COASTAL MANAGEMENT AND CLIMATE CHANGE

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Coastal Systems vulnerable to Climate Change

- Morphology
- Ecosystems
- People & properties
- Infrastructure
- Coastal protection structures
- Embankments protecting estuaries
Impacts of Climate Change on Coastal Zone

• Accelerated sea level rise and coastal inundation including that of backwater/estuary
• Coral bleaching
• Increased reach of erosion
• Increased storm frequency & intensity
• Changes in rainfall, and related flooding
Impacts of Climate Change on Coastal Zone

- Increase in SST
- Changes in chemical characteristics like ocean acidification
- Physical characteristics like thermal stratification of marine systems
- Saltwater intrusion into groundwater aquifers
- Saltwater intrusion into backwaters and rivers
Impacts of Climate Change on Coastal Zone

• Increased harmful algal blooms
• Increased spread of invasive species
• Habitat loss (especially coastal wetlands)
• Species migrations
• Changes in population dynamics among marine and coastal species
• Affects economic activities like coastal tourism, salt manufacturing, etc
Sea Level Rise

Types of Sea Level changes

- Waves – wind generated
- Tides - gravitational pull of moon & sun
- Storm surges – cyclone generated
- Tsunamis – earthquake generated
- Sea Level Rise – melting of glaciers & global warming
Causes of SLR

- Global warming – due to greenhouse gases – thermal expansion
- Melting of ice and glaciers in the mountains
- Melting of Antarctica and Greenland glaciers
- Changes in terrestrial storage of water
Eustasy
- rise and fall of sea level relative to land (due to glaciation & interglacial warming)

Isostasy
- rise and fall of land causing relative change in sea level (due to tectonic activity)
Past Sea Level changes

Global average sea level rise

- at an average rate of 0.5 mm/yr over the last 6000 years
- at an average rate of 0.1 to 0.2 mm/yr over the last 3000 years.
Recent trends in SLR
(Unnikrishnan et al 2013)

<table>
<thead>
<tr>
<th>Period</th>
<th>Rate (mm/yr)</th>
<th>Range (mm/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1901-2010</td>
<td>1.7</td>
<td>1.5 – 1.9</td>
</tr>
<tr>
<td>1971 - 2010</td>
<td>2.0</td>
<td>1.7 - 2.3</td>
</tr>
<tr>
<td>1993 - 2010</td>
<td>3.2</td>
<td>2.8 – 3.6</td>
</tr>
</tbody>
</table>

Expected SLR in 2010-2100: 0.52 to 0.98 with 1986-2005 average
## SLR along the Indian coast

(Unnikrishnan et al 2006)

<table>
<thead>
<tr>
<th>Location</th>
<th>Period of analysis</th>
<th>SLR (mm/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mumbai</td>
<td>1878 - 1993</td>
<td>1.20</td>
</tr>
<tr>
<td>Kochi</td>
<td>1939 - 2003</td>
<td>1.75</td>
</tr>
<tr>
<td>Vishakhapatnam</td>
<td>1939 - 200</td>
<td>1.09</td>
</tr>
<tr>
<td>Diamond Harbour (Kolkata)</td>
<td>1948 - 2004</td>
<td>5.74</td>
</tr>
</tbody>
</table>
Factors on which vulnerability depends

- Geology & geomorphology
- Waves & Tides; Currents
- Anthropogenic activities such as land use
- Sea Level Rise
Impacts depend on Coastal morphology
Coastal Morphology

Inlets

Salt pans

Sand dunes

Tidal flats

Filtration ponds
Mudbanks along Central Kerala coast
Impacts on Ecosystems & livelihood activities

Mangroves
Impacts on Activities
Enhancing vulnerability

Reclamation

Mangrove destruction

Beach sand mining
Lost more than 50 m of land
Impacts of SLR on the coast

- inundates wetlands and other low-lying lands
- modifies morphology
- intensifies flooding
- increases salinity of rivers, bays, and groundwater tables
- adverse effects of enhanced protection measures
Coastal erosion and modification of morphology

• increase in coastal erosion
• landward migration of barrier beaches and barrier islands
• parallel retreat of the shoreline
• Sand dunes get eroded
• enhanced scouring at the foot of earth cliffs
• Pocket beaches disappear
• increase vulnerability of hinterlands to waves and storm surges.
Can get flooded without SLR...!!!

Reclamation for industries & harbour in adjoining wetlands has been responsible
Studies on impacts

Coastal wetland loss:

• 2100 sq km out of 3604 sq km in West Bengal (Dwivedi & Sharma 2005)
• 8453 sq km out of 25083 sq km in Gujarat (Dwivedi & Sharma 2005)
• 13.79% of Dahej land area will be affected; 5.80 sq km will be agricultural land (Mahapatra et al 2013)
• Inundation
## Vulnerability of Indian coast (INCOIS)

<table>
<thead>
<tr>
<th>State</th>
<th>Coast km</th>
<th>High %</th>
<th>Very high %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guj</td>
<td>2308</td>
<td>6.12</td>
<td>5.36</td>
</tr>
<tr>
<td>Maha</td>
<td>940</td>
<td>10.34</td>
<td>1.22</td>
</tr>
<tr>
<td>Karna &amp; Goa</td>
<td>503</td>
<td>9.54</td>
<td>1.61</td>
</tr>
<tr>
<td>Kerala</td>
<td>623</td>
<td>8.46</td>
<td>2.39</td>
</tr>
<tr>
<td>T N</td>
<td>1025</td>
<td>7.79</td>
<td>6.38</td>
</tr>
<tr>
<td>A P</td>
<td>1073</td>
<td>20.84</td>
<td>0.55</td>
</tr>
<tr>
<td>Odisha</td>
<td>496</td>
<td>17.42</td>
<td>7.51</td>
</tr>
<tr>
<td>WB</td>
<td>1927</td>
<td>20.29</td>
<td>2.56</td>
</tr>
<tr>
<td>Laksha</td>
<td>152</td>
<td>0.81</td>
<td>5.24</td>
</tr>
<tr>
<td>A &amp; N</td>
<td>3252</td>
<td>7.50</td>
<td>0.96</td>
</tr>
</tbody>
</table>
Management of sea level rise

• Containing emission of GHG and controlling global warming
• Strengthening coastal protection measures
• Increased protection for important infrastructures
• Relocating people from low lying areas
• Locating new constructions in safe areas
• Sustaining existing flood plains
• Strengthening tidal barrages.
Coastal Protection to tackle SLR

- Seawall
- Cliff toe protection
- Groins
- Artificial reef
Management of sea level rise impacts – Kerala initiative

- Separate management plan for different morphological units to deal with SLR
- Identifying hot spots & Vulnerability mapping
- CRZ would be one of the supporting tools in reducing the impacts
BACKGROUND

Coastal stretch- 690 km
Accounts for 25% fish catch
Coastal area - 16% (of 39000 km$^2$)
Coastal population- 30% (of 32 Million)
Coastal districts- 10 (of 14)
Coastal Panchayats- 193 (of 971)
Coastal City Corporations- 3 (of 5)
Coastal Municipalities- 24 (of 60)
Population density- 400-13000/km$^2$
Overall Coastal density >2000/km$^2$
CHARACTERISTICS

• Development stress- Tourism, Industry, Infrastructure, Fishery, Mining
• 250 large & medium and 5000 small industries
• 101 seafood factories, 210 peeling sheds & 217 ice plants
• Two major thermal power plants
• Kochi port, 20 minor ports and 75 fish landing centres
• Large container terminals (Kochi & upcoming one at Trivandrum)
• Beaches, heritage sites & backwaters, the main tourism products
SLR hotspots – Kerala perspective

• Vulnerability to Sea Level Rise (SLR) is dependent on the impact due to exposure to seas, estuaries and backwaters

• Impact is dependent on the morphology

• Morphological hotspots to SLR are determined based on the varying levels of resistance offered by morphological forms to the impacts due to SLR
Hot Spots of SLR

- Depends on Coastal Morphology
- Backwater Islands – most vulnerable
- Barrier beaches and spits – most vulnerable
- Sandy beaches & Coastal plains
- Tidal inlets, Estuaries and backwaters
- Vegetated coasts
- Pocket beaches
- Sand dune beaches
- Headlands and Cliffs
Hot Spots of SLR

- Overtopping and flooding on the landward side makes coast protected with seawalls unsafe.
- Coasts fronted with cliffs and headlands and sand dune beaches are very safe from the impacts of SLR.
- Landuse determines risk level of hot spots.
Hot Spots

Low lying backwater islands - Inundation from all sides

Major hot spots identified are backwater islands and low lying areas, Barrier beaches and spits.
Morphological Hotspots

Backwater islands & Filtration ponds

• Inundation from all sides
Estuaries/backwaters of Kerala
Identified Hot Spots

Barrier beaches & Spits:

- Low lying
- Increased reach of waves
- Increased level of set up
- Inundation from backwater side
SLR Hotspots

• Major hot spots of SLR are the backwater islands and adjoining filtration ponds
• Sandy beaches, especially barrier beaches are the next set of hot spots.
• Overtopping and flooding on the landward side makes coast protected with seawalls unsafe
• Coasts fronted with cliffs and headlands are very safe from the impacts of SLR.
• Separate management plan required for each of the different sets of morphological units to deal with SLR.
• CRZ would be one of the supporting tools in reducing the impacts
Coastal Regulation Zone

- Intertidal zone- area between HTL & LTL
- 500 m along sea coast
- 100 m on banks of bay, creek, estuary, backwater, river
- Waterbody & the bed
- 12 nm – Territorial waters
- HTL to HTL for estuaries, backwaters, etc
Concepts on which CRZ is built

- Coast & nearshore are sensitive systems
- Coast is primarily for coastal communities
- Life & property are at risk from hazards
- Requires protection from pollution
CRZ 2011

Water area:
• Upto 12 nm in the sea
• LTL to LTL on the opposite bank for backwaters

Lagoons & holding ponds are Also CRZ IV

CRZ for backwater islands is 50 m

Land area falling between hazard line & 500 m line in CRZ
Critically Vulnerable Coastal Area

- Sundarbans
- Gulf of Khambat and Gulf of Kutchch
- Malvan and Achra-Ratnagiri
- Karwar and Coondapur
- Vembanad
- Gulf of Mannar
- Bhaitarkanika
- Coringa, East Godavari and Krishna

IMP to be prepared for CVCA based on which regulations to be formulated
Setback Line

Ecosystem, Activity & Development based

- 500, 200 & 100 m landward of HTL along coast
- 100 m for backwaters, estuaries, etc
- Hazard line
- 50 m buffer zone for mangroves of 1000m² coverage
- Existing road for developed areas (CRZ II)
- Existing line of building (CRZ II)
- Different setback lines for dwelling units, community requirements, fishery related activities and industries
How to tackle........

Wise uses to sustain morphology

Wise use of rules like EPA, EIA, CRZ, Wetland
CRZ map of Vasai
HTL (TOE OF THE CLIFF LINE)

INTER-TIDAL ZONE

25 1 2002
Signatures for HTL

Monsoon berm crest is HTL

Foot of cliff is HTL

Foot of Earth Cliff is HTL
HTL – Protected coasts

- Seawall
- Groin protected
- Cliff toe protected
Beach profile at Valiathura

Distance offshore (m)
Elevation (m)
25/3/1992
6/1/2004
SWL
CRZ- OPERATIONAL ISSUES

• Field level difficulties to deal with conflicting directions
• Sectoral interests & conflicts; lack of coordinating platform
• Difficulty to establish acceptable trade offs between conflicting development aspirations.
• Coastal land dominated by private property-
  • strong tendency to resist/ circumvent any legislation that impose restrictions on individual property rights
• Weak or limited enforcement capacity, at the local level
• Rely on the already overstretched local administration system
• Perceived as central notification obstructing development, often no great political will at the local level for enforcement
CRZ VIOLATIONS

• Violations of initial years especially 1991-1998
• Violations out of economic and social constraints
  • especially on account of acute shortage of land
  • particularly among the landless fishing community
• Difficulty to accept reconstruction without change in plinth area
• Ambiguities in CZMP
• Inadequacies of KCZMA
• Urbanization, landuse changes & compulsions
• Inadequate capacitation at the local level
• Poor transparency and reach
• Centralization & deficient redressal mechanism
• Poor flexibility for decisions
• High transaction costs for CRZ clearances
Island Protection Zone (IPZ)

- For A & N and Lakshadweep
- ICRZ for larger islands in A & N
- IIMP for smaller islands of A & N
- IIMP for all islands of Lakshadweep
## Lakshadweep Islands

<table>
<thead>
<tr>
<th>Islands</th>
<th>Area (Sq. km.)</th>
<th>Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Androth</td>
<td>4.84</td>
<td>10720</td>
</tr>
<tr>
<td>Minicoy</td>
<td>4.37</td>
<td>9495</td>
</tr>
<tr>
<td>Kavaratti</td>
<td>3.63</td>
<td>10113</td>
</tr>
<tr>
<td>Kadamat</td>
<td>3.12</td>
<td>5319</td>
</tr>
<tr>
<td>Agatti</td>
<td>2.71</td>
<td>7007</td>
</tr>
<tr>
<td>Amini</td>
<td>2.59</td>
<td>7340</td>
</tr>
<tr>
<td>Kalpeni</td>
<td>2.28</td>
<td>4319</td>
</tr>
<tr>
<td>Kiltan</td>
<td>1.63</td>
<td>3664</td>
</tr>
<tr>
<td>Chetlet</td>
<td>1.04</td>
<td>2289</td>
</tr>
<tr>
<td>Bangaram</td>
<td>0.58</td>
<td>65</td>
</tr>
<tr>
<td>Bitra</td>
<td>0.1</td>
<td>284</td>
</tr>
</tbody>
</table>
## Details of uninhabited Islands

<table>
<thead>
<tr>
<th>Name of Island</th>
<th>Area of Land (Sq.Km)</th>
<th>Area of Lagoon (Sq.Km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bangaram</td>
<td>0.465</td>
<td>46.5</td>
</tr>
<tr>
<td>Tinnakara</td>
<td>0.312</td>
<td></td>
</tr>
<tr>
<td>Cheriyam</td>
<td>0.454</td>
<td>25.6</td>
</tr>
<tr>
<td>Suheli (2)</td>
<td>0.81</td>
<td>78.96</td>
</tr>
</tbody>
</table>
The Islands

- 12 atoll reefs and 3 submerged banks along the Laccadive-Chagos ridge
- Total land area: 32 km²
- Lagoonal area: 4200 km²
- Territorial Waters: 20,000 km²
- Population: 60,595
- Pop. Density: 2126/km²
- Union Territory of India – most activities are government controlled, private enterprise low, social disparities low
<table>
<thead>
<tr>
<th>YEAR</th>
<th>LIVE</th>
<th>DEAD</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>32.7</td>
<td>30.3</td>
</tr>
<tr>
<td>2004</td>
<td>40.2</td>
<td>41.6</td>
</tr>
</tbody>
</table>
IIMP for Amini, Lakshadweep
Andaman and Nicobar
TDE GAUGE & WEATHER MONITORING STATION
(1\textit{Deployed by Port Dept})

- Tide gauge
- Solar panel
- Anemometer
- Rain gauge
- Temperature sensor
A dissenting note

- impact of SLR would not be as serious as being projected
- rising sea level is a natural phenomenon & happens during interglacial periods
- sea level has risen by about 100 m since the earth emerged from the last Ice Age some 20,000 years ago
- earth got itself adjusted to this change in sea level
- earth will get itself adjusted to sea level rise during the 21st century also.
- forecasts of future sea level rise are questioned
- forecasts fluctuate widely depending on the method used
- inaccuracies in assumptions used in models for prediction leads to larger inaccuracies in projected values
- sea levels do not rise uniformly world over
- No need to spend huge amounts of funds and efforts for a 'speculative' disaster
THANKS ........
Thank You