United Nations Framework Convention on Climate Change

CGE TRAINING MATERIALS ON VULNERABILITY AND ADAPTATION ASSESSMENT

Coastal Resources

Outline

- Overview of potential drivers of climate change on the coastal zone
- Overview of impacts of climate change
- Methods for integrated assessment of coastal zones under climate change
- Associated tools and data requirements
- Adaptation planning in coastal zones
- Case Study

Overview of potential drivers and impacts of climate change on the coastal zone

Climate change and coastal resources

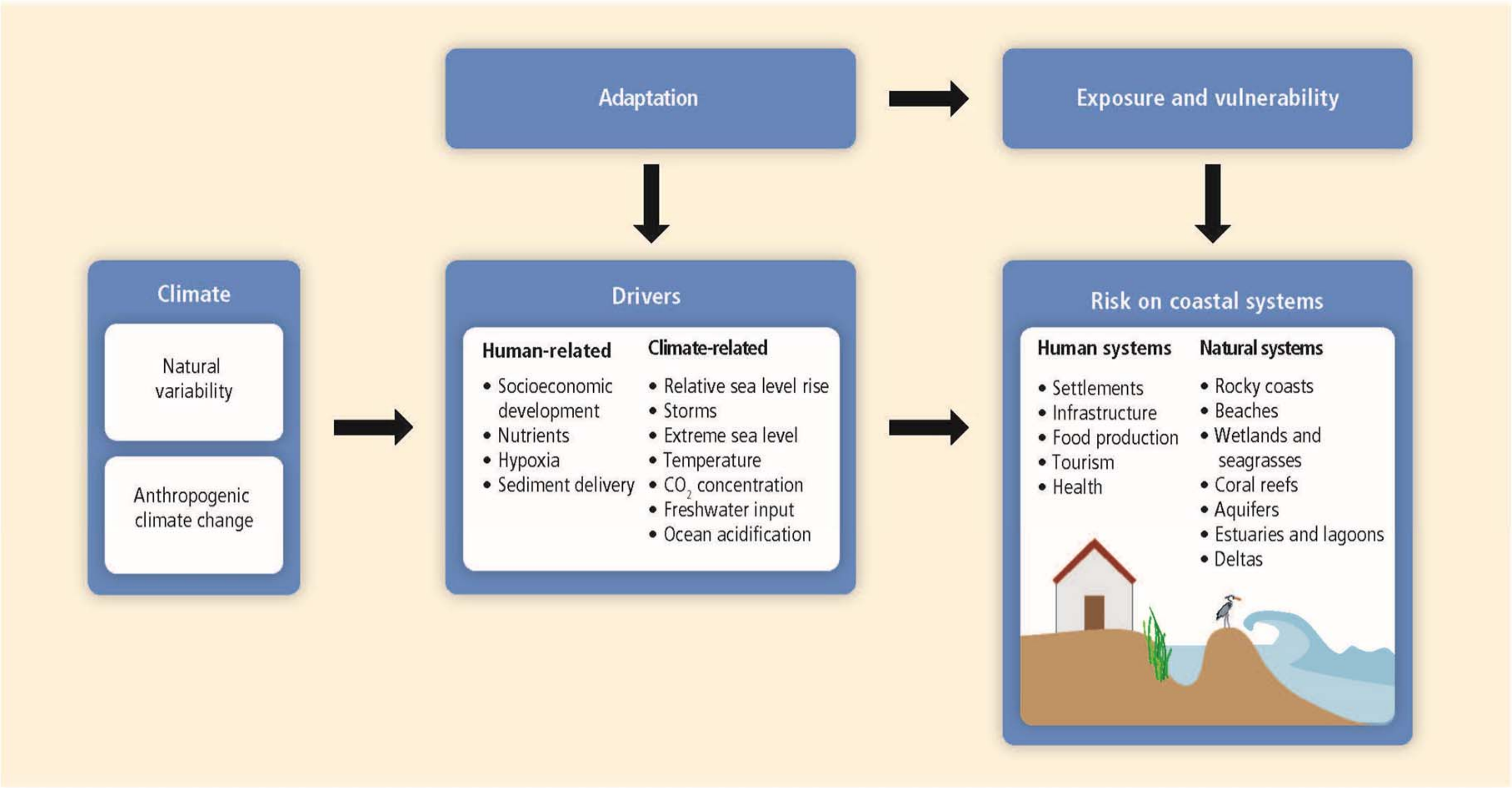
- Coastal resources will be affected by a number of consequences of climate change, including:
  a) Higher sea levels
  b) Higher sea surface temperatures (SSTs)
  c) Changes in precipitation patterns and coastal run-off
  d) Changes in storm tracks, frequencies and intensities
  e) Other factors such as wave climate, storminess and land subsidence (non-climate)

- Climate variability such as extreme events and ENSO must also be considered

- Non-climate drivers are also significant

Coastal systems and climate change

From Chapter 5, IPCC AR5, WG II



Coastal climate change drivers

Primary drivers of coastal climate change impacts, secondary drivers and processes (adapted from NCCOE, 2004)	
Primary driver	Secondary or process variable
• **Mean sea level** • **SST** • **CO_2 concentration (ocean acidification)** • **Wind climate** • **Wave climate** • **Rainfall/run-off** • **Ocean currents** • **Air temperature**	• Local (relative) sea level • Local currents • Local winds • Local waves • Groundwater • Coastal flooding • Coastal morphodynamics (erosion/accretion) • Estuarine and coastal hydrodynamics • Coastal water quality • Ecological status, such as ○ Wetlands (saltmarsh/mangroves) ○ Coral reefs ○ Sea grass

Potential Impacts

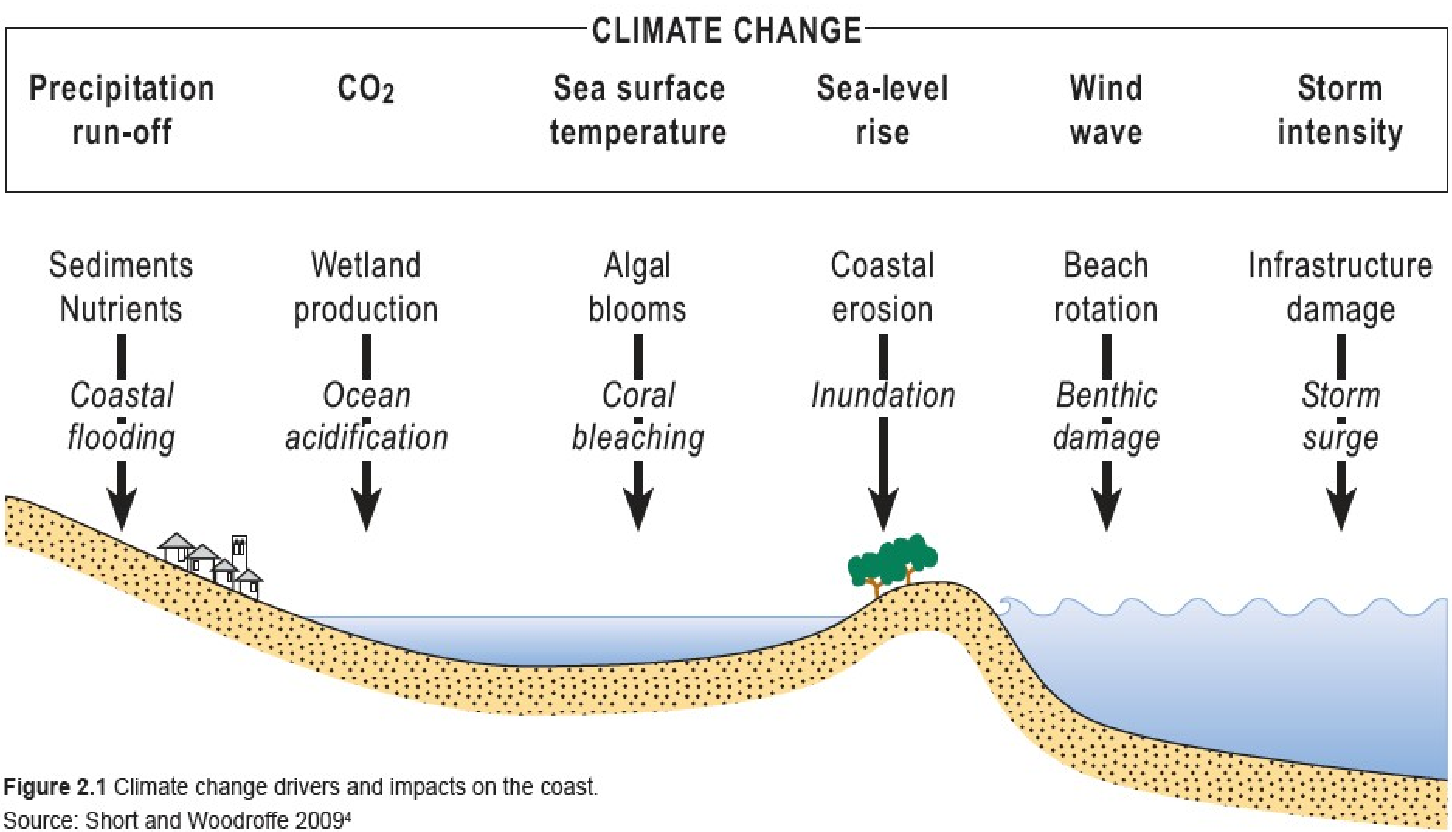


Figure 2.1 Climate change drivers and impacts on the coast.
Source: Short and Woodroffe 2009[4]

Higher Sea Level

Sea-level rise (SLR) can cause more than flooding – 5 other impacts

1. Can contaminate our drinking water
2. Can interfere with farming
3. Can change our coastal plant life
4. Can threaten wildlife populations
5. Can affect the economy

What makes the SLR more important is increasing development in coastal areas.

SLR is a significant long-term climate change issue that has important implications now and into the future for us all, internationally, nationally or locally.

Wave Climate

Climate change may bring bigger waves for down under
Hemer, M. A et al., Nature Climate Change, 2013

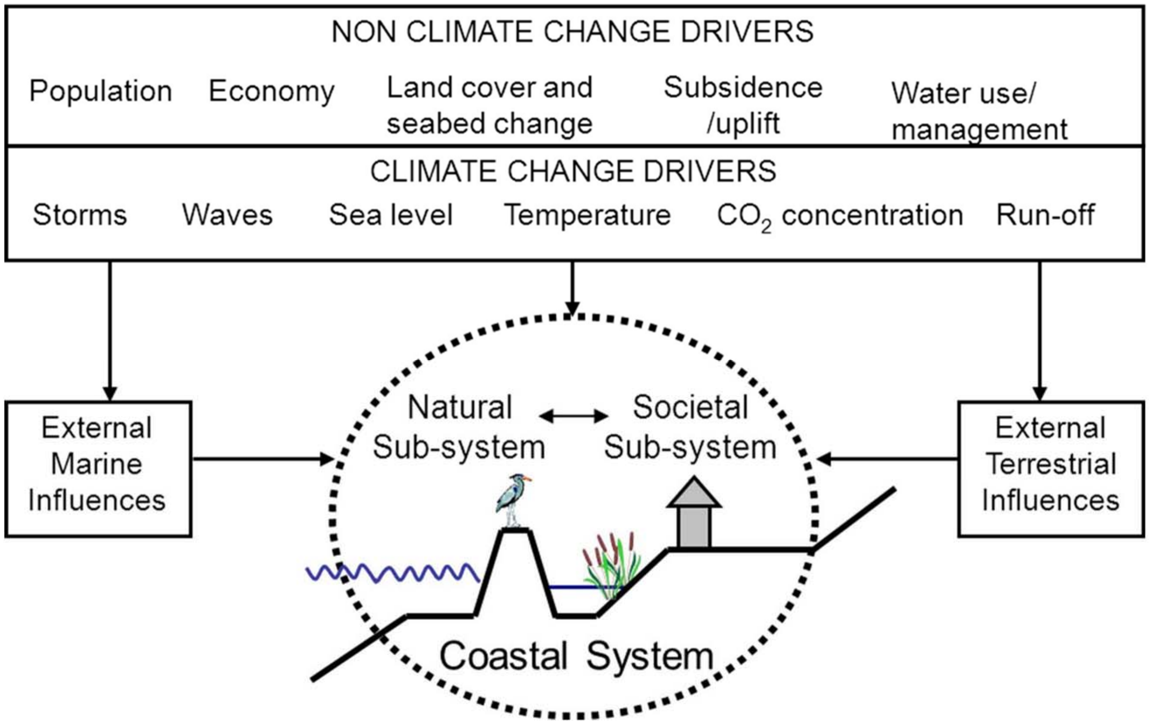
Coasts will be exposed to increased risks. Coastal areas will be affected, as waves shape beach profiles and morphology.

Implications for the fishing industry as well as for coastal mitigation efforts.

The projected effects of climate change on wave heights are at least as important for coastal impacts in many areas as increasing sea levels.

The coastal system: Non-climate drivers

Taken from Nicholls et al. (2014)



Land subsidence

Sudden subsidence on the coast of Turkey following an earthquake in 1999

Science summary

- Under a high-emissions scenario (RCP8.5), SLR up to 1 m is plausible by the end of the century: a rise of up to 2 m cannot be discounted for the purposes of vulnerability and adaptation assessment.

- Higher mean sea level, possibly enhanced by bigger surges, will lead to escalating risks of coastal inundation and flooding. Under the highest SLR scenario, by mid-century, inundations that previously occurred once every hundred years could happen several times a year.

- SLR will not stabilize by 2100. Regardless of reductions in greenhouse gas emissions, sea level will continue to rise for centuries; an eventual rise of several meters is possible even with strident climate change mitigation.

Some Climate Change Factors

		Timeframe	Cause	Predictability
Net extreme event hazards	Recurring extremes (storm surge/tide)	Hour–days	Wave, wind, storms	Moderate to uncertain
	Tide ranges	Daily–yearly	Gravitational cycle	Predictable
	Regional sea level variability	Seasonal–decadal	Wave climate, ENSO, PDO	Moderate; not well known
Net regional mean sea level rise (SLR)	Regional net land movement	Decades–millennia	Tectonic	Predictable once measured
	Regional SLR	Months–-decades	Ocean warm/ current/climate	Observable; future uncertain
	Global mean SLR	Decades – centuries	Climate change (temp, ice melt)	Short term understandable; future uncertain

Overview of impacts of climate change

Biophysical impacts of climate change

Climate driver (trend)	Main physical/ecosystem effects on coastal ecosystems
(CO_2) concentration	Increased CO_2 concentration decreases ocean acidification, negatively impacting coral reefs and other pH
Surface sea temperature (SST) (I, R) ***(I: increasing, R: Regional variability)***	Increased stratification/changes circulation; reduced incidence of sea ice at higher latitudes; increased coral bleaching and mortality; pole-ward species migration; increased algal blooms
Sea level (I, R)	Inundation, flood and storm damage; erosion; saltwater intrusion; rising water tables/impeded drainage; wetland loss (and change)
Storm intensity (I, R)	Increased extreme water levels and wave heights; increased episodic erosion, storm damage, risk of flooding and defence failure
Storm frequency (?, R); Storm track (?, R)	Altered surges and storm waves, and hence risk of storm damage and flooding
Wave climate	Altered wave conditions, including swell; altered patterns of erosion and accretion; re-orientation of beach plan form
Run-off (R)	Altered flood risk in coastal lowlands; altered water quality/salinity; altered fluvial sediment supply; altered circulation and nutrient supply

Impacts of sea level rise, including interacting factors

Biophysical impact		Interacting factors: Climate	Interacting factors: Non-climate
1. Inundation, flood and storm damage	a. Surge (sea flooding)	Wave/storm climate Erosion Sediment supply	Sediment supply Flood management Erosion Land reclamation
	b. Backwater effect (river flooding)	Run-off	Catchment management Land use
2. Wetland loss (and change)		CO_2 fertilisation of biomass production Sediment supply Migration space	Sediment supply Migration space Land reclamation
3. Erosion (of "soft" morphology)		Sediment supply Wave/storm climate	Sediment supply
4. Saltwater Intrusion	a. Surface Waters	Run-off	Catchment management Land use
	b. Ground-water	Rainfall	Land use Aquifer use
5. Rising water tables/ impeded drainage		Rainfall Run-off	Land use Aquifer use Catchment management

After Nicholls (2010)

Potential Impacts

Effect category	Example effects on the coastal Environment
Bio-geophysical	❖ Displacement of coastal lowlands and wetlands ❖ Increased coastal erosion ❖ Increased flooding ❖ Salinization of surface groundwater
Socio-economic	❖ Loss of property and lands ❖ Increased flood risk/loss of life ❖ Damage to coastal infrastructures ❖ Loss of renewable and subsistence resources ❖ Loss of tourism and coastal habitants ❖ Impacts of agriculture/aquiculture and a decline in soil and water quality

Effects of Climate Change on the Coastal Zone

Effect category	Example effects on the coastal Environment
Secondary impacts of accelerated SLR	❖ Impact on livelihoods and human health ❖ Decline in healthy/living standards as a result of decline in drinking water quality ❖ Threat to housing quality
Infrastructure and economic activity	❖ Diversion of resources to adaptation responses to SLR impacts ❖ Increasing protection costs ❖ Increasing insurance premiums ❖ Political and institutional instability, and social unrest ❖ Threats to particular cultures and ways of life

Threats to the Coastal Environment

Sector	Climate Change Threats	Other Human Threats
Coral Reefs, Coastal Wetlands and Ecosystems	• Loss of coral reefs from **coral bleaching** and **ocean acidification** • **Loss or migration of coastal wetland ecosystems,** including salt marshes and mangroves • Runoff from more intense **precipitation** causing coastal erosion, and sedimentation adversely affecting estuaries and coral reefs • Nutrient rich runoff under conditions of higher **sea surface temperature** promoting coastal hypoxia and marine **dead zones** • Change in the distribution and **abundance** of commercially valuable marine species • Increased spread of **exotic** and **invasive species**	• 30 percent of the world's **coral reefs** have been lost as a consequence of overfishing, pollution, and habitat destruction • Intense coastal development and **habitat loss** • Pollution and marine **dead zones** • **Conversion of mangroves** and wetlands for mariculture • Disruption of the quantity, quality, and timing of **freshwater inflows** to estuaries • Damage to **seagrass beds** from sedimentation, recreational boating, fishing and tourism • **Coral mining** for construction and lime making • **Oil spills** from shipping • Spread of **invasive species** • Coastal reinforcement disrupts natural **shoreline processes** • Sand and gravel **mining** of riverbeds and beaches
Capture Fisheries	• Overall decline in ocean productivity • **Eutrophication** and coral mortality leading to reduced fish catch • **Loss or shifts in critical fish habitat** • **Temperature shifts** causing migration of fishes • Extreme events, temperature increases and oxygen depletion reducing spawning areas in some regions • **Temperature changes** affecting the abundance and distribution of marine pathogens • **Ocean acidification** and increases in temperature damaging coral reefs	• **Over-harvesting** • **Destructive fishing** practices (e.g., bottom trawling, dynamite fishing, beach seining) • Land-based sources of **pollution** (sewage, industrial waste, nutrient runoff, etc.) • **Sedimentation** of coastal systems from land-based sources

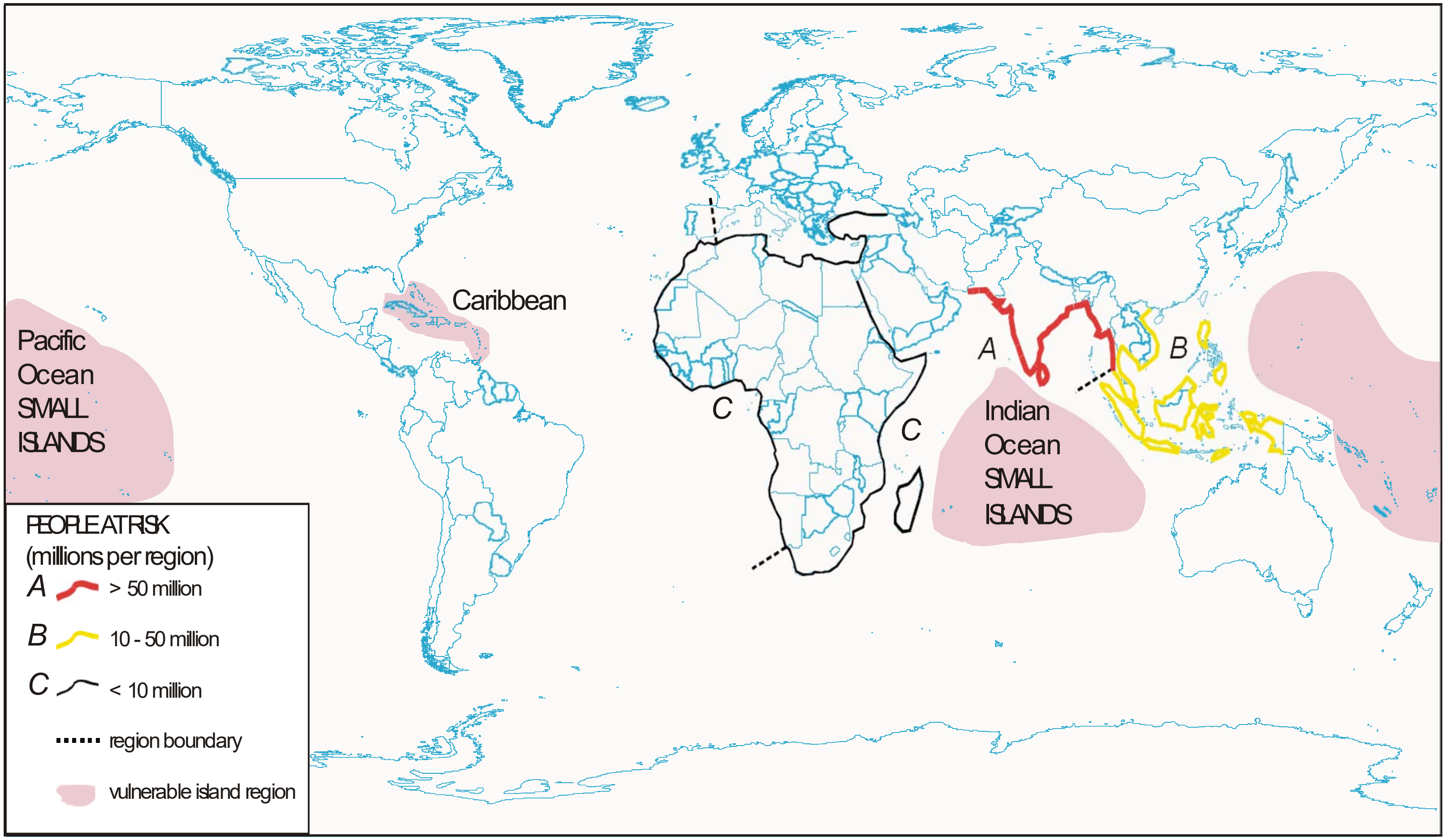
Threats to the Coastal Environment (continued)

Sector	Climate Change Threats	Other Human Threats
Mariculture	• Increases in water temperature could result in **unpredictable changes** in culture productivity • Environmental changes could increase stress and vulnerability to **pathogens** and parasites in cultured organisms • Overall decline in **ocean productivity** reduces supplies of wild fish used for fish meal for mariculture sector • Changes in weather patterns and extreme weather events reduce **productivity** and damage operations (loss of infrastructure and stock)	• **Overexploitation** of juveniles and larvae seed stock for fish farms • Release of chemicals, nutrients and sediment in pond effluents • **Spreading of pathogens** and disease to local ecosystems and neighboring culture operations • **Loss of protective habitats** from improper siting of mariculture facilities
Recreation and Tourism	• **Storms, erosion, and precipitation** damaging infrastructure and causing losses to beaches • Compromised **water quality** and increasing beach closures • Increases in tourism **insurance costs** on high-risk coasts	• **Improper siting** of tourist facilities • **Alteration** of the shoreline, coastal processes and habitat • Strain on **freshwater resources** for tourist facilities • **Marine pollution** and habitat disruption from recreational boating
Freshwater Resources	• **Saltwater intrusion** of freshwater sources • Encroachment of saltwater into estuaries and coastal rivers • Waves and **storm surges** reaching further inland, increasing coastal inundation and **flooding** • **Decreased precipitation**, enhancing saltwater intrusion, and exacerbating water supply problems	• Discharge of untreated sewage and chemical **contamination** of coastal waters • Unregulated **freshwater extraction** and withdrawal of groundwater • Upstream **dams** • Enlargement and **dredging** of waterways

Threats to the Coastal Environment (continued)

Human Settlements	• Coastal **inundation** causing relocation inland • Building and infrastructure damage from increasing coastal **storm intensity** and flood exposure • **Sea level rise** raising water levels during storm surge • Reduced clearance under bridges • Overtopping of coastal defense structures • **Sea level rise,** erosion, and extreme weather events leading to degradation of natural coastal defense structures	• Rapid increase in **coastal development** projected to impact 91% of all inhabited coasts by 2050 • Inappropriate **siting** of infrastructure • Shoreline **armoring** • **Habitat conversion and biodiversity loss**
Human Health	• **Heat stress** from extremely hot periods • Injuries, illness, and loss of lives due to **extreme weather events** • **Malnutrition** and food shortages during extreme events • Increased spread of vector-borne **disease** (dengue fever and malaria), waterborne diseases (diarrhea) and toxic algae (ciguatera)	• **Pollution** and water contamination
Conflict	• **Coastal land loss** leading to coastal land and resource scarcity or loss, and human migration • **Water use** conflicts due to scarcity • Population **migration** to urban areas as ocean productivity and food availability declines and fishers are displaced	• **Displacement** and loss of shore access resulting from tourism and coastal development

Vulnerable Regions Mid-estimate by the 2080s



Vulnerable regions by type

- Small islands
- Deltaic areas
- Coastal cities
- Coastal wetlands and other ecosystems
- Geographically

Methods for integrated assessment of coastal zones under climate change

Three levels of assessment are suggested

Level of assessment	Time-scale	Precision	Prior knowledge	Issues considered
1. Screening assessment (issue scoping)	2–3 months	Lowest	Low	Define the key issues and directions of change in broad qualitative or semi-quantitative terms. Strong focus on sea level rise.
2. Impact assessment (initial impact and adaptation assessment)	1–2 years	Medium	Medium	Building on the screening assessment, impacts are quantified, including the possible role of other climate change and non-climate drivers. The adaptive capacity should be considered.
3. Planning assessment (linking to wider coastal management)	Ongoing (as part of adaptation processes)	Highest	High	Building on impact assessment, more comprehensive assessments are conducted considering all relevant drivers (using multiple scenarios to explore uncertainty). Adaptation is integral.

Assessment Level 1: Screening assessment

- A rapid assessment to highlight possible impacts of a sea level rise and identify information/data gaps
- **Qualitative or semi-quantitative**
- Steps
  a) Collation of existing coastal data
  b) Assessment of the possible impacts
     (using a 1-m sea level rise scenario)
  c) Implications of future development
  d) Consider possible responses

Step 1: Collation of existing data

- Topographic surveys
- Aerial/remote sensing images – topography/land cover
- Coastal geomorphology classification
- Evidence of subsidence
- Long-term relative sea level rise
- Magnitude and damage caused by flooding
- Coastal erosion
- Population density
- Activities located on the coast (cities, ports, resort areas and tourist beaches, industrial and agricultural areas)

Step 2: Assessment of possible impacts of 1-m sea level rise

- Four main impacts are considered, although other issues can be introduced if desired:
  a) Increased storm flooding
  b) Beach/bluff erosion
  c) Wetland and mangrove inundation and loss
  d) Salt water intrusion
  e) Others?

(i) Increased storm flooding

- Describe what is located in flood-prone coastal areas
- Describe historical floods, including location, magnitude and damage, the response of the local people and the response of government
- How have policies towards coastal flooding evolved?

(ii) Beach/bluff erosion

- Describe what is located within 300 m of the ocean coast.
- Describe beach types.
- Describe the various livelihoods of the people living in coastal areas such as commercial fishers, international-based coastal tourism or subsistence lifestyles.
- Describe any existing problems of beach erosion, including quantitative data. These areas will experience more rapid erosion given accelerated sea-level rise.
- For important beach areas, conduct a Bruun rule analysis (Nicholls, 1998) to assess the potential for shoreline recession given a 1-m rise in sea level – assume retreat is 100 times the rise in sea level.
- What coastal infrastructure might be impacted by such recession?

(iii) Wetland and mangrove inundation

- Describe the wetland areas, including human activities and resources that depend on the wetlands. For instance, are mangroves being cut and used, or do fisheries depend on wetlands?

- Have wetlands or mangroves been reclaimed for other uses, and is this likely to continue?

- Are these wetlands viewed as a valuable resource for coastal fisheries and hunting or merely thought of as wasteland?

(iv) Salt water intrusion

- Is there any existing problem with the water supply for drinking purposes?
- Does it seem likely that salinization due to sea-level rise will be a problem for surface and/or subsurface water?

Step 3: Implications of future developments

- Possible examples include:
  a) New and existing river dams and impacts on downstream deltas
  b) New coastal settlements
  c) Expansion of coastal tourism
  d) Possibility of transmigration
  e) Others?

Step 4: Responses to the sea level rise impacts

- What adaptation responses might be considered, recognising that there are three major types of response
  a) Protect (i.e., hard and soft defences, seawalls, beach nourishment)
  b) Accommodate (i.e., raise buildings above flood levels)
  c) Planned retreat (i.e., setback of defenses)

Screening assessment matrix (biophysical vs. socioeconomic impacts)

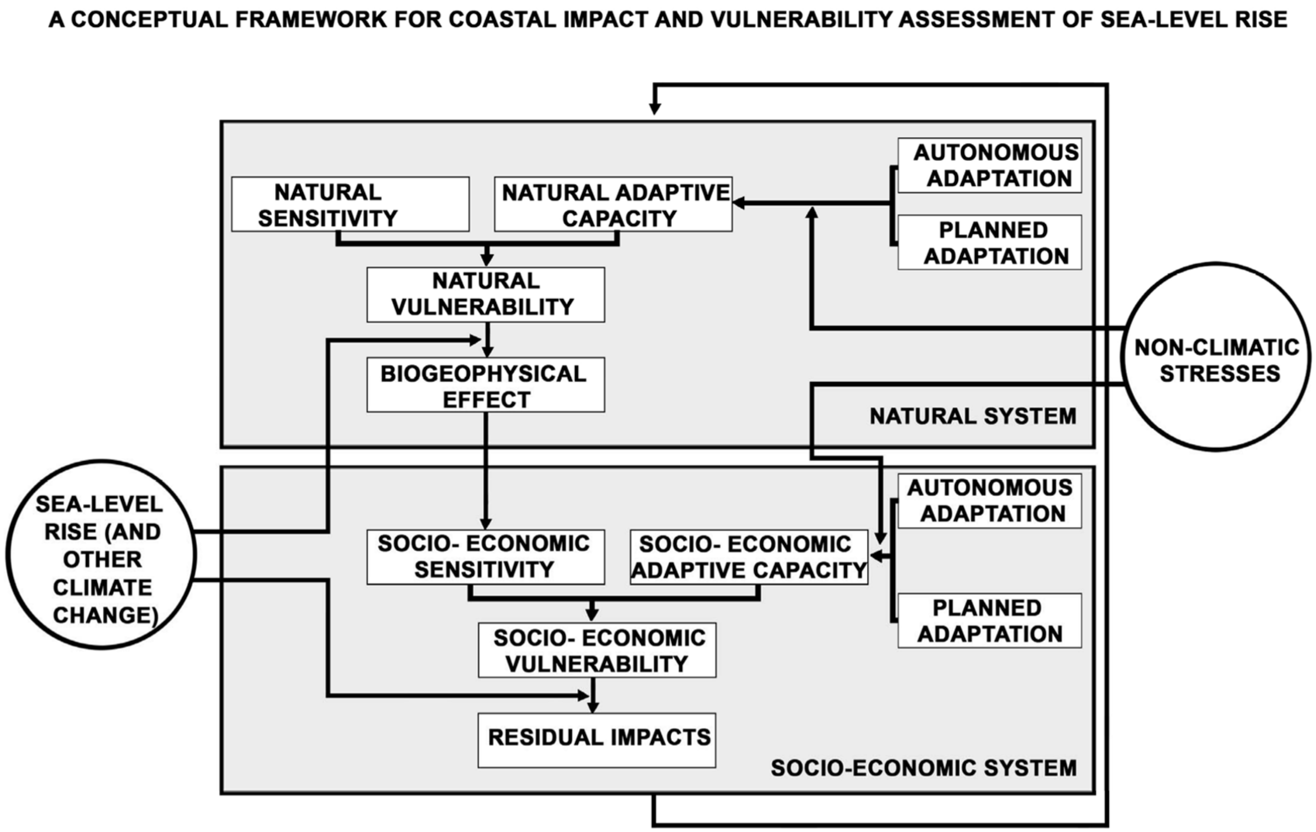
Biophysical impacts	Socio-economic impacts								
	Tourism	Human settlements	Agriculture	Water supply	Fisheries	Financial services	Human health	Gender	Others (add)?
Inundation									
Erosion									
Flooding									
Salinization									
Others (add)?									

Assessment Level 2: Impact assessment

- Building on screening assessment, impacts are quantified, including other climate change and non-climate drivers. Adaptation responses and adaptive capacity should be explicitly considered. Duration: 1–2 years.

- Issues:
  I. Erosion
  II. Flooding
  III. Coastal wetland/ecosystem loss
  IV. Other issues?

Coastal Vulnerability Assessment



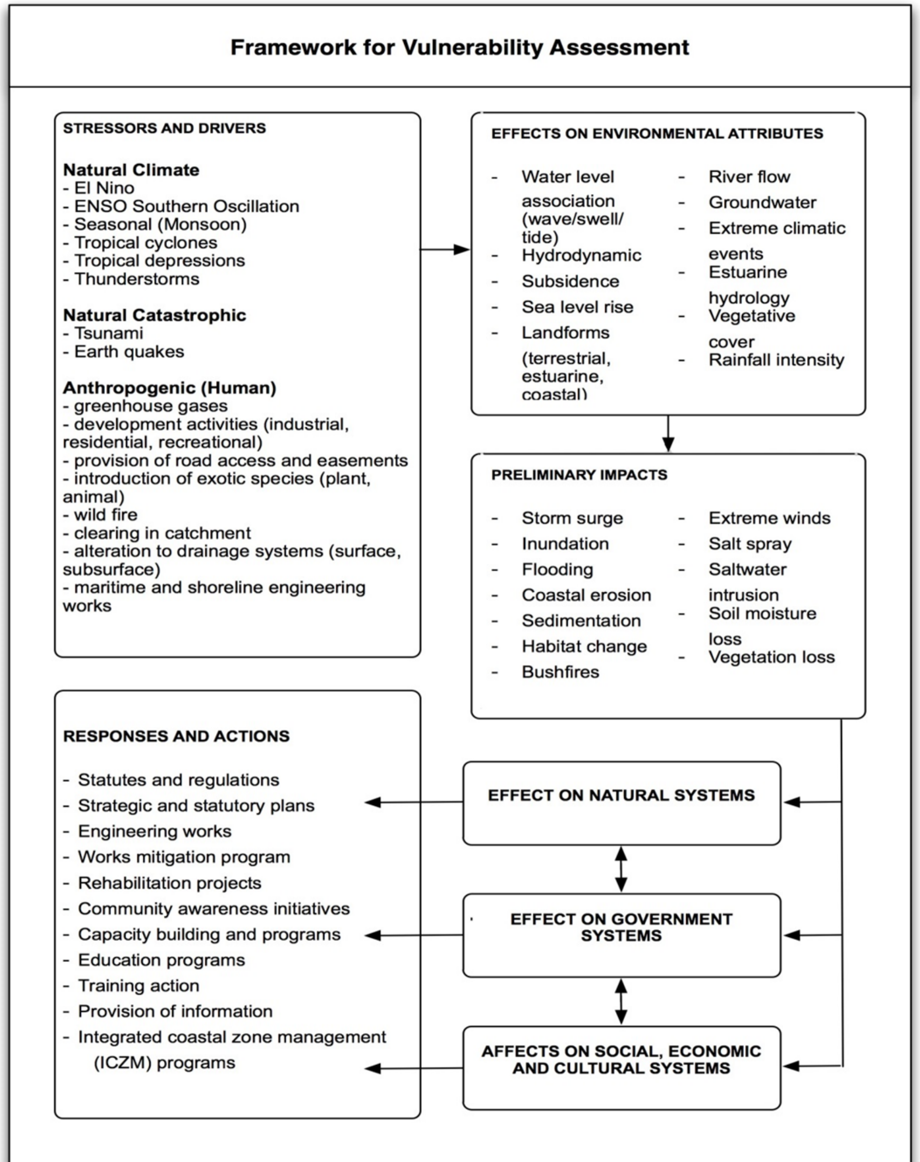
Nicholls, 2002

Impact Assessment

Three levels of assessment are suggested

Level of assessment	Timescale required	Precision	Prior knowledge	Other scenarios in addition to SLR
Strategic level (screening assessment)	2-3 months	Lowest	Low	Direction of change
Vulnerability assessment	1-2 years	Medium	Medium	Likely socio-economic scenarios and key scenarios of key climate drivers
Site-specific level (planning assessment)	Ongoing	Highest	High	All climate change drivers (often with multiple scenarios)

Impact assessment



Source: Kay et al (2006)

(i) Impact assessment: Beach erosion

..Human factors outweigh…

Sediment Budget
The existence of a sandy beach depends on the balance between the power in waves and currents and the sediment available for transport. This balance, or budget, is calculated from the sediment flux contributions and losses to the cell.

Much like a bank account, there are deposits (sediment flux from streams), withdrawals (loss to shelf and submarine canyons) and the balance (sand in transport along the beach).

Shorelines are subjected to change, with the ocean eroding landward as well as building seaward. Underlying the seasonal damage caused by natural occurrences one could find that human factors, unwise planning and man-made modifications contributed to the problem.

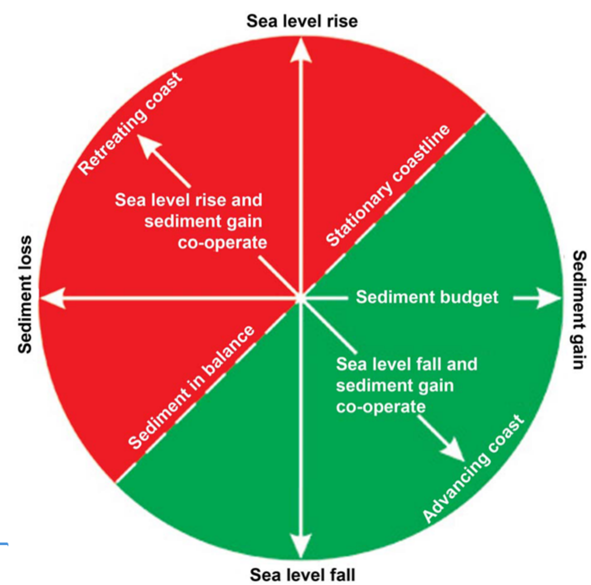
SLR will be a inexorable cause of beach erosion

Eos, Transactions American Geophysical Union , Vol. 81, Issue 6, 2011

Sea Level Rise Shown to Drive Coastal Erosion

The link is highly multiplicative, with the long-term shoreline retreat rate averaging about 150 times that of sea level rise.

SLR will be an inexorable cause of beach erosion in shoreline revision zones of man-made structures.



(ii) Impact assessment: Coastal flooding

- Increase in flood levels due to rise in sea level

- Increase in inundation probability and flood risk (e.g., damage per events and year)

- Increase in populations in coastal floodplain

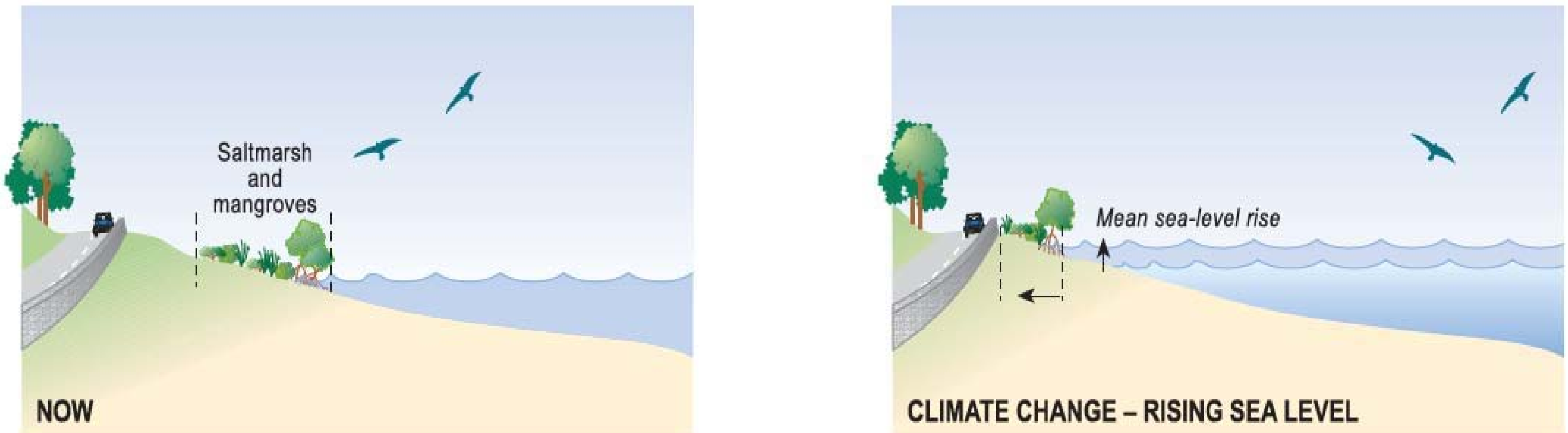
- Adaptation:
  a) Increase in flood protection
  b) Management and planning in the floodplain

(iii) Impact assessment: Wetland/ecosystem loss

- Inundation and displacement of wetlands, e.g., mangroves, saltmarsh, intertidal areas
  a) Wetlands provide:
    - Flood protection
    - Nursery areas for fisheries
    - Important areas for nature conservation

- Loss of valuable resources, tourism

Coastal squeeze (of coastal wetlands)

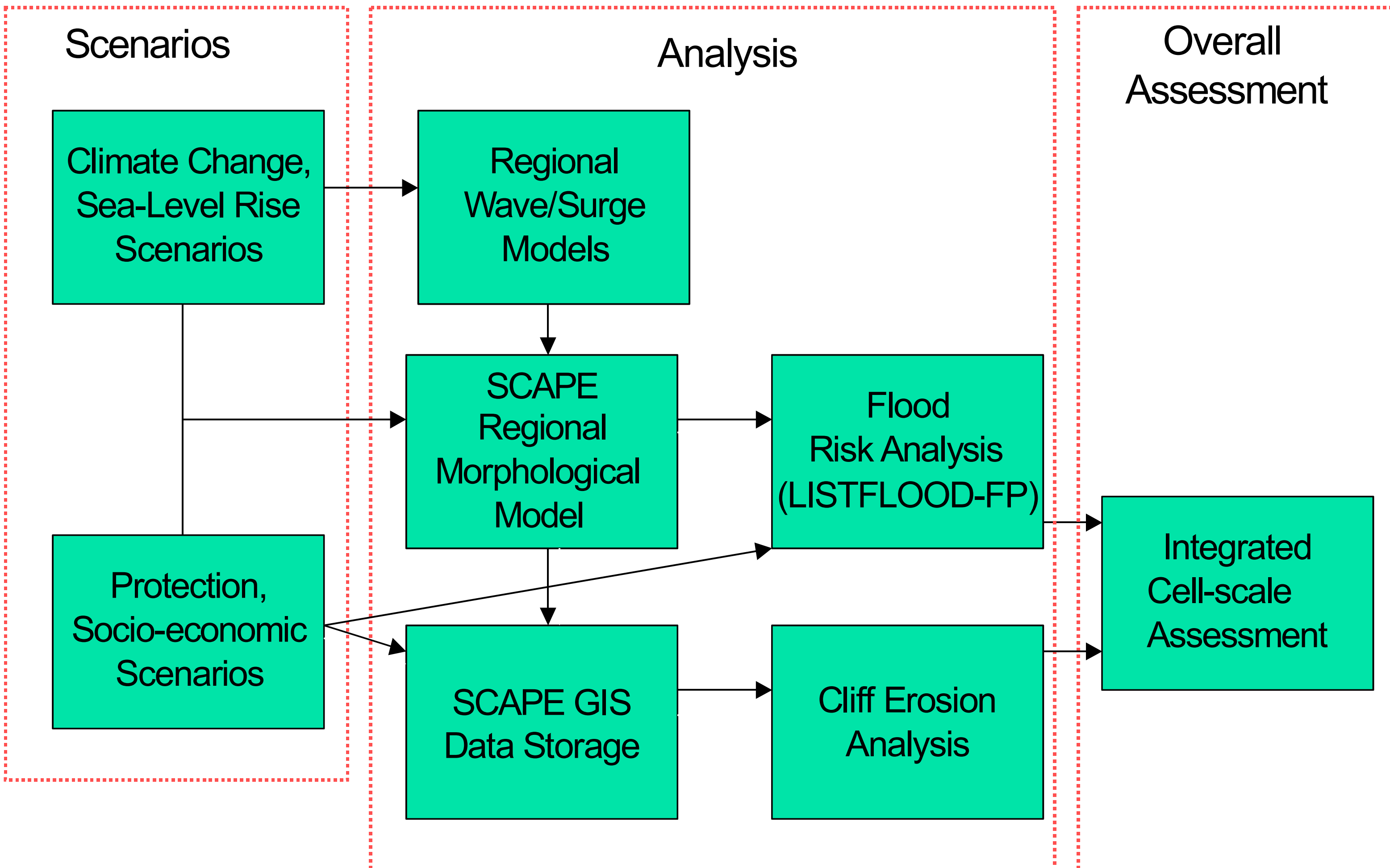


Coastal squeeze under SLR, wetlands are squeezed between the rising sea level and fixed (and protected) human development (Image: DCCEE, 2009).

Assessment Level 3: Planning assessment

- Building on impact assessment, more comprehensive assessments are conducted considering all relevant drivers
- Uncertainty analysis is essential
- Understanding adaptation is integral
- Needs to be embedded in wider coastal management processes – mainstreaming the activity

Method for planning assessment



Results

- The more you protect the cliffs (lower erosion risk), the more the flood risk increases in the coastal lowlands

- Erosion damage is much smaller than flood damage, so managing flood risk is a priority

- If the coast is allowed to erode under rising sea levels, cliff-top land and properties are lost, but the sediment produced is sufficient to maintain wide beaches and greatly minimise flood risk

- This research emphasises the important trade-offs in coastal management under changing climate, which need to be assessed more widely

Associated tools and data requirements

Tools for vulnerability and adaptation assessment

Examples associated with the UNFCCC Compendium

Method	Strengths	Limitations
Shoreline planning method	Widespread application around the world's coasts in coastal management based on a one-dimensional data model (Box 5-1).	Requires customization to individual coastal zone management administrative systems.
Coastal vulnerability indices (CVI)	Generally easily calculated and employed for rapid vulnerability assessment.	Requires customization of variables for case-by-case use.
Dynamic interactive vulnerability analysis (DIVA)	Provides an overview of climatic and socio-economic scenarios and adaptation policies on regional and global scales. Could be downscaled providing a useful database resource.	Provides coarse-scale resolution of potential coastal impacts at a national scale, some limited perspectives on vulnerability of the coast to climate change. Downscaling requires significant data collection and is not well documented (not currently available for download).
CoastClim and SimClim	Commercial decision-making aid for changed climate conditions.	Requires purchase.
Smartline	Cost effective and rapid geomorphic mapping of coastal sensitivity; applicable at multiple scales.	Adaptation to local and site-specific scale will require testing and validation.

Example datasets

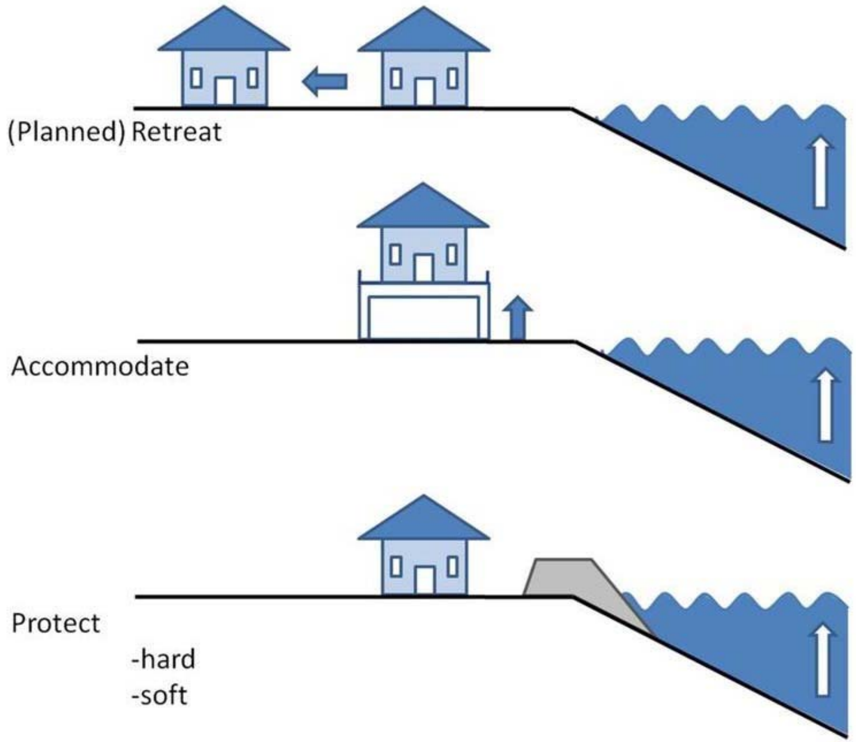
Category	Title	Description	Link
Sea-level data	Permanent Service for Mean Sea Level (PSMSL)	The PSMSL is the global data bank for long-term sea-level change information from tide gauges and bottom pressure recorders around the globe	http://www.psmsl.org/
Sea-level data	Global Sea Level Observing System (GLOSS)	The GLOSS provides data from 290 sea-level stations around the world for long-term climate change and oceanographic sea-level monitoring	https://www.gloss-sealevel.org/
Remotely sensed topography data	Land Process Distributed Active Archive Centre (LP DAAC)	The LP DAAC is a component of NASAs Earth Observing System Data and Information System (EOSDIS) that processes, archives and distributed land data and products derived from EOS sensors	https://lpdaac.usgs.gov/
Remotely sensed topography data	Shuttle Radar Topography Mission (SRTM)	The SRTM is a NASA project providing high-resolution digital topographic database of the Earth, excluding the high latitudes	https://www2.jpl.nasa.gov/srtm/
Oceanographic drivers	NOAA National Oceanographic Data Center (NODC)	The NODC provides global and regional data on a range of oceanic drivers and parameters	https://www.nodc.noaa.gov/

Adaptation planning in coastal zones

Adaptation

- Mitigation and/or adaptation?
- Socio-economic systems in coastal zones also have the capacity to respond autonomously to climate change
- Farmers may switch to more salt-tolerant crops, people may move out of areas increasingly susceptible to flooding and property prices may change – *autonomous adaptation*
- Because impacts are likely to be significant, even considering autonomous adaptation, *planned adaptation* is needed

Planned adaptation to sea level rise



Example approach to adaptation measures

- Caribbean small island developing country

- Climate change predictions:
  a) Rise in sea level
  b) Increase in number and intensity of tropical weather systems
  c) Increase in severity of storm surges
  d) Changes in rainfall
  e) Reclamation of land, sand mining and lack of comprehensive natural system engineering approaches to control flooding and sedimentation have increased the vulnerability to erosion, coastal flooding and storm damage in Antigua

Example approach to adaptation measures (cont.)

- Coastal impacts:
  a) Damage to property/infrastructure – particularly in low-lying areas, which can affect the employment structure of the country
  b) Damage/loss of coastal/marine ecosystems
  c) Destruction of hotels and tourism facilities – create psychological effects to visitors
  d) Increased risk of disease – increased risk of various infectious diseases, increased mental and physical stress
  e) Damage/loss of fisheries infrastructure
  f) General loss of biodiversity
  g) Submergence/inundation of coastal areas

Example approach to adaptation measures (cont.)

- Adaptation (retreat, protect, accommodate):
  a) Improved physical planning and development control
  b) Strengthening/implementation of Environmental Impact Assessments (EIA) regulations
  c) Formulation of Coastal Zone Management Plan
  d) Monitoring of coastal habitats, including beaches
  e) Formulation of national climate change policy
  f) Public awareness and education.

Adaptation options related to goals

Adaptation Option	Climate Stressor Addressed	Additional Management Goals Addressed	Benefits	Constraints	Examples
Retreat from and abandonment of coastal barriers	Sea level rise	Maintain/restore wetlansd	May help protect estuaries, allowing them to return to their natural habitats	Not politically favored due to the high value of coastal property and infrastructure	
Purchase upland development rights or property rights	Changes in percipitation; Sea level rise	Maintain/restore wetland; Maintain water quality	Protects habitats downstream	Costly; uncertainty about sea level rise means uncertainty in the amount of property purchased	San Francisco Estuary Project (planned); Massachusetts Climate Protection Plan
Expand the planning horizons of land use planning to incorporate longer climate predictions	Changes in precipitation; Sea level rise	Preserve coastal land/development	Could inhibit risky development and provide protection for estuarine habitats	Land use plans rarely incorporate hard prohibitions against development close to sensitive habitats and have limited durability over time	San Francisco Bay Conversation and Development Commission (SFBCDC) has proposed recommendations

Source: U.S. EPA, 2008

Adaptation planning, integration, and mainstreaming

- Coastal managers, stakeholders and decision-makers can use the following range of criteria in deciding the best adaptation option within a given local context:
  a) Technical effectiveness: How effective will the adaptation option be in solving problems?
  b) Costs: What is the cost to implement the adaptation option and what are the benefits?
  c) Benefits: What are the direct climate change-related benefits?
     - Does taking action avoid damages to human health, property or livelihoods?
     - Or, does it reduce insurance premiums?
- Implementation considerations:
  a) How easy is it to design and implement the option in terms of level of skill required, information needed, scale of implementation and other barriers?
- Most adaptation measures can help in achieving multiple objectives and benefits. "No regrets" measures should be the priority.

Case Study

IMPLICATIONS OF SEA LEVEL RISE SCENARIOS ON LAND USE/ LAND COVER CLASSES OF THE COASTAL ZONES OF COCHIN, INDIA

Journal of Environmental Management 148 (2015) 124e133

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

Implications of sea level rise scenarios on land use /land cover classes of the coastal zones of Cochin, India

R. Mani Murali [a,*], P.K. Dinesh Kumar [b]

[a] CSIR-National Institute of Oceanography, Dona Paula, Goa 403004, India
[b] Regional Centre, CSIR-National Institute of Oceanography, Kochi, India

Article history:
Received 15 July 2013
Received in revised form
21 March 2014
Accepted 10 June 2014
Available online 16 July 2014

a b s t r a c t

Physical responses of the coastal zones in the vicinity of Cochin, India due to sea level rise are investi- gated based on analysis of inundation scenarios. Quantifi cation of po tential habitat loss w as m a de by merging the Land use/Land cover (LU/LC) prepared from the satellite imagery with the digital elevation mode l. Scenarios w e re generated for tw o different rates of sea level rise and responses of changes occurred w e re m a de to ascertain the vulnerability and loss in extent. LU/LC classes overlaid on 1 m and 2 m elevation show ed tha t it w as mostly covered by vegetation areas followed by w ater and urb an zones. For the sea level rise scenarios of 1 m and 2 m, the total inundation zones were estimated to be 169.11 km ^{2} and 598.83 k m ^{2} respectively using Geographic Inform ation Syste m (GIS). The losses of urban areas w e re estimated at 43 km ^{2} and 187 km ^{2} for the 1 m and 2 m sea level rise respectively w hich is alarm ing information for the most densely popu lated state of India. Quantitative comparison of other LU/ LC classes show ed signifi cant changes under each of the inundation scenarios. The results obtained conclusively point that sea level rise scenarios will bring profound effects on the land use and land cover classes as well as on coastal landforms in the stud y region. Coastal inundation would leave ocean front and inland properties vulnerable. Increase in these w ater levels would alter the coastal drainage gra- dients. Reduction in these gradients would increase flooding attributable to rainstorms w hich could promote salt water intrusion into coastal aquifers and force water tables to rise. Changes in the coastal landforms associated with inundation generate concern in the background that the coastal region may continue to remain vulnerable in the coming decades due to population growth and development pressures.

1. Introduction

Global sea level rise (SLR) ranging from 0.5 m to 2 m has been predicted over the next century and it w ould disrupt the p hysical processes, economic activities and social systems in the coastal zones (Gommes et al., 1997 ; NOAA Report, 1999; Solomon et al., 2007). Besides the destruction through increased rates of erosion, sea level rise situations increase the risk of inundation (Nicholls et al., 1999). Among the different impacts of climate change, sea level rise raise much concern mainly due to the direct physical impact of inundation and potential habitat loss. A comparative analysis on the impact of permanent inundation due to sea level rise on 84 countries of the world revealed that hundreds of millions

* Corresponding author.
E-mail addresses: mmurai@nio.org, niomurali@gmail.com (R. Mani Murali), pkdineshkumar@yahoo.com (P.K. Dinesh Kumar).

http://dx.doi.org/10.1016/j.jenvman.2014.06.010

Background

The effects of climate change are placing coastal communities at increasing risk of inundation. Variations resulting will be site specific and depending on coastal configuration

Sustainable development relies upon effective management of the risk of hundation

Aims to provide an example of good practice in preparedness for and awareness of sea level related hazards

Elements, approaches and tools used could be replicated for similar conditions, or to provide a basis more appropriate for other regions to create safer coasts in future

May provide insights and lessons for managers, policy makers and development planners at national/local levels

Presentation Orientation

Genesis
Case study
Environmental setting
Methodology
Results
Implications, Impacts
Significant impact concerns
Information gains and future

Genesis

Coastal Cities - Grown dramatically over the past 50 years, a trend that is projected to continue into the foreseeable future, stimulated by the expanding economy, stresses fragile but important ecosystems.

Urbanization, Population growth, Expansion of economic activities, Environmental and resource over use

Added up problem: CLIMATE CHANGE

Wider Perspectives - An opportunity than a problem

Will show measures to reduce vulnerabilities

Related to actions that promote urban development for the future – not just in theory

…Genesis

Conceptual framework of relative environmental constancy and planning

Inadequacy of short-term economic planning in terms of achieving sustainable development

Stress on: ‘climate change’ component

Need to review the planning processes to incorporate the elements of environmental changes into future development planning

The change in perspective is now nowhere more important than in human use in coastal cities

Case Study


India
KERALA
J & K
Himachal Pradesh
Punjab
Haryana
Delhi
Uttar Pradesh
Rajasthan
Gujarat
Madhya Pradesh
Maharashtra
Sikkim
Bihar
Arunachal Pradesh
Assam
Nagaland
Meghalaya
Manipur
Mizoram
Tripura
West Bengal
Orissa
Andhra Pradesh
Karnataka
Goa
Lakshadweep
Tamil Nadu
Pondicherry
Andaman and Nicobar Islands

Physical Setting

Cochin - Largest city along the west coast after Mumbai.
High population density, mostly dndustrialized

Major rivers; chain of brackish water bodies - Largest of its kind on the west coast of India

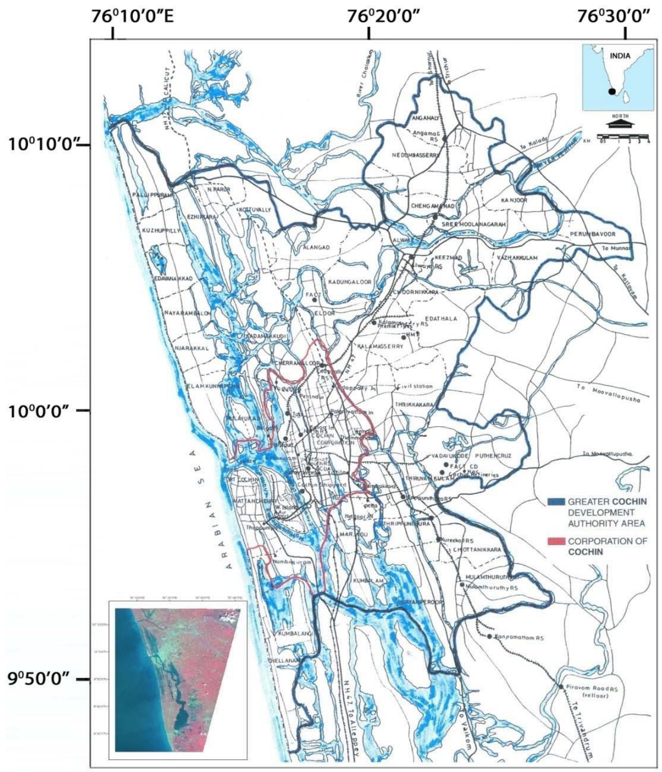
Support fishery, avian fauna, mangroves, agriculture, recreation, tourism, inland navigation

Finest natural harbor indispensable medium for living

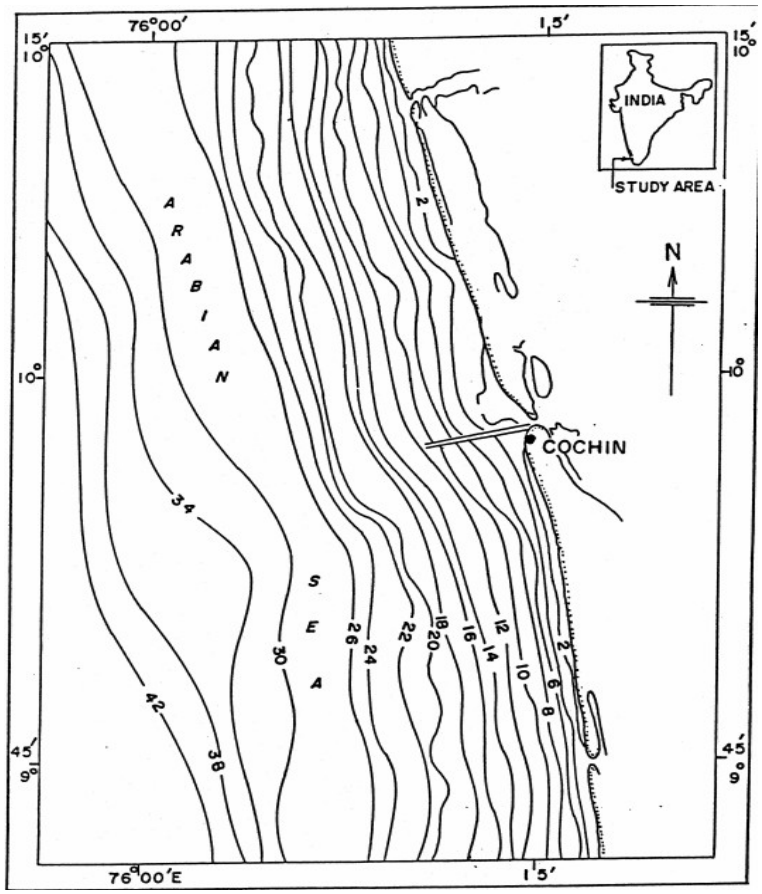
Significant role in the socio-economic/cultural history



…Physical Setting



….Physical Setting



Methodology

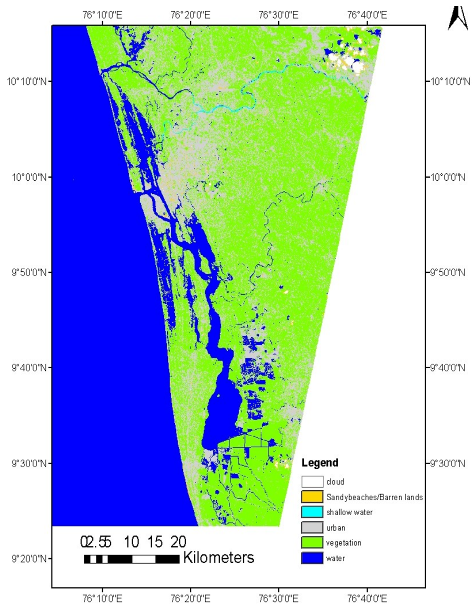
Inundation mapping and analysis of flooding impacts demands data on land surface elevations, land use and land cover

Quantification of potential habitat loss can be estimated by merging the land use /land cover with the digital elevation model

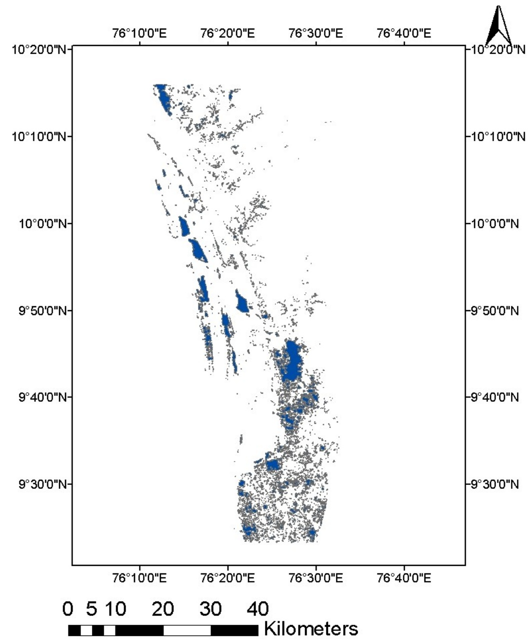
IRS P6 LISS-3 image of 2007 has been used for deriving the different land use/ land cover classes and SRTM digital elevation model is used to extract the different elevation areas. Topo-sheets were geo-referenced and mosaic using image processing software ERDAS 9.1

Supervised classification was used to generate the land use and land cover map of the region. Different land use and land cover classes within the area of inundation due to sea level rise and different water level rise scenarios were demarcated

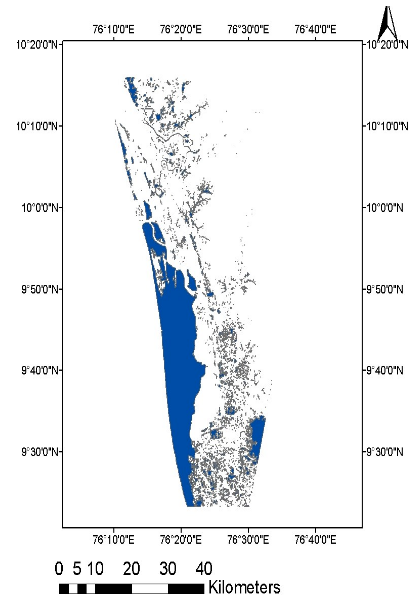
Results



Legend
cloud
Sandybeaches/Barren lands
shallow water
urban
vegetation
water
02.55 10 15 20
Kilometers

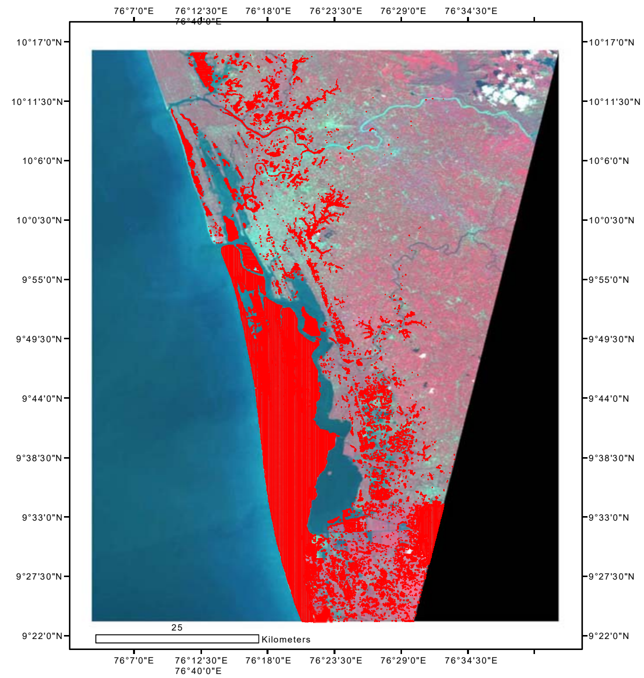


76°10'0"E
76°20'0"E
76°30'0"E
76°40'0"E
10°20'0"N
10°10'0"N
10°0'0"N
9°50'0"N
9°40'0"N
9°30'0"N
0 5 10 20 30 40
Kilometers



0 5 10 20 30 40
Kilometers

…Results


76°7'0"E
76°12'30"E
76°18'0"E
76°23'30"E
76°29'0"E
76°34'30"E
76°40'0"E
10°17'0"N
10°11'30"N
10°6'0"N
10°0'30"N
9°55'0"N
9°49'30"N
9°44'0"N
9°38'30"N
9°33'0"N
9°27'30"N
9°22'0"N
25
Kilometers

Impacts, Implications

Increased risk of flooding, direct physical impact of inundation and potential habitat loss
Existing intertidal area to become permanently submerged.
Slope is critical
Sediment redistribution
Sediment availability to override first order effects
Destruction of barrier lands
Ocean front structures to be more vulnerable

Scenarios:

Coincides with those observed today. Sea water spills and inundations aggregate the water logging problems and associated engineering problems due to elevation of water tables. Remaining coastal ridges will be over washed. Part of the city, including the port, will be inundated at high seas. Environmental and health related problems related to domestic waste disposal will escalate. Severe infrastructure failures and collapse of economy.

Significant Impact Concerns..

The results obtained conclusively point that sea level rise scenarios will bring profound effects on the land use and land cover classes as well as on coastal landforms in the study region.

Coastal inundation would leave ocean front and inland properties vulnerable.

Increase in these water levels would alter the coastal drainage gradients.

Reduction in these gradients would increase flooding attributable to rainstorms which could promote saltwater intrusion into coastal aquifers and force water tables to rise

Changes in the coastal land forms associated with inundation generate concern in the background that the coastal region may continue to remain vulnerable in the coming decades due to population growth and development pressures

Information gains..looks into the future..

Signatures of the inundation were found to be strong

Inundation also leads to geomorphic differences in the coastal zones and adjacent water bodies which lead to modified flows. Flooding would leave ocean front and inland properties vulnerable. Higher water levels would reduce coastal drainage gradients. Reduction in these gradients would increase flooding attributable to rainstorms, could promote saltwater intrusion into coastal aquifers and force water tables to rise

Millions of dollars are invested for the infrastructural projects recently such as Metro rail. Overall probable inundation zones, its land use, land cover, the expansion plans of future and the assessment of current situation will help to devise the adaptive management. Preventive planning will reduce the hassles in the future and long-term planning of managing the urban and industrial areas should be initiated at the earliest

Thank you