the shoreline change may be due glacial melting, orogenic cycles which alter the sea level or due to tectonic movements which cause land subsidence or emergence of the coast. On the other hand as a result of short-term process, the shoreline change may be due to storms, winds, change in littoral currents, wave actions, etc.

Table 2.3. Shoreline changes and its causes

Cause	Effect
Geological changes and human interactions (groynes, cliff protection, detached breakwaters)	Erosion, backshore changes and emergence of headlands
Change in hydrodynamic forces	Change in wave diffraction in headland and offshore bank environments

Change to hydrodynamic influences	The influence of new tidal inlets and deltas on drift
Alterations of the sediment budget	Switch of shorelines from drift to swash alignment, exhaustion of sediment sources

Shoreline erosion that constantly change and shape the coast, puts the coastal population at risks. During the past centuries, the shoreline erosion has been in the increasing rate. With the growth of population, there is a continuous increase in the construction of homes, roads and other business structures on the coastal area. This increased developments makes the buffer zones such as coastal forests and wetlands to diminish, making the coast more vulnerable to erosion and flooding.

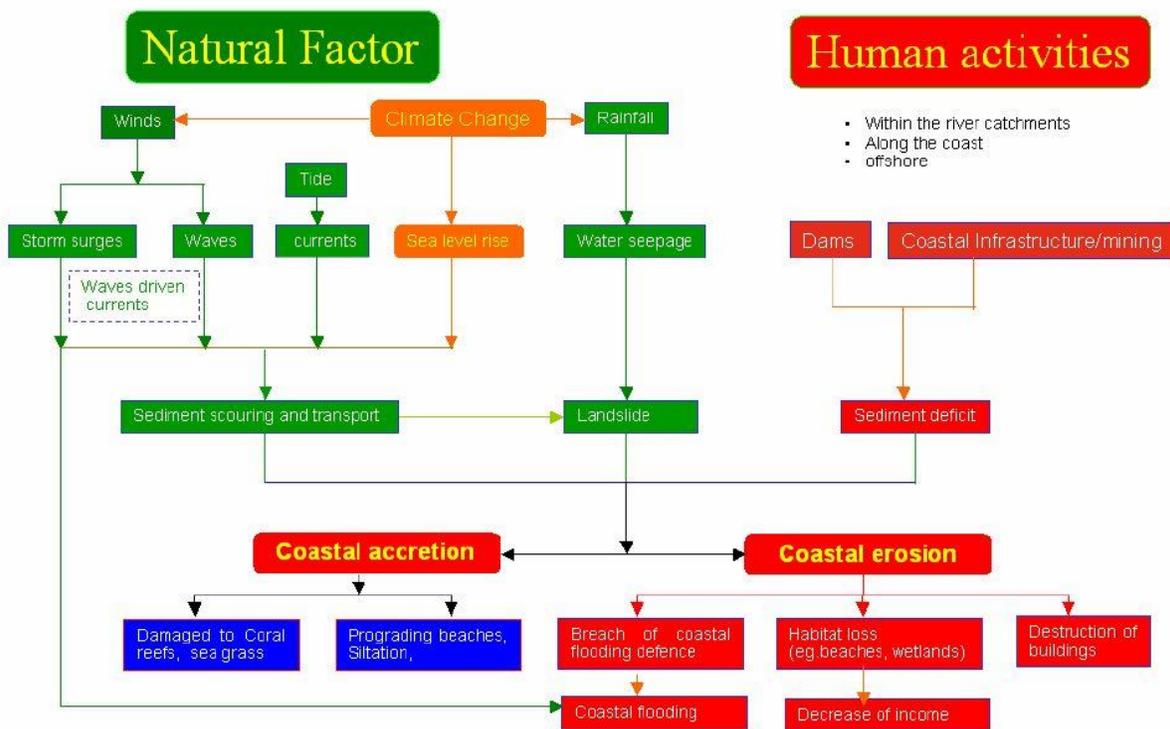


Fig.2.2. Complex process of shoreline change (Source: The role of coastal forests and trees in protecting against coastal erosion)

2.5. COASTAL PROTECTION AND MANAGEMENT

2.5.1. Protection Measures

Protection measures in general term involves the approach of protection and the other activities against particular problem. In the case of coastal protection, the protection measures comprises of two methods which are acting against coastal hazards such as flooding, shoreline erosion, inundation of low lying areas, tidal effects, salt water intrusion, loss of habitat and natural resources, etc. The two approaches/ methods include

1. Hard Solutions
2. Soft Solutions

1. HARD SOLUTIONS

These defences are followed by the coastal population as a traditional method of protection from the risks. The structures are tangible and act as a solid barrier between land and sea and thus protecting from the wave and tide effects. Some of the examples of hard solutions are discussed below.

Groynes:

Groynes are structures constructed perpendicular to the shoreline into the sea to prevent longshore sediment transport and the littoral current. These groynes are suitable in sandy areas to trap sediments moving into the sea. These structures can be constructed with materials like wood, bamboo, rocks, etc. and help in maintaining or stabilizing the beach width. It also helps in extending the life of beach fill.

The only disadvantage is that these structure are subjected to toe erosion and requires more than one structure at regular intervals.

Breakwaters:

Breakwaters are structures built parallel to the shoreline in order to form shielding of waves. These breakwaters may be submerged becoming invisible to the users without disturbing the visibility attractive. These breakwaters also help in the littoral drift of sediments.

The submerged breakwaters also serve as multi- purpose artificial reefs where the fish habitats develop and enhance. The detached breakwaters are one which have no connection with the shore so that waves reduce their action and pass between the breakwaters.

Seawalls:

Seawalls are hard engineering structures that are built primarily to protect the coast from the further erosion of the shoreline. They are built parallel to the shore line and helps in dissipating the wave energy. In addition it also helps in holding or preventing the soil that slide. Seawalls are constructed vertical or sloping using a wide variety of materials.

If designed and constructed properly, a seawall can be able to fix the boundary between the land and sea to ensure that no further erosion to occur. It protects the cliffs from wave attack and helps in stabilizing the slope. Seawalls are subjected to significant loading as a result of wave attack and hence while designing seawalls, the rise of sea level, wave heights and increase in storm intensity due to climate change should also be considered.

The disadvantage of seawall is that it interrupt the easy access of beach to the handicaps and also becomes unpleasing in case if the site is recreational and affects the tourist economy of the place.

Other engineering structures:

Dikes- high volume structures built to protect low lying coastal areas from inundation by the sea under extreme conditions.

Storm surge barriers and closure dams- these are structures providing high degree of protection against coastal flooding by preventing storm surges not entering the low lying estuarine areas.

Flood proofing- elevated structures above flood plain with designs and building materials which makes structures more resilient to flood damage and prevent flood water entering the zone.

2. SOFT SOLUTIONS

Soft solutions are in contrast to hard solutions. Hard solutions fight against natural process such as wave action, tide effects, etc., whereas soft solution adapt to or supplement these natural process. Some examples of soft solutions are provided in this topic continuation.

Beach Nourishment:

Beach Nourishment is a adaption technology used primarily in the case of erosion protection. To a considerable extend, it can help in coastal flood prevention. This type of protection is mostly suitable for sandy beaches. Beach nourishment is the addition of sediments to the already existing sand in the shore that maintains the width of the beach.

The nourishment can also be termed as recharge, infill, replenishment, re-nourishment, beach feeding. These act as natural beach and avoids the population to think it as artificial. In case of wide beaches, it helps to maintain the width by preventing the process of erosion. The addition of sediment increases the health and provide storm protection.

It is also important to nourish with suitable materials that would adapt the natural sediment. Care should be taken in the selection of the fill material or else the result will

have a negative impact on the users and the environment. When this technique is used in combination with hard solutions, the expected result will be better and economical. This would be a better option to improve the recreation of the site where it is suffering a sediment deficit problem.

These method would be successful when it is re-invested, i.e. the process requires maintenance. The only disadvantage is that the nourishment with other material by depositing over the existing sediment will cause direct burial of organisms living on it and also disrupt the birds and turtles nesting in the sand.

Artificial dunes and dune rehabilitation:

Naturally formed dunes are naturally formed sand deposit representing the sediment storage in the zone due to high tides. Artificial dunes are engineered structures constructed to minimize the dune process. Both natural and artificial dunes help in the protection of adjacent coastlands from the effect of both erosion and flooding.

Dune rehabilitation refers to the restoration of natural or artificial sand dunes to enhance their function in order to obtain maximum benefits. One of the method of dune rehabilitation is done by fencing the dunes on the seaward side by trapping the sediment movement. These fences can be made by branches so that these break out once its trapping function is over.

In order to enhance the dune growth one of the best method is to plant vegetation so that soil gets accumulated at the stems of the planting preventing the wind to blow away the sediment.

With careful management, dunes can serve as a better protection against erosion and flooding. Dunes with vegetation can make a sustainable coastal environment as they provide physical and tangible defence. Sand dunes also provide a better environment ecologically and recreationally as it helps the growth of plant species and other dependent organisms.

The construction of communities in many areas has resulted in the destruction of dunes saying the fact that they become barrier to the direct view of the sea. This destruction will lead to future increased coastal risks.

Plantation:

The roots and stems of the plants become natural barriers by trapping the sediment against the action of winds, waves and currents. Plantation is a better option in flat beaches and provide strength by protecting the sediment and reinforcing them. By improving the slope stability, consolidating the sediment and reducing the wave action, plantation is well suitable method for erosion prevention.

Mangrove forest which are the highly productive ecosystem of most of the tropical areas and tidal inlets serve as a habitat and nursery for marine species.

Green Belts/ Buffer zones:

Green belts and buffer zones protecting the coast from erosion and other coastal hazards, additionally serves as way for ecological sustainability and gives a status to the communities. They serve the purpose of

- Sediment trapping against wind and wave action and stabilize shoreline changes
- Provide a natural habitat for wildlife and benefit bio diversity and becomes a spot for eco-tourism
- Provides the coastal habitats with food, materials and income to locals
- Helping to attenuate the devastating effect of storm surges and cyclones accompanying tsunamis

Role of ecosystems in coastal protection:

Coastal ecosystems such as coastal wetlands and mangroves play a critical role in disaster risk reduction by trapping the sediment movement, attenuating the wave energy and by mitigating the storm surge. Dense vegetation in coastal areas reduce the wave

velocity and flow resulting in the deposition of sediments thus helping in the process of accretion.

Salt marshes and mangroves have the same capacity as engineered structures when their height is in accordance with the sea level rise. In many tropical regions, the extreme storm events are dissipated by the coral reefs. The coral reefs with their rough surface reduce the wave action and transfer the energy.

Floating agricultural system:

Floating agriculture is a way of utilizing areas which are waterlogged for long periods of time in the production of food. The technology is mainly aimed at adapting to more regular or prolonged flooding. The approach employs beds of rotting vegetation, which act as compost for crop growth. These beds are able to float on the surface of the water, thus creating areas of land suitable for agriculture within waterlogged regions.

2.5.2. Coastal Management

The adaptation technology in coastal zone would be better by considering the concept of protect, retreat and accommodate.

Table 2.4. Adaptation technology for coastal zone (Source: Presentation made by UNEP at MFF Regional Training on ‘Applying Project Cycle Tools to Support Integrated Coastal Zone Management’, Semarang, Indonesia, October, 2008)

Protect	Retreat	Accommodate
Protect existing assets and livelihood from Sea Level Rise Seek to exclude the hazard	Avoiding SLR in order to eliminate a direct impact Seek to remove human activities from hazardous zone	Accommodate SLR, reducing the overall severity of damages Allows human activities and hazard to co-exist
<ul style="list-style-type: none"> • Hard structures – dykes, sea-walls, tidal barriers, detached breakwaters • Soft structures – dune or wetland restoration or creation, beach nourishment, greenbelts, biodiversity conservation • Indigenous options walls of wood, stone or coconut leaf, afforestation 	<ul style="list-style-type: none"> • Establishing set-back zones • Re-locating threatened buildings • Phasing out development in exposed areas • Creating upland buffers • Rolling easements 	<ul style="list-style-type: none"> • Early warning and evacuation systems/ increased awareness • Hazard insurance • New agricultural practices, such as using salt-resistant crops • New building codes • Desalination systems

The reduction in the disaster risk and for the better management of the coastal zone, the following terms can be used as a basis.

Table 2.5. Terms used in Disaster Risk Reduction (DRR) (Source: UNISDR, 2009)

Terms	Comments
Prevention	The outright avoidance of adverse impacts of hazards and related disasters.
Mitigation	The lessening or limitation of the adverse impacts of hazards and related disasters.
Preparedness	The knowledge and capacities developed by governments, professional response and recovery organizations, communities and individuals to effectively anticipate, respond to, and recover from, the impacts of likely, imminent or current hazard events or conditions.
Adaption	The adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities.
Response	The provision of emergency services and public assistance during or immediately after a disaster in order to save lives reduces health impacts, ensure public safety and meet the basic subsistence needs of the people affected.
Recovery	The restoration, and improvement where appropriate, of facilities, livelihoods and living conditions of disaster-affected communities, including efforts to reduce disaster risk factors.

THE HYOGO FRAMEWORK FOR ACTION (HFA):

HFA has been adopted by the countries around the world as a framework for DRR. HFA offers five areas of priorities for action, guiding principles and practical means for achieving disaster resilience for vulnerable communities in the context of sustainable development.

Table 2.6. Priority action for HFA

HFA Priority for Action 1	Ensure that disaster risk reduction is a national and a local priority with a strong institutional basis for implementation.
HFA Priority for Action 2	Identify, assess and monitor disaster risk and enhance early warning.
HFA Priority for Action 3	Use knowledge, innovation and education to build a culture of safety and resilience of all levels.
HFA Priority for Action 4	Reduce the underlying risk factors.
HFA Priority for Action 5	Strengthen disaster preparedness for effective response at all levels

INTEGRATED COASTAL ZONE MANAGEMENT:

Integrated coastal zone management (ICZM) or Integrated Coastal Management (ICM) is a process for the management of the coast using an integrated approach, regarding all aspects of the coastal zone, including geographical and political boundaries, in an attempt to achieve sustainability.

The concept behind the idea of ICZM is sustainability. For ICZM to succeed, it must be sustainable. Sustainability entails a continuous process of decision making, so

there is never an end-state just a readjustment of the equilibrium between development and the protection of the environment.

Below are four identified goals of ICZM:

- Maintaining the functional integrity of the coastal resource systems;
- Reducing resource-use conflicts;
- Maintaining the health of the environment;
- Facilitating the progress of multi- sectoral development

WARNINGS AND FORECASTING:

Early forecasting and warning systems for severe storm and tsunami help people to prepare and decide when to evacuate, saving lives and potentially reduce property loss.

Inaccurate warning results in both high coast and low confidence in the forecasting systems often causing residents to ignore subsequent warnings. Hence advance forecasting and warning at right time that is reliable is important to make people aware of the coming hazard. More data is required for making accurate forecasting to be reliable.

Integrated Coastal Zone Management requires monitoring, regulation and good governance. Adequate governance structure and institutional coherence are therefore crucial to effectively respond to growing pressures on the world's ocean. Well-designed and managed Marine Protected Areas (MPAs) provide a valuable tool for habitat and biodiversity protection, ecosystem resilience, ecotourism, and as a contributor to sustainable fisheries.

Tackling these requires multidisciplinary action and especially the need to engage with all stakeholders rather than imposing actions from outside is most importantly to be considered.

Success is more likely if society engages in the responses; communities restoring habitats on vulnerable coasts and increasing protection increase both the chances of success and awareness of the problem.

Other management actions required are:

Flood Hazard Mapping- Flood hazard mapping is an exercise to define those coastal areas which are at risk of flooding under extreme conditions. As such, its primary objective is to reduce the impact of coastal flooding. However, mapping of erosion risk areas may serve to achieve erosion risk reduction. It acts as an information system to enhance our understanding and awareness of coastal risk.

Retreat Approach- Retreat here, refers to a proactive or planned withdrawal from the coast, rather than an unplanned or forced retreat, which is also potentially possible in the face of SLR and climate change.

Managed Realignment- Managed realignment is able to reduce both coastal flooding and erosion. It is the deliberate process of altering flood defences to allow flooding of a presently defended area.

Coastal Setbacks- A setback may dictate a minimum distance from the shoreline for new buildings or infrastructure facilities, or may state a minimum elevation above sea level for development. Elevation setbacks are used to adapt to coastal flooding, while lateral setbacks deal with coastal erosion. A setback line can be defined as the landward limit of the buffer zone behind the coastline. This buffer zone is the area where restriction on construction and other activities should be applied. Knowledge and Capacity Building Requirements.

CHAPTER 3 EROSION HAZARD

Erosion is the physical movement of sediment away from the shore through the action of wind and water currents. Wind, waves, and long shore currents are the driving forces behind coastal erosion. This removal and deposition of sand permanently changes beach shape and structure. Additional factors involved in coastal erosion include human activity, sea-level rise, seasonal fluctuations, and climate change. Shoreline erosion is typically a chronic hazard, but severe shoreline erosion may be induced by a single storm event.

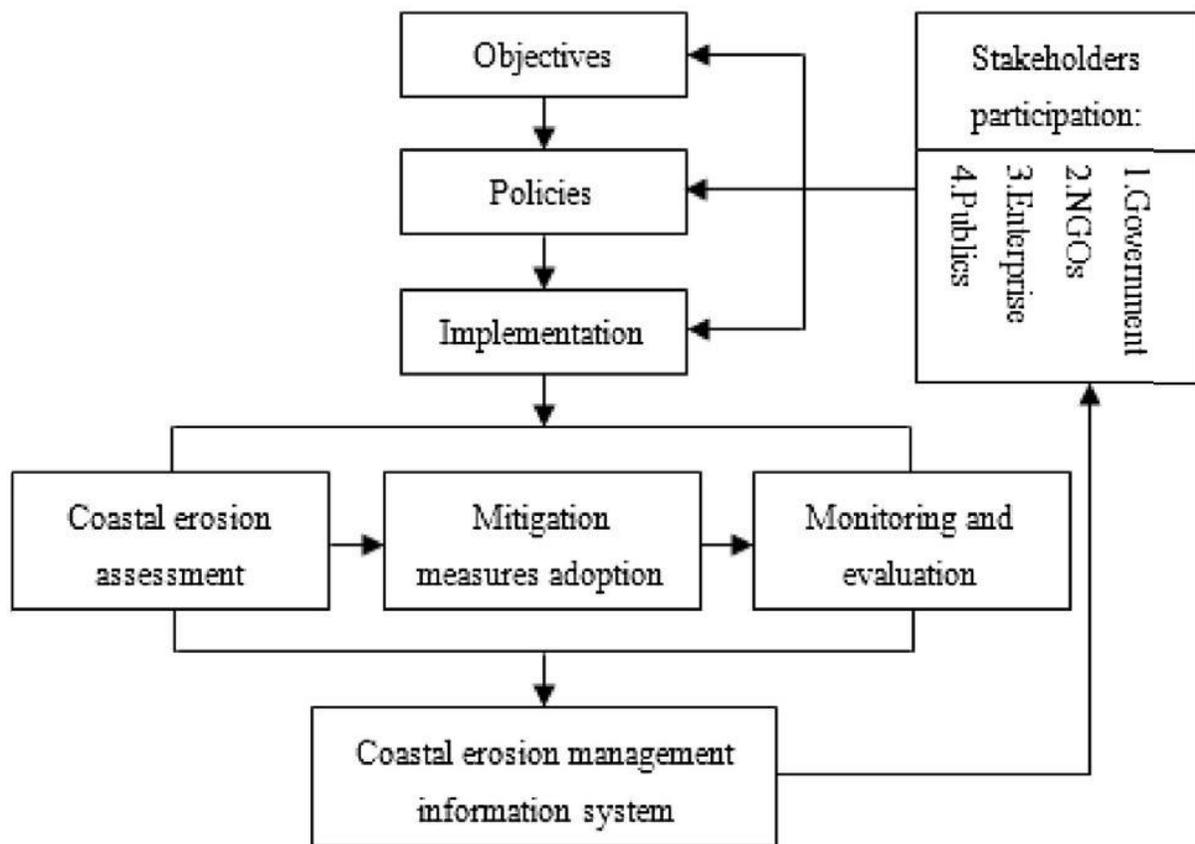


Fig.3.1. Management system for coastal erosion protection (Source: Shilong, 2014)

3.1. CASE STUDY- INDIA

3.1.1. INTRODUCTION TO INDIAN COASTLINE

The Indian sub-continent has one third of its population living along the coastline. About 23% of its coastline are under erosion and shore line change is one of the important impact due to the development of ports, harbours, breakwaters, jetties and so on.

The rapid urbanization has made the coastal areas in demand and this demand in turn rises the risks on the population living along the coast.

3.1.2. CHENNAI COAST

Chennai- primarily a fishing village known as 'Madarasapatinum' is located on the Coromandel Coast of India. During 1639, The British East India Company build 'Fort St. George' which later became the nucleus for the urban development.



Fig. 3.2. A painting of 18th century showing St. George Fort

Chennai is located on the South-eastern coast of India at the North-eastern part of Tamil Nadu on the flat coastal plains known as Eastern Coastal Plains. This coast is blessed with the world's second largest urban beach about 5.6 km known as the Marina beach. It has two major rivers namely the Adayar River and the River Cooum which opens into Bay of Bengal.

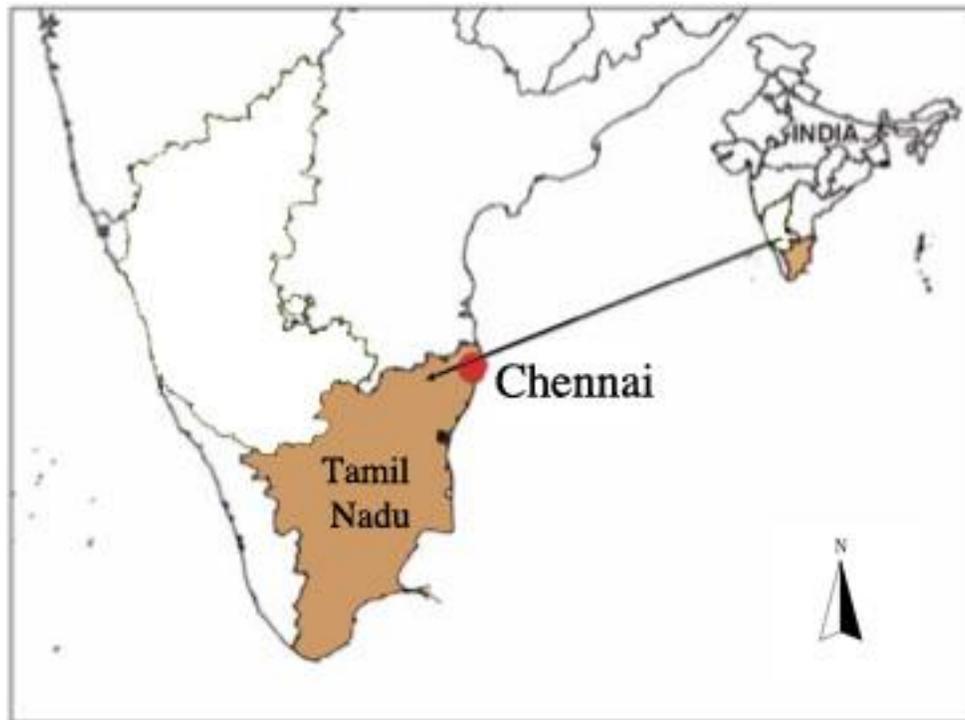


Fig 3.3. Location of Chennai

Geographically, the coast is dominated with flat sandy areas such as beaches and dunes and has a tropical climate. It is dependent on the north-east monsoons and cyclones for its major rainfall. Lying on the thermal equator, the extreme temperature is prevented by the coast and falls under seismic zone III with moderate risks.

3.1.3. EROSION IN THE COAST

The landward displacement of the shoreline in the Chennai coast has been a problem for most of the years. The coast is covered by sandy beaches and dunes mostly and consists of clay mixed sands at places where the two major rivers namely the Adayar

and Cooum forms delta with the coast. The Chennai coast is undergoing the process of erosion on its Northern part and accretion on the Southern part, having the Port of Chennai at the middle.

Ports - A conflict

Chennai port, India's second largest artificial port was constructed in the year 1876 became a cause for the coastal erosion due to the construction of jetties and breakwaters which altered the natural coastal process of the region. As a result of subsequent development of the port entrances, the part north to the port started eroding. As per records 350 ha of land was lost due to coastal erosion in this area.

The Ennore Port, 16 km north of Chennai port was constructed in the year 2001 to reduce congestion of the existing port added to the growing erosional problem. The presence of shoals and breakwaters influence the sediment dynamics and altered the equilibrium of the beach.

Erosion/ Accretion Spots of Chennai coast

Severe erosion is noticed along the coast in the port region due to the development of jetties, breakwaters, etc. It is noticed that the northern region of the coast shows erosion rate of high to very high. The Royapuram fishing harbour located north of Chennai port also show high erosion rate. The other regions including Thiruvottiyur and north region of Ennore port has high erosion rate due to the presence of man-made structures. On the other hand, the Marina beach at the delta region of both Adyar and Cooum rivers shows accretion. Other beaches like Elliots beach at Bessant Nagar, Foreshore Estate beach and thirvanmiyur shows low to moderate accretion rates.

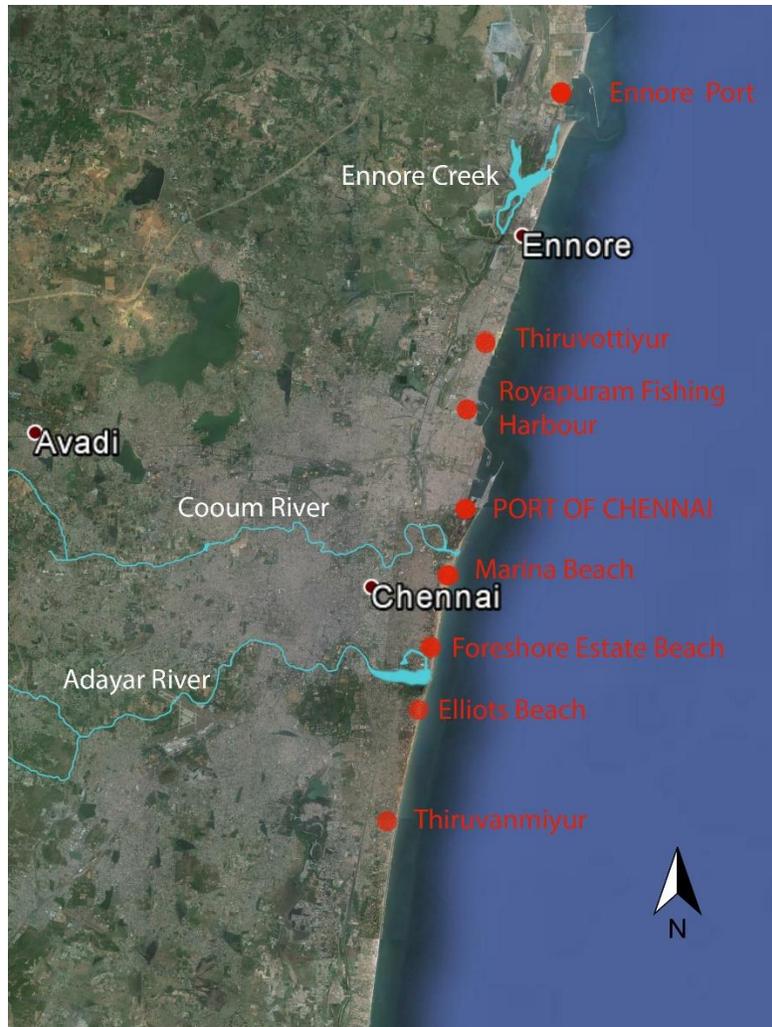


Fig 3.4. Erosion/ Accretion along Chennai Coast

3.1.4. PROTECTION MEASURES

Engineering Structures

Engineering solutions like seawalls, concrete tubes, etc., were constructed along these erosion sites to protect the coast. The result was that the seawalls prevented the erosion of the soil in the updrift side but failed to prevent down drift side erosion. As a result the down drift side of these coastal structures continued showing erosion. At some places artificial nourishment and dunes were constructed which prevented erosion but did not last long.

In the year 2004, Groynes were constructed between the Port of Chennai and Thiruvottiyur. Studies on the performance of these groynes shows that these groynes are performing well and the rates of erosion are seen to be reducing. At places of high erosion, the erosion rate has reduced to low and at places of low erosion, it had started accretion resulting in the widening of beaches.



Fig.3.5. Natural and man- made protection measures in north Chennai that prevented tsunami inundation

The North Chennai region was found slightly protected during the time of Tsunami due to the presence of Shoreline protection structures. The Groynes constructed in the north Chennai region serves not only the purpose of protection but also acts as a mini fishing harbour.

Plans and Policies

FIVE YEAR PLANS AND THEIR ACHEIVEMENTS- INTEGRATED COASTAL AND MARINE AREA MANAGEMENT PROJECT DIRECTORATE

The Integrated Coastal and Marine Area Management Project Directorate(ICMAM PD), an attached office of Ministry of Earth Sciences (MoES), Government of India, was established at Chennai during Jan.1998 for implementing IDA assisted Environment Management Capacity Building Project. Presently, the Project Directorate is continuing its activities in the field of Coastal Research, fully funded by MoES.

NINTH FIVE YEAR PLAN PROJECTS

Development of guidelines for Environmental Impact Assessment (EIA) studies for marine and coastal developmental activities and processes:

EIA Guidelines have been developed through NIOT (National Institute of Ocean Technology) for conducting Environmental Impact Assessment studies in the Ports and Harbours, tourism related activities in the coastal marine areas and for waste disposal from domestic and industrial sources including discharge of waste through pipelines, etc.

Development of Model Integrated Coastal and Marine Area Management (ICMAM) Plans for Selected Sites along the Coastline of India:

It was proposed to demonstrate the use of tools and techniques like GIS, Remote Sensing and Mathematical Modelling in the prediction of cross-impacts by thoroughly analysing the problems using these tools. Solving the cross-impacts is the basic requirement of an integrated management. Hence, it was felt that by preparing model Integrated Coastal and Marine Area Management (ICMAM) Plans, the practical utility of above tools can be demonstrated. Accordingly, model ICMAM Plan have been prepared by ICMAM-PD for Chennai.

TENTH FIVE YEAR PLAN ACTIVITIES

Shoreline Management Plan for Ennore Coast:

“Shoreline Management along Ennore” was formulated to conduct detailed field and model investigations on various dynamical aspects (water level variations, currents & circulation, tides, waves, bathymetric variations, sediment transport, shoreline changes etc) of Ennore coast covering Ennore creek to Pulicat mouth, located further north of Chennai. The objective of the project is to develop hindcast, nowcast and forecast models on shoreline changes in priority areas for identification of vulnerable areas of erosion/accretion to arrive at remedial measures for protection of coastline from natural and human perturbations.

TWELFTH YEAR PLAN PROGRAMMES

Having implemented the above projects at various locations successfully, as a continuation on research in coastal zone, during 12th plan both the ICMAM and COMAPS programmes have been integrated and called as Coastal Research. The projects undertaken for Chennai are

- Prediction of water quality along the coasts of Chennai
- Capacity Buildings

TRAINING

ICMAM PD has been conducting training programmes on Coastal zone management, marine pollution, GIS for disaster management, satellite oceanography etc since 2000. Since these training programmes have been found to be useful to technical personnel of coastal states, universities etc., it is proposed to continue these activities during the 12th plan. The training programmes will be largely executed by scientists of ICMAM PD and experts from selected institutions.

COASTAL REGULATION ZONE

Other than these above mentioned projects, there are many laws and legislations followed throughout India for better management of the coast. In particular India has “COASTAL REGULATION ZONE (CRZ) Notification, 2011” which provides details for the developments along its coastal zones.

On February 19, 1991, the Ministry of Environment and Forests (“MoEF”) issued a notification under Section 3 of the **Environment Protection Act of 1986**, seeking to regulate development activity on India’s coastline. The approach adopted by the first notification was to define the ‘High Tide Line’ (“HTL”) and ‘Coastal Regulation Zone’ (“CRZ”) and thereafter specify the activities permitted and restricted in the vicinity of the CRZ. This regulated zone was further divided into four categories (CRZ I-IV) as per permitted land use.

With several amendments the Ministry finally passed this as Coastal Regulation Zone Notification 2011 on January 6, 2011. The notification regulates a range of activities along the coastal stretches on the landward side measuring a width of 500 meters from the High Tide Line. The three main objectives of this notification are

- (i) Protection of livelihoods of traditional fisher-folk communities;
- (ii) Preservation of coastal ecology; and
- (iii) Promotion of economic activity that have necessarily to be located in coastal regions.

The concept of classification of CRZ into four zones has continued in the 2011 notification with the following delineation:

1. CRZ I- ecologically sensitive areas such as mangroves, coral reefs, salt marshes, turtle nesting ground and the inter-tidal zone.
2. CRZ II- areas close to the shoreline, and which have been developed.
3. CRZ III- Coastal areas that are not substantially built up, including rural coastal areas.
4. CRZ IV- water area from LTL to the limit of territorial waters of India.

3.2. CASE STUDY - SPAIN

3.2.1. INTRODUCTION TO SPANISH COASTLINE

Spain is predominantly a coastal country, mostly surrounded by water. The country comprises of 25 coastal provinces and 487 coastal towns which borders the Mediterranean Sea and the Atlantic Ocean. Over the last 50 years, the coastline of 7,883 km length has undergone extensive transformation due to the intensive use of coastal areas which triggered a series of economic, social and environmental imbalances. This must be taken into consideration for the development of sustainable coastline in the future.

3.2.2. COAST OF VALENCIA

Valencia is the port city of Spain, located on the southeastern orange blossom coast, Iberian Peninsula where the river Turia meets the Mediterranean Sea. It is fronted by the Gulf of Valencia and has a sub-tropical Mediterranean climate with very mild winters and long warm to hot summer. It has several beaches, wetland, trails and bird watching. It is the third largest city in Spain with 800,000 inhabitants. The Port of Valencia located in this coast is the 5th busiest container port in Europe.



Fig.3.6. Location of Valencia

3.2.3. EROSION IN THE COAST

The coastline of Valencia has undergone severe erosion problems since the last 50 years. The generalized erosion problem in these coastline can be described due to three reasons mainly- damming, port development and urban development. The current erosion problem in these areas not only affect specific sites along the coast but also have an impact on the wider part of the nearby coastal areas.

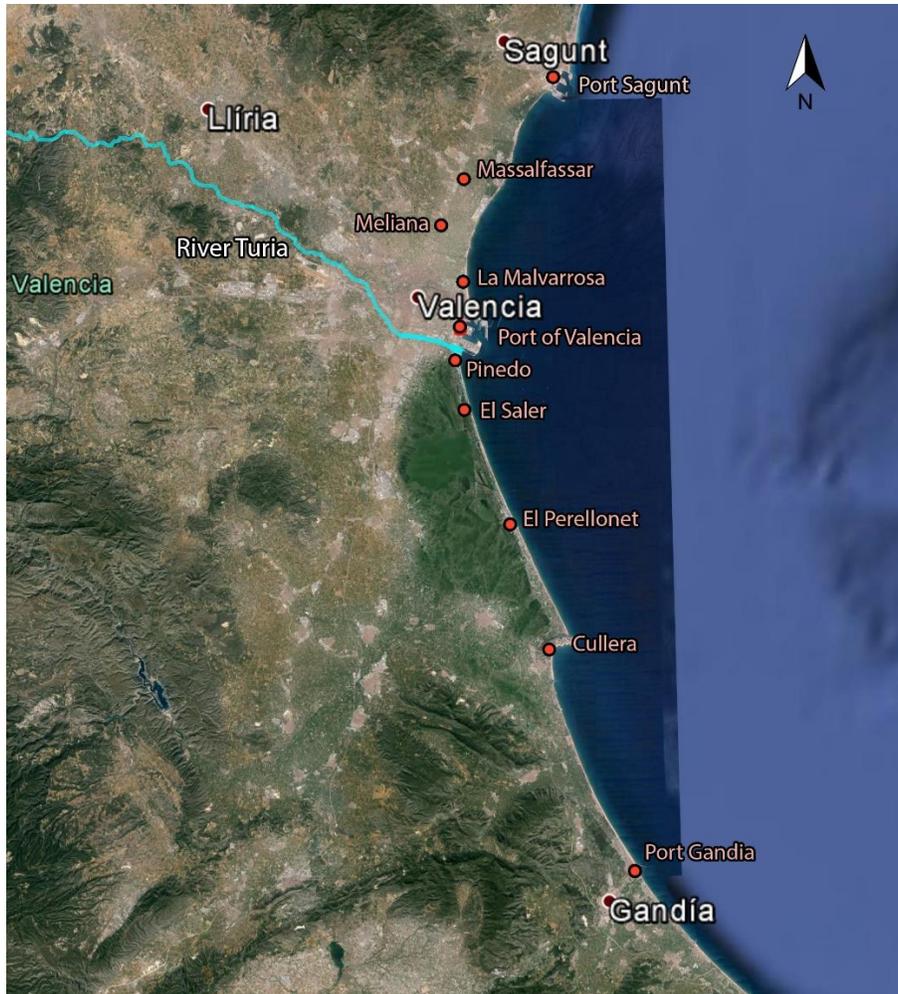


Fig.3.7. Valencia coast with erosion and accretion spots

Damming and Sediment Extraction

The main infrastructure problem for erosion in this coastline is Damming. The construction of dams across the river in the area has interrupted the natural fluvial coarse sediment transport to the beach. This lack of fluvial deposit of sediment on the coastline cause direct erosion of delta and affects the balance of the coastline. The dam on the Turia River trap the coarse sediment and thus result in the reduced discharge of sediment to the coast.

The south of Cullera has shown coastal erosion as a result of deficit in coastal sediment due to extraction of sand from the river for industrial purposes, effects of dams and extraction of sediment from beach.



Fig 3.8. South of Cullera showing erosion due to sediment deficit (Source: Sanjaume et 2005)

Port and barrier constructions

The second reason for erosion of coastline is the construction of barriers for longshore transport, groins and barriers for coastal protection and breakwaters for port. Further the extension of the existing port is an important factor affecting the coast. These engineering structures modify or interrupt the balance of the coastline creating erosion and accretion of these areas.

The Valencia coast has three ports including Port of Valencia. The other two ports, Sagunto and Gandia are controlled by the Port Authority of Valencian cause similar

consequence as that of the Valencia port even though they only stop partial littoral drift. These three ports are located along the 80 km stretch of the coastline.

Damage of seawalls cause sand loses which made the dissipative Pinedo beach, which is immediate next to the Port of Valencia into a dominantly reflective beach.

Port of Valencia

In the last thirty years, the port of Valencia has experienced considerable growth in terms of container cargo transport meeting the globalization process. This development had environmental impact on its other side. This larger area of the port acts completely as a sediment trap. During the period 1980-2010, the port has increased fourfold and the traffic in this region has increased seven fold.

The expansion during this period resulted in the problem of reclamation of land to accommodate the new port facilities. The land for this expansion was reclaimed from the sea and part of the land was from the nearby area which was purely meant for agricultural purpose. The construction of a new quays protruding into the sea affected the coastal hydrography, resulting in the erosion of the nearby beaches due to lack of sediment supply. Similarly, due to the expansion of the port to further south resulted in the conversion of Nazaret beach to container terminal accommodating bigger vessels. Thus the recreational opportunity of the area lost and now the area lack its traditional landscape. Due to the expansion, the nearby neighbourhood faces increased traffic problems due to the trucks coming to the port.

Urban Planning

Urban planning which allows the construction of buildings near the coast is addition problem which increases the economic damage due to erosion in these areas.

3.2.4. PROTECTION MEASURES

Engineering Solutions

Hard solutions

To protect the area from direct storm attacks, seawalls have been built which protects the land and not the beach. These structures do not provide protection on long-term coastal change. Additionally, the seawalls during strong storms undercut which on the passage of time partially collapse. This can be commonly seen in seawalls built along the highway between Massalfassar and Meliana.



Fig.3.9. Damage of seawall protecting the highway between Massalfassar and Meliana
(Source: Sanjaume et 2005)

The construction of structures like piers, jetties and groins perpendicular to the shoreline near the harbour interrupt the long shore drift. This causes increase in beach width along the southern side of the harbour(La Malvarrosa) and the northern side beaches are seen retreating(Pinedo and El Saler).

Soft Solutions

The infill with the industrial waste from iron and steel factory on the south of Sagunt harbour prevented the predicted erosion by this harbour. This artificial infill not only prevented recession but also lead to significant accretion. The infill served as a cementation and blocked the alongshore littoral transport which made the coast stabilized.

Most of the nourishment projects have been done in Sagunt, Saler and Cullera where the erosion is strong or it has high tourist value. In Meliana, the nourishment is done by crushed materials from quarries.

El Saler has dune regeneration artificially or semi- artificially accelerating sand accumulation using permeable fences. El Perellonet regenerated dunes naturally because of its best conditions which had no interference by roads or building or other rigid structures built on this coast area.

Policies and Frameworks

INTEGRATED COASTAL ZONE MANAGEMENT

An Integrated Coastal Zone Management strategy (ICZM) is currently underway.

The recently signed “Protocol on Integrated Coastal Zone Management in the Mediterranean” (PAP/RAC, 2007) specifies that (sic) “the Parties, with a view to preventing and mitigating the negative impact of coastal erosion more effectively, will undertake to adopt the necessary measures to maintain or restore the natural capacity of the coast to adapt to changes, including those caused by the rise in sea levels. The Parties shall endeavour to anticipate the impacts of coastal erosion through the integrated management of activities, including adoption of special measures for coastal sediments and coastal works. The Parties undertake to share scientific data that may improve knowledge on the state, development and impacts of coastal erosion”.

Initiative Measures taken in Strategy for Integrated Coastal Zone Management are

1. Master Plan for Coastal Sustainability
2. Sustainability Observatory for the Spanish Coast
3. Agreements with coastal regions
4. National Coast Council
5. Purchase of land for protection and restoration
6. Support for R&D in coastal areas
7. Education, continuous education and training activities for coastal managers

The Master Plan for Coastal Sustainability incorporates the new European recommendations on the implementation of Integrated Coastal Zone Management, while also laying down guidelines for action and criteria for integrated management. It is the basis for annual programming of coastal actions.

COASTAL RESILIENCE

Coastal resilience has been defined in the framework of the EuroSION project (European Commission, 2004) as the inherent ability of the coast to accommodate changes induced by sea level rise, extreme events and occasional human impacts, whilst maintaining the functions fulfilled by the coastal system in the longer term. These three processes or agents can be easily associated to three different time scales: long-term (centuries), episodic (random) and medium-term (decades), respectively.

STRATEGIC ACTIONS UNDERTAKEN AT NATIONAL LEVEL

In 2005, a communication document entitled 'Hacia una gestión sostenible del litoral español' ('Towards sustainable coastal management in Spain') was published. This document is a roadmap to sustainable coastal management. The roadmap does not refer to climate issues but calls for a national coastal management plan, following the EU Recommendation on Integrated Coastal Zone Management.

Such a National Strategy for Sustainable Coastal Management, is currently underway. The Canaries will also be accounted for in this forthcoming strategy. The main

challenges identified for this strategy include adaptation to climate change, the need to slow coastal urbanisation, to restore physical as well as natural functionalities of the coast and to change the coastal management model. These challenges will be further discussed with stakeholders at national and regional level before finalising the national integrated coastal management strategy.

The expenditure against erosion is funded by the national government, through the budget of the Directorate-General for the Sustainability of the Coast and the Sea.

STAKE HOLDERS

- Valencia Coastal Branch, Spanish Ministry of Environment (Demarcación de Costas de Valencia, Ministerio de Medio Ambiente).
- The main actors involved at national level are the Ministry of Environment and Rural and Marine Affairs (Ministerio de Medio Ambiente - Medio Rural - Marino - MARM) and its Directorate- General for the Sustainability of the Coast and the Sea. These authorities are responsible for all aspects of the marine and coastal environment within the Maritime Public Domain.
- Regional governments have the competency to develop urban planning of the coastal area. When necessary, coastal protection is entrusted by the Spanish Constitution to the national government. Funding for coastal protection comes from the national government through the budget of the Directorate-General for the Sustainability of the Coast and the Sea.

3.3. COMPARITIVE ANALYSIS OF THE TWO COASTS

From the above discussed features of the two coasts, comparison made is shown in the following tabular column.

Table 3.1. Comparison of the coasts Chennai and Valencia

	Chennai Coast	Coast of Valencia
Climate	Tropical climate	Sub-tropical Mediterranean climate
Geography	Sandy areas with beaches and dunes	Sandy areas with beaches, dunes and wetlands
River	Adayar and Cooum forming delta	River Turia forms delta
Port	Port of Chennai and Ennore Port	Port of Valencia, Sagunt Port and Gandia Port
Problem	Erosion	Erosion of the coast
Causes	Man-made structures like ports, seawalls, etc.	Damming, Port development and Urban Planning
Hard Engineering Solutions	Seawall constructions, concrete tubes, Groynes	Seawalls, Groynes
Soft Measures	Beach nourishment	Beach nourishment
Advantages/ Disadvantages	Hard solutions: The construction of groynes have performed well in reducing erosion rates and also help in accretion in certain areas like Elliot beach. In case of seawalls and concrete tubes, the	Hard Solutions: The seawalls constructed were not able to withstand strong storm events. The groynes constructed also interrupted the coastal process.

	<p>structures caused erosion on the down-drift side and accretion on the up-drift side of it.</p> <p>Soft solutions: Beach nourishments at places show good results but does not last longer</p>	<p>Soft Solutions: The beach nourishment with infill showed better results in the management of erosion. The materials chosen to the infill is important and with suitable selection of these infill materials, the management measures can protect the coast from further erosion.</p>
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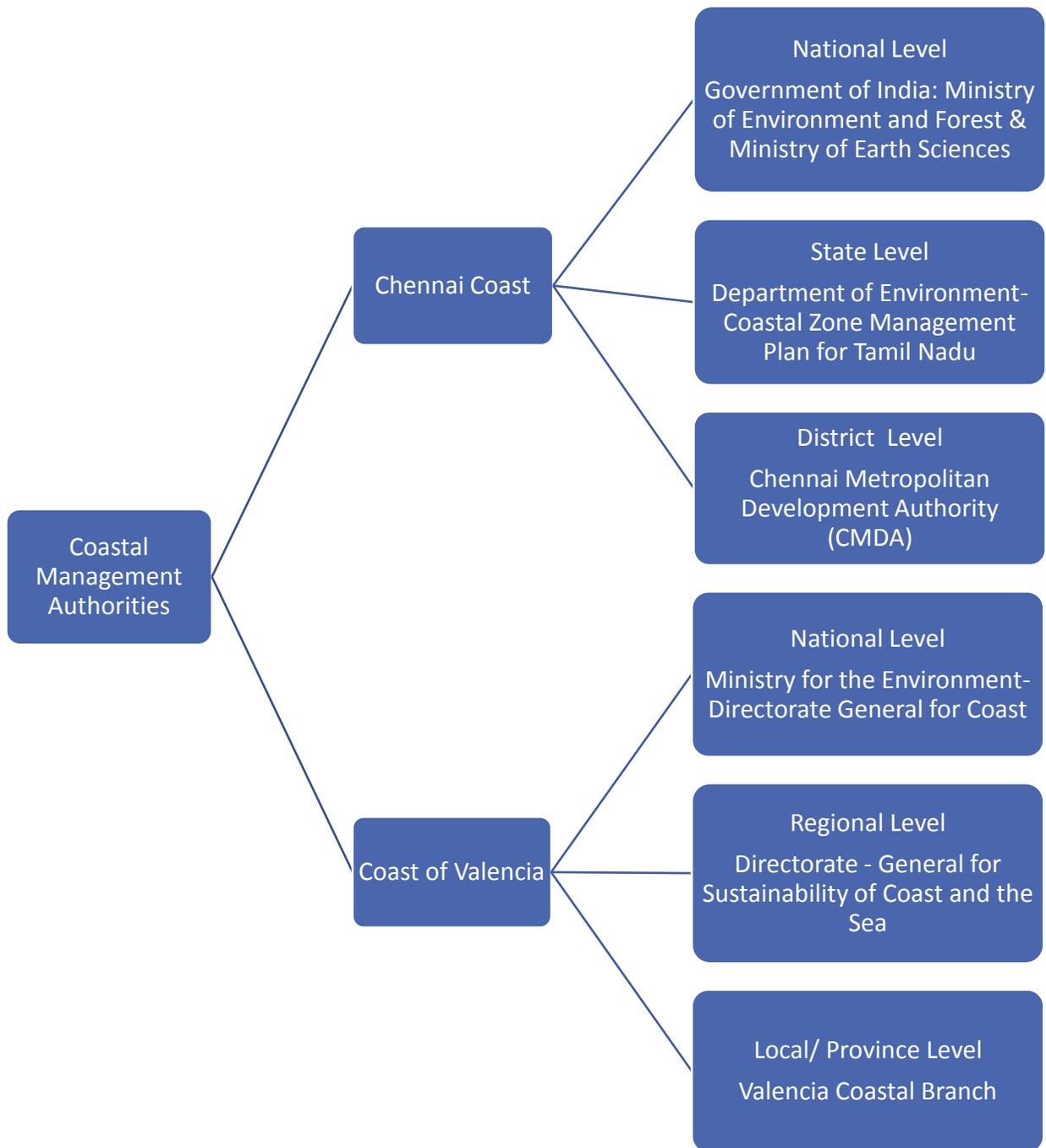


Fig.3.10. Government Authorities Responsible for Coastal Management

CHAPTER 4

CONCLUSION

As there is continued growth in coastal population, there is a need for resilient coastal protection measures to the effect of storms, sea level rise, flooding, erosion, inundation, etc. The forecasting and warning systems should be advanced, making it the way of saving lives and reducing property risk to minimal.

The policies for coastal protection should be based on the stakeholder's involvement and the coastal protection measures should be based on best possible measures on accurate information from improved mapping and advanced, accurate forecasting.

Climate change adds additional risks to the coastal area and the role of ecosystem in coastal protection will be a better option as they play a vital role in cost-effective vulnerability reduction. The solution that cause `interruptions to the natural ecosystems should be avoided and before the implementation of any solution, the ecosystem of the particular area has to be taken into consideration to make it eco-friendly.

The people living along the coast must be taught and trained about the hazards and the awareness about these hazards. The rapid urbanization process makes it impossible to move people away from the vulnerable zones. Hence it is necessary to teach people to be resilient to the hazards with better protection and management measures provided.

Hard engineering solutions even though provide better solutions to coastal protection, in many situation they disrupt the natural process causing other problems. Similar is the case of soft solutions when used separately, they become expensive. Thus studies and various cases prove that the combined solution of coastal protection including hard and soft solutions is the ideal way for reducing the risk to a maximum extend. This combined solution protect the coast from natural hazards and in the same time supplement to the natural process of the marine environment.

Above all the planning policies formed for the protection of coast has to be implemented in a proper way. After the implementation of the method or policy, it is very important to monitor the implementation at various stages to make the implementation successful in reality. In addition to monitoring, evaluation of the particular method or policy should be made and accordingly modifications should be brought to make the protection measures suitable for sustainability of the coast.

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Comparative Study on Coastal Hazards and its Management

Abstract:

The coastal areas are showing an increasing population and more than half of the world's population live in these coastal zones. The vibrant beauty, recreational opportunities and economic benefits they offer attracts population and hence is treasured world over. This also comes with a unique number of hazards putting the population at risks with the increase in sea level and climate change. Even though there are numerous protection measures and management actions taken, the safety of the coast and the surrounding ecosystem with the population is not guaranteed. Thus along with the implementation of strategies for Integrated Coastal Zone Management for the sustainable development, it is necessary to monitor and evaluate the strategies to make the implementation valuable. This research focus on the general hazards and its protection measures and is limited to the comparative study for two cities namely Chennai and Valencia, taking erosion as a hazard. The measures taken to reduce erosion in the two sites is mentioned along with their performances. In these cases, the protection measures such as soft and hard engineering solutions perform well but it would be better to make combined hard and soft solutions so that the negative effect caused due to one method can be compromised by the other and vice versa.

Keywords :

Coastal hazards, Sea level rise, Climate change, Protection, Sustainable development, Resilient coast.

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