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Climate Change: A Major Threat to Sustainable Development

Case of a Sea-Level Rise in Ganges-Brahmaputra Delta in Asia

Sustainable Development: Core Elements

"Sustainable development is development that meets the needs of the present, without compromising the ability of future generations to meet their own needs."

- ***Our Common Future*** (Burndtland Report), October 1987, United Nations

Multifaceted Impacts of Climate change

- Change in Temperature and Precipitation
- Shifting weather patterns
- Extreme weather events
- Rising Sea-level

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Dangers of Sea-Level Rise in a Changing Climate

- Land loss from permanent inundation in low-elevation coastal areas
- Intensified inundation from cyclonic storm surges
- Increase in coastal erosion
- Loss of critical wetlands, for example mangroves
- Progressive salinization of soil and water
- Drainage disruption
- Loss of critical assets and economic activities

Presentation Outline

1. Sea-level rise: Past and Future
2. Impacts of Sea-Level Rise
3. Illustrations from Mekong Delta and Nile Delta
4. Adaptation to Sea-Level Rise
5. Concluding Remarks
6. Research Questions of Interest

Sea-Level Rise: Past and Future

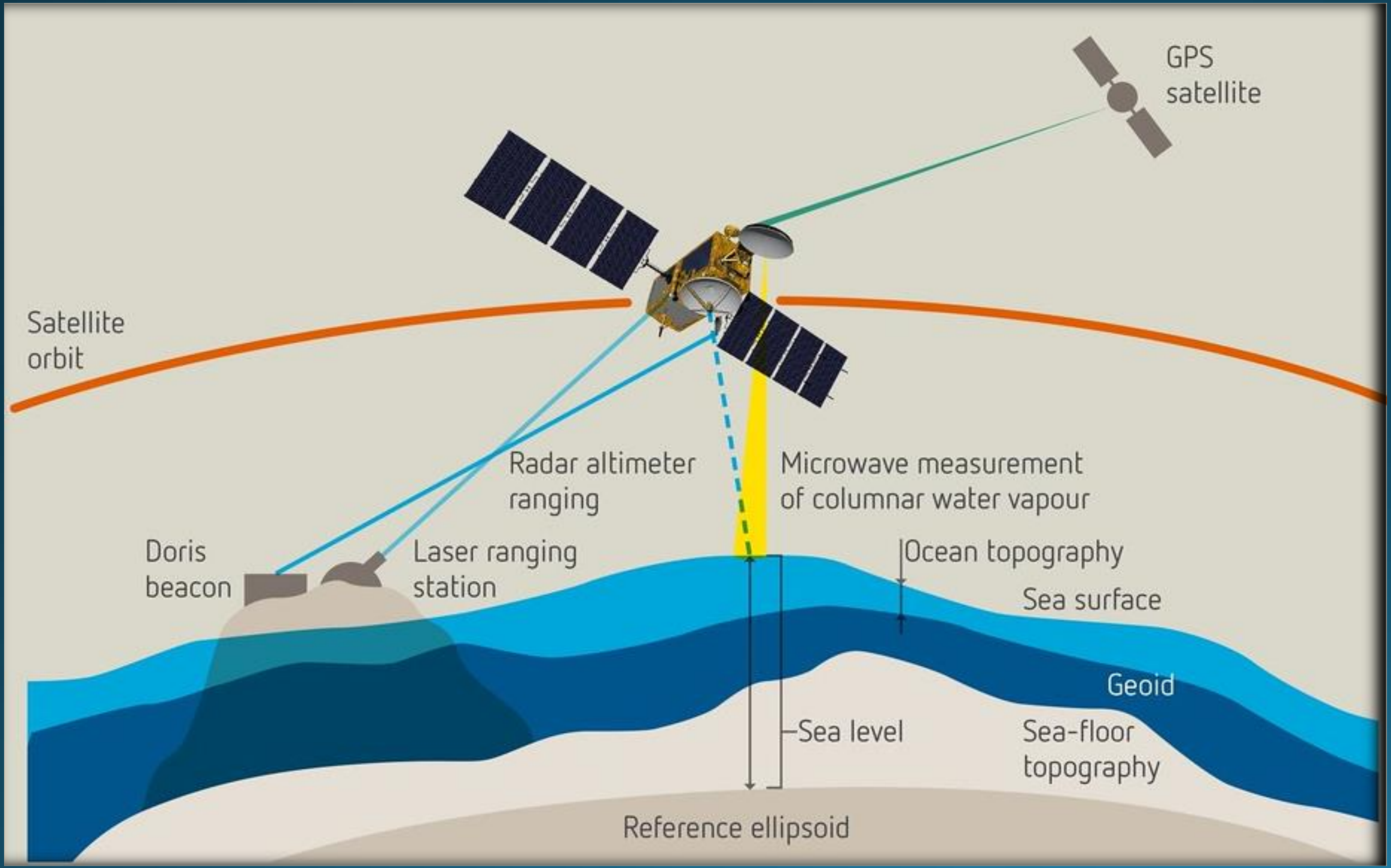
Global Mean Sea-Level Rise: Increasing Trend & Increasing Rate of Increase

- From about 3,000 years ago to about 100 years ago, sea levels naturally rose and declined slightly, with little change in the overall trend (NASA-JPL).
- Trend of Global mean sea level:
  Increased by 5.91 to 9.84 inches (or 0.15 to 0.25 m) between 1901 and 2018
  - About half of that rise occurred since 1993
- Rate of global sea level rise:
  - 3.7 mm (0.15 inch) per year from 2006 to 2018
  - 1.9 mm (0.08 inch) per year from 1971 to 2006
  - 1.3 mm (0.05 inch) per year between 1901 and 1971.

Sea-Level Rise: Paleoclimatic Evidence

- Between about 21,000 years and about 11,700 years ago,
  - Earth warmed about 4 degrees C, and
  - The ocean rose about 280 feet.
- After the warming ended,
  - Sea levels continued to rise another 150 feet
  - Sea levels reached its modern level about 3,000 years ago

Sea Level is measured by Satellite Altimeter

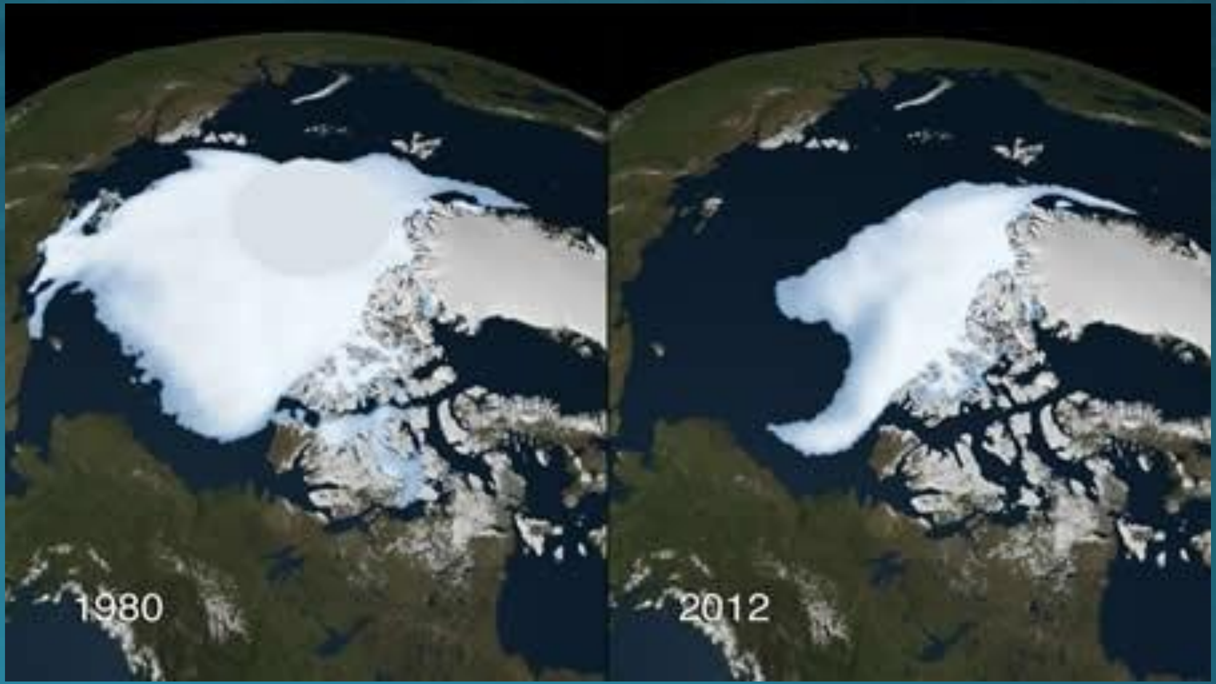


Google Image

Sea Level Rise: Major Contributing Factors

1. Thermal Expansion
2. Melting of Polar Icesheets
3. Melting of Glaciers and Ice Caps other than polar icesheets

- Sum of glacier and icesheet contributions is now the dominant source of global mean sea-level rise (IPCC AR6).



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Sea-Level Rise: Future Projections

- Sea-level rise is not globally uniform but varies regionally.
- A rise in global mean sea level between 0.28 m to 1.01 m (11 inches - 40 inches approximately 1 ft to 3.5 ft) by 2100 relative to 1995–2014, across different future scenarios (IPCC AR6).
  - Icesheet dynamics related to global warming is very complex and uncertain.
- Sea level may rise up to 3 m by 2100.
- Sea level will continue to rise for centuries due to continuing deep ocean heat uptake and mass loss of the polar icesheets and will remain elevated for thousands of years (Source: IPCC AR6).

Impacts & Threats of Sea Level Rise

Impacts & Threats of Sea Level Rise

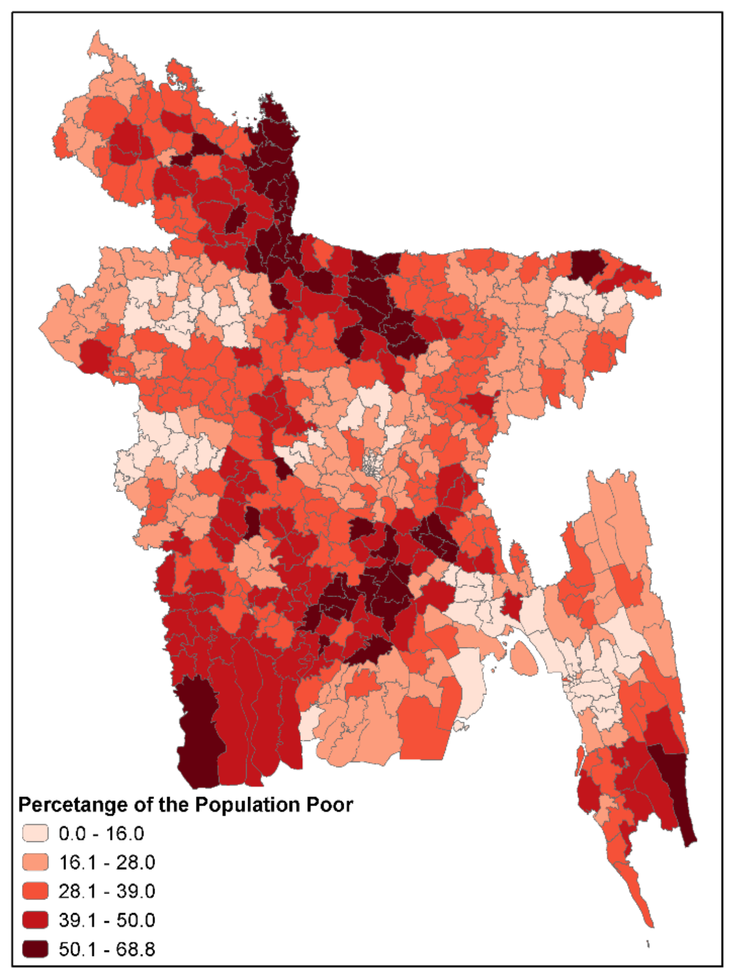
Case Study: Ganges-Brahmaputra Delta (Bangladesh)

- Elevation of nearly two third of the country is less than 5 meter above sea-level
  - Permanent Loss of Land
  - Progressive Salinization of Water and Soil
  - Intensified Inundation from Cyclonic Storm Surges

At present, 600 million people live in low-lying coastal areas worldwide.

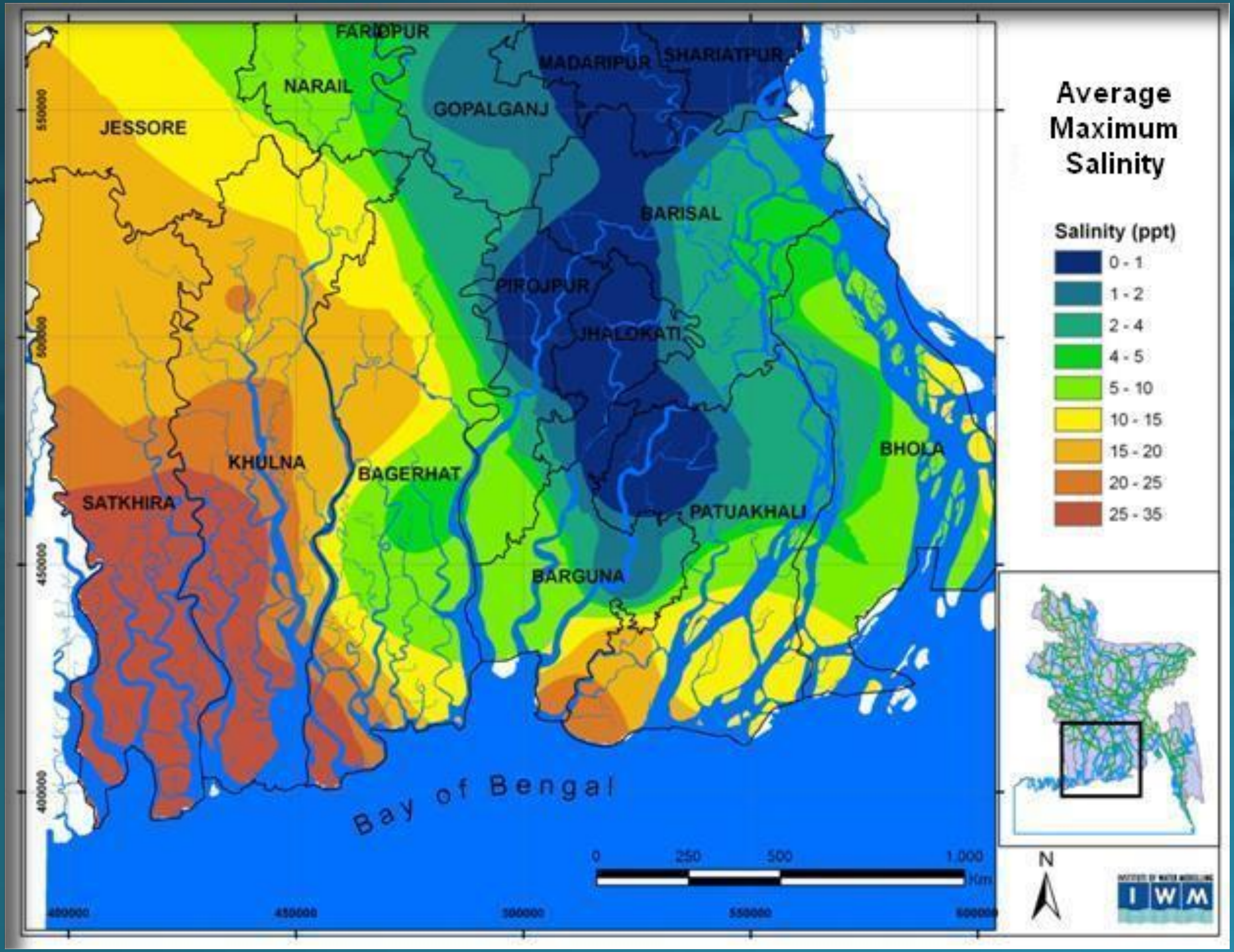
Families in coastal Bangladesh are already on the "front line" of climate change. Their experience foretells future decisions by hundreds of millions of families worldwide who will face similar threats well before 2100.

Poverty Map of Bangladesh - 2010



- 43.2 million people in Bangladesh live in poverty.
- 24.4 million extremely poor do not meet the basic needs of food expenditure.

River Salinity in Coastal Bangladesh



Spatial variation of maximum river salinity during 2011-2012

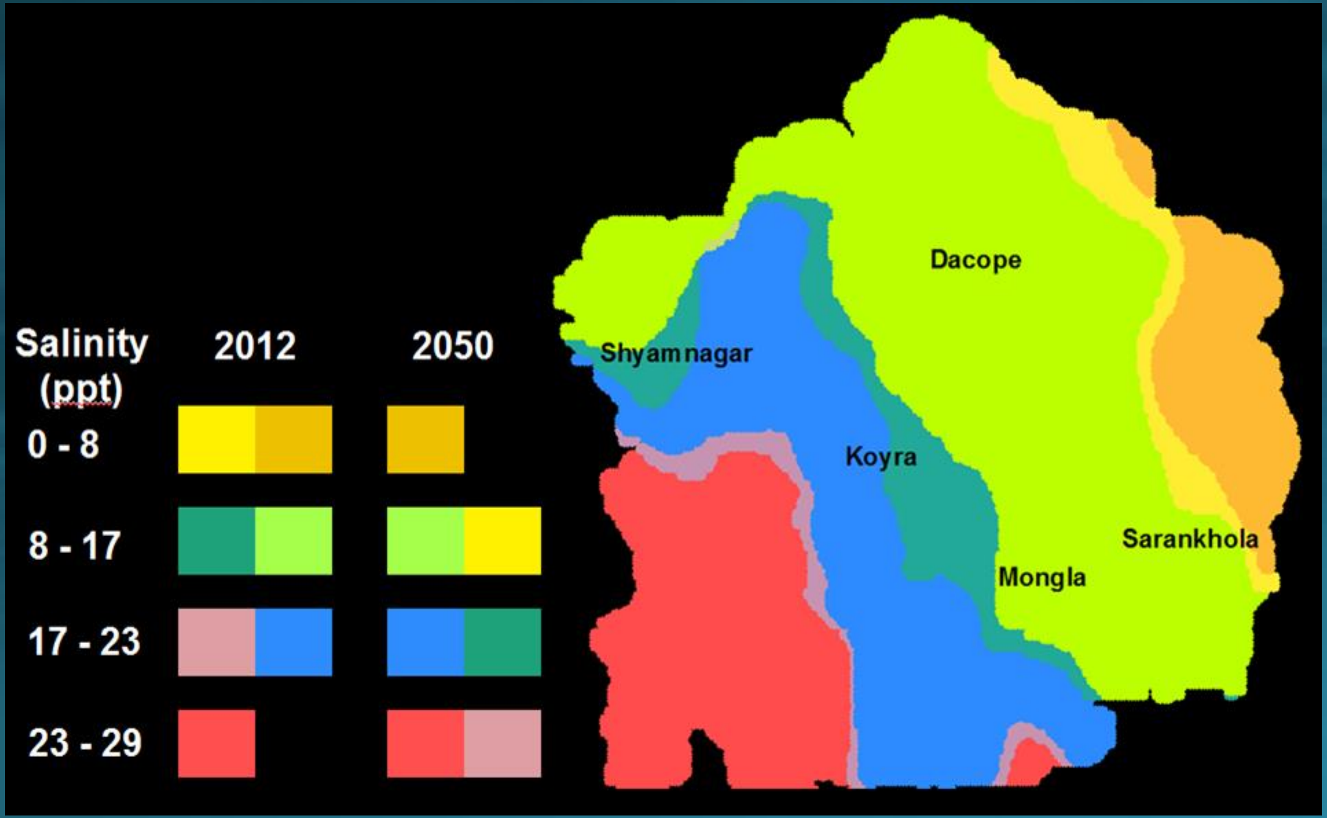
Source: IWM, 2013

Southwest Coastal Bangladesh: Water and Soil Salinity

- Average salinity is higher in the dry season than in the monsoon.
- Steady increase in salinity from October to late May.
- In early June, salinity drops sharply with the onset of monsoon rain.
- At present, the rivers and soil are highly saline.
- Scarcity of drinking water and water for irrigation in the are apparent and serious.
- Salinity problem worsens after cyclones.

Water Salinization: Threat to Southwest Bangladesh

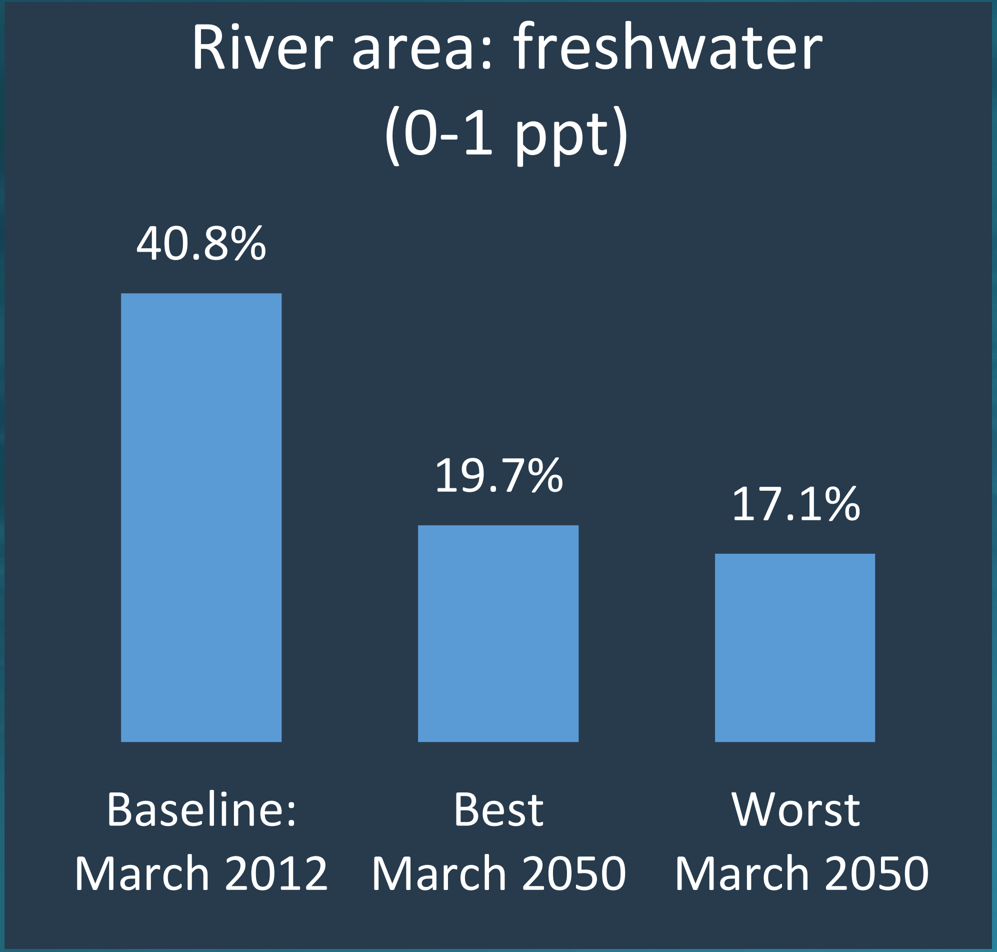
Illustration: Southwest Bangladesh

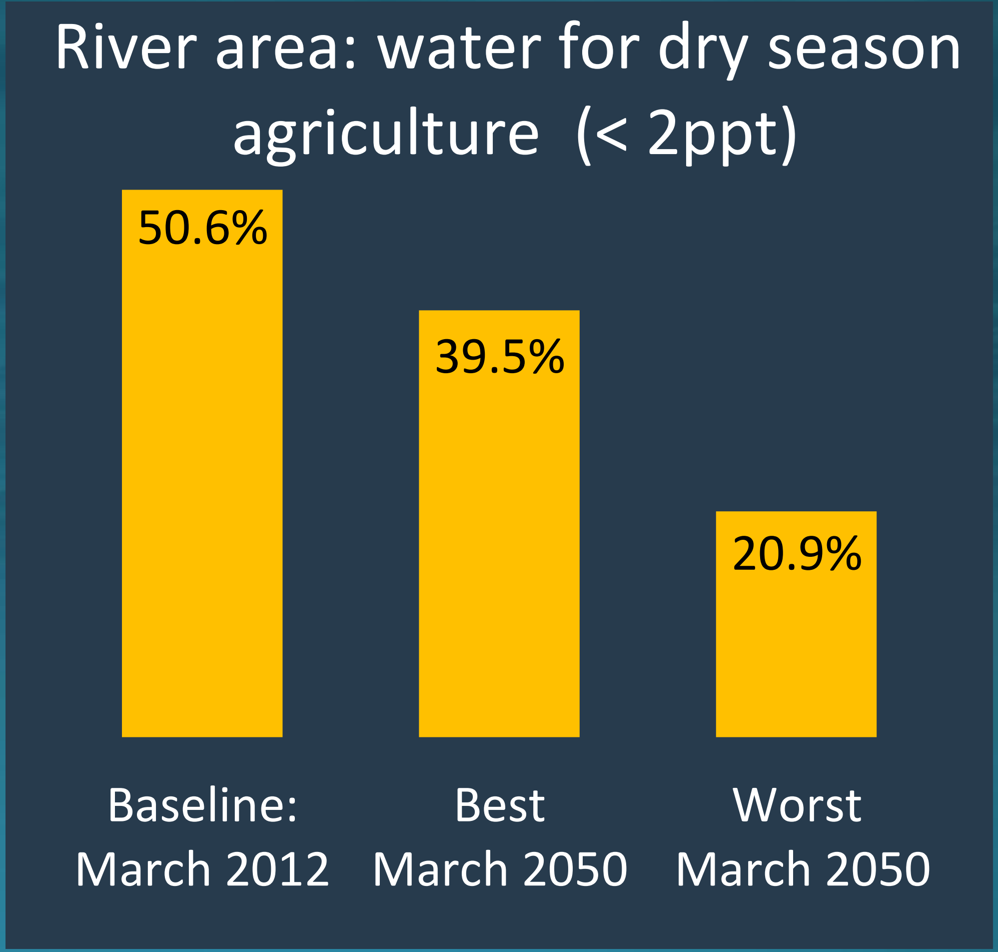


Progressive water salinization is expected with sea-level rise and shortage of freshwater from upstream river systems

Source: Dasgupta et al. 2015. River Salinity and Climate Change: Evidence from Coastal Bangladesh in Asia and the World Economy- Actions on Climate Change by Asian Countries. World Scientific Press, 205-242.

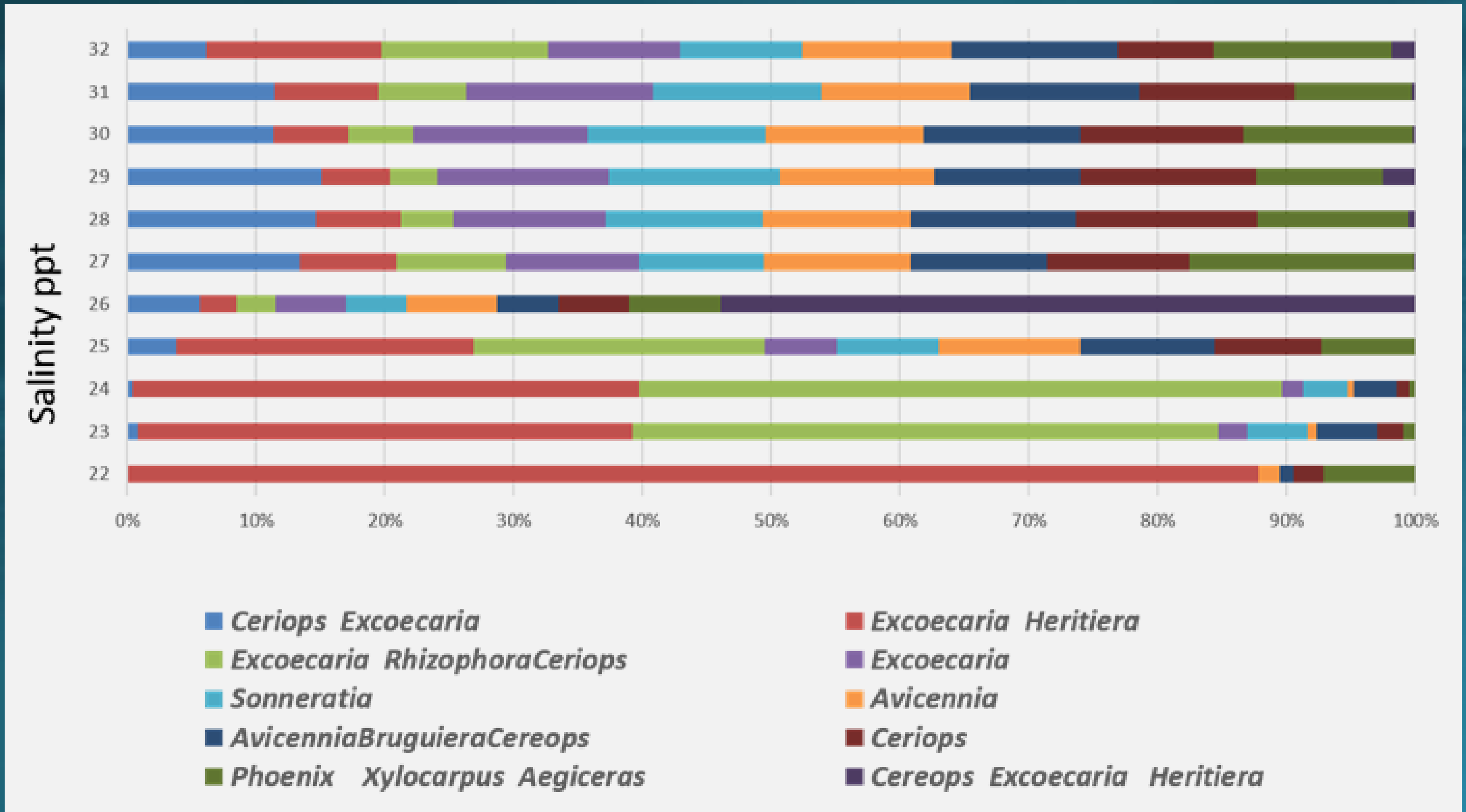
Expected Impacts of River Salinity





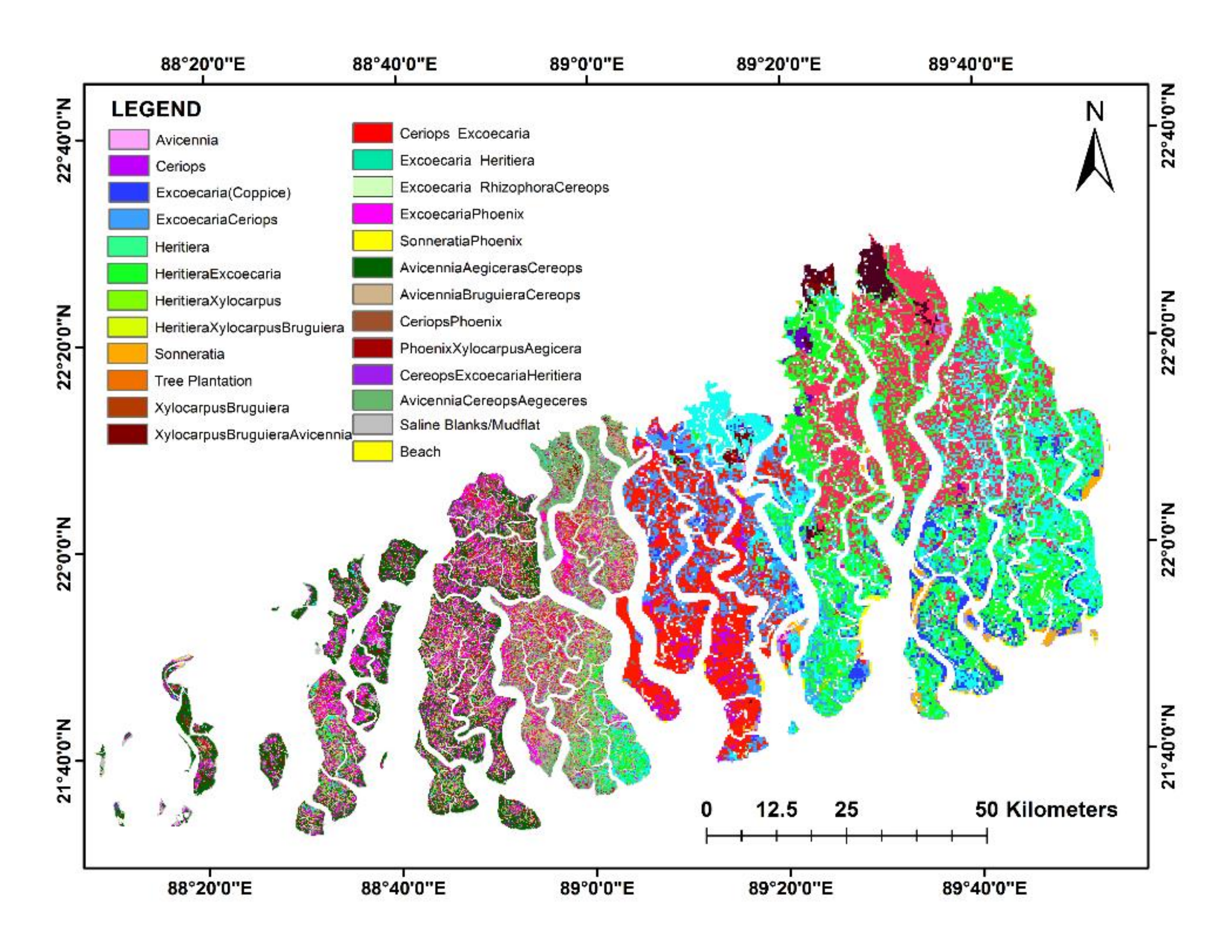
Impacts of Water Salinization on Mangroves

In Sunderbans (UNESCO Heritage site), a shift in mangrove species is expected.



- A shift in species is expected from freshwater species to salt-tolerant species.
- A negative impact on standing stock of timber in the region is inevitable with growing dominance of salt-tolerant species.

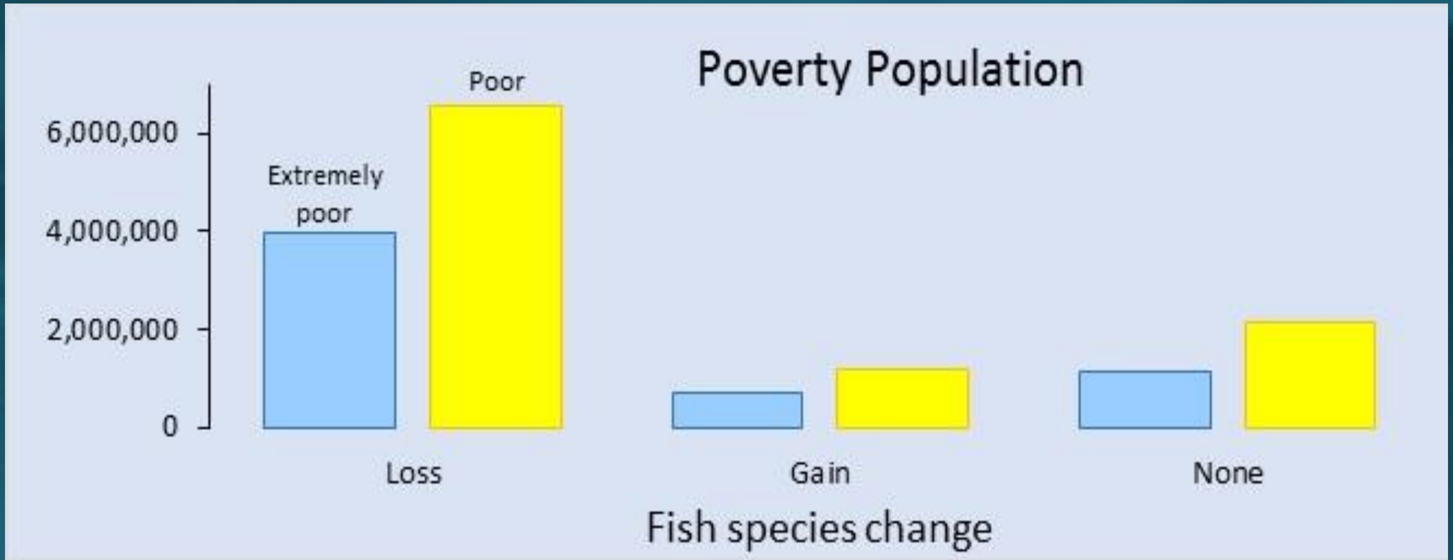
Impacts of Water Salinization on Mangroves



- Changes in mangrove species will change the prospects for forest-based livelihoods of nearby communities.
- Overall honey production is likely to increase.
- Human and wildlife conflicts in Sundarbans will increase.

Impacts of Water Salinization on Fish

- Analysis is based on 83 fish species consumed in the region.
- Areas with poor population that lose freshwater fish species are 6 times more prevalent than areas gaining species



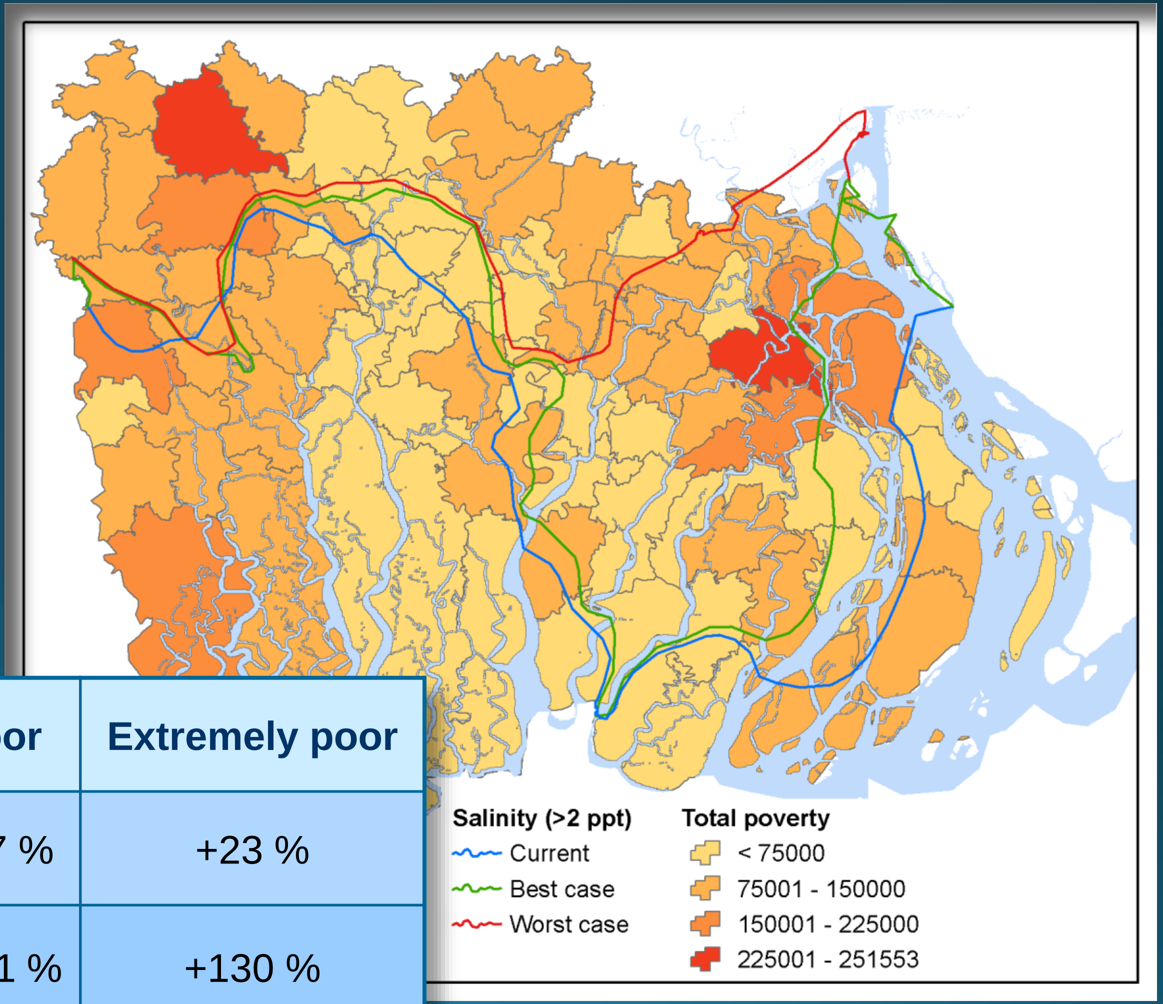
Source: Dasgupta et al. 2017. *Ecological Economics*. https://www.sciencedirect.com/science/article/pii/S0921800916312137

- 9.9 million poor (including 5.9 million extreme poor) live near Sundarbans.
- Small low-value freshwater fish species are the most important animal-source food (essential protein, micronutrients etc.) for the poor.
- Significant impact on animal-source food intake of poor women and children is expected.

Health Implications of Increased Water Salinity

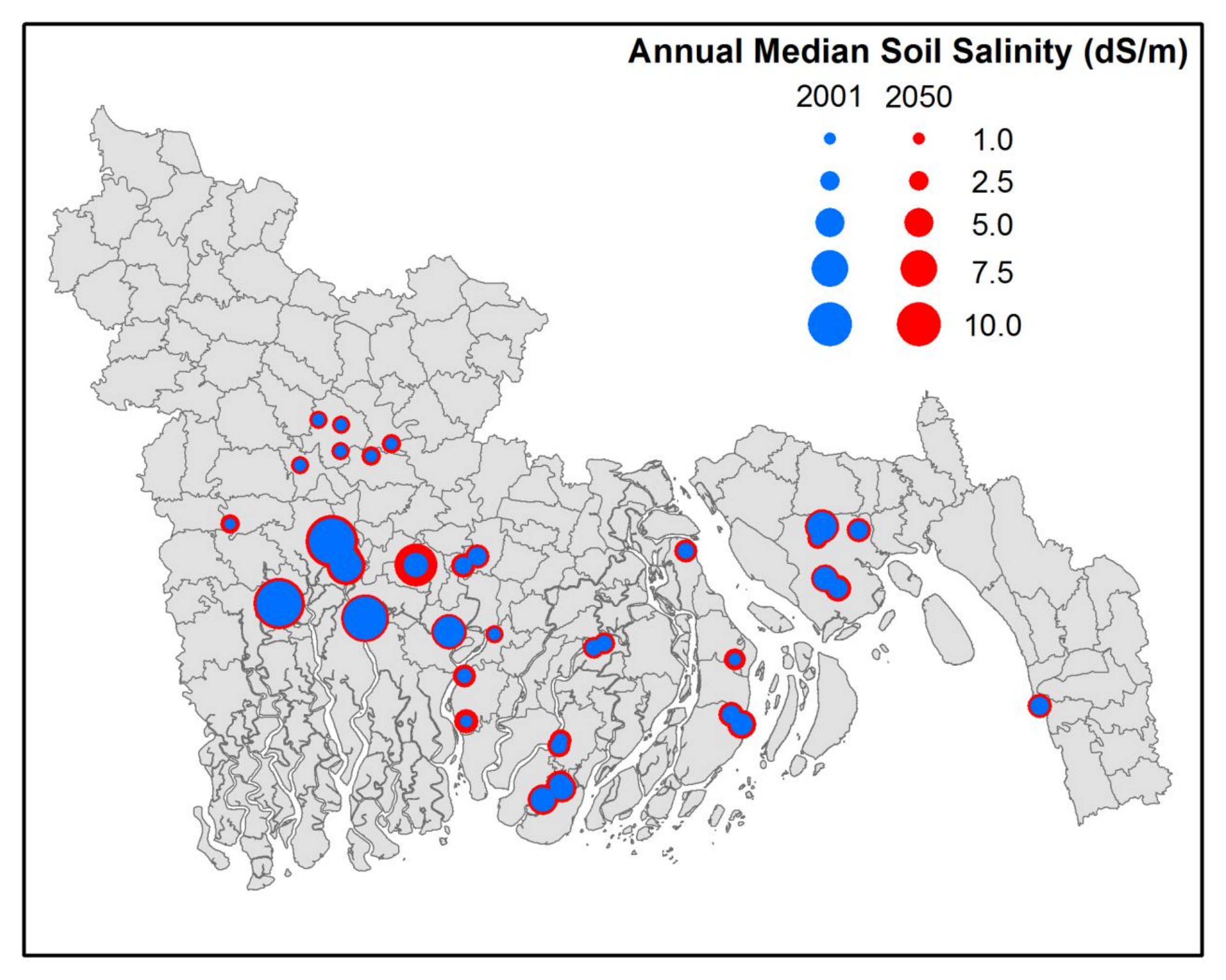
- Controlling for many other determinants of infant mortality, the econometric analysis found high significance for salinity exposure of mothers during the last month of pregnancy.
- The estimated impact of salinity on infant mortality is comparable in magnitude to the estimated effects of traditionally-cited variables such as maternal age and education, gender of the household head, household wealth, toilet facilities, drinking water sources and cooking fuels.

Exposure of Poor to Increased River Salinity



	Total population	Poor	Extremely poor
Change from the current situation to the best future (2050)	+15 %	+17 %	+23 %
Change from the current situation to the worst future (2050)	+100 %	+111 %	+130 %

Significant Increase in Soil Salinity by 2050



Range of increase: 2% - 73% across 41 monitoring stations.

Source: Dasgupta et al. 2015. Ambio. https://link.springer.com/article/10.1007/s13280-015-0681-5

Multifaceted Impacts of River Salinity

Health effects of increased drinking water salinity (dehydration, hypertension, infant mortality)

Scarcity of water for irrigation

Increased soil salinity

Agricultural productivity loss

Increased infrastructure maintenance costs

Reduced availability of fresh-water fish

Reduced availability of essential nutrients (stunting/ wasting, maternal anemia)

Loss of capture fishery

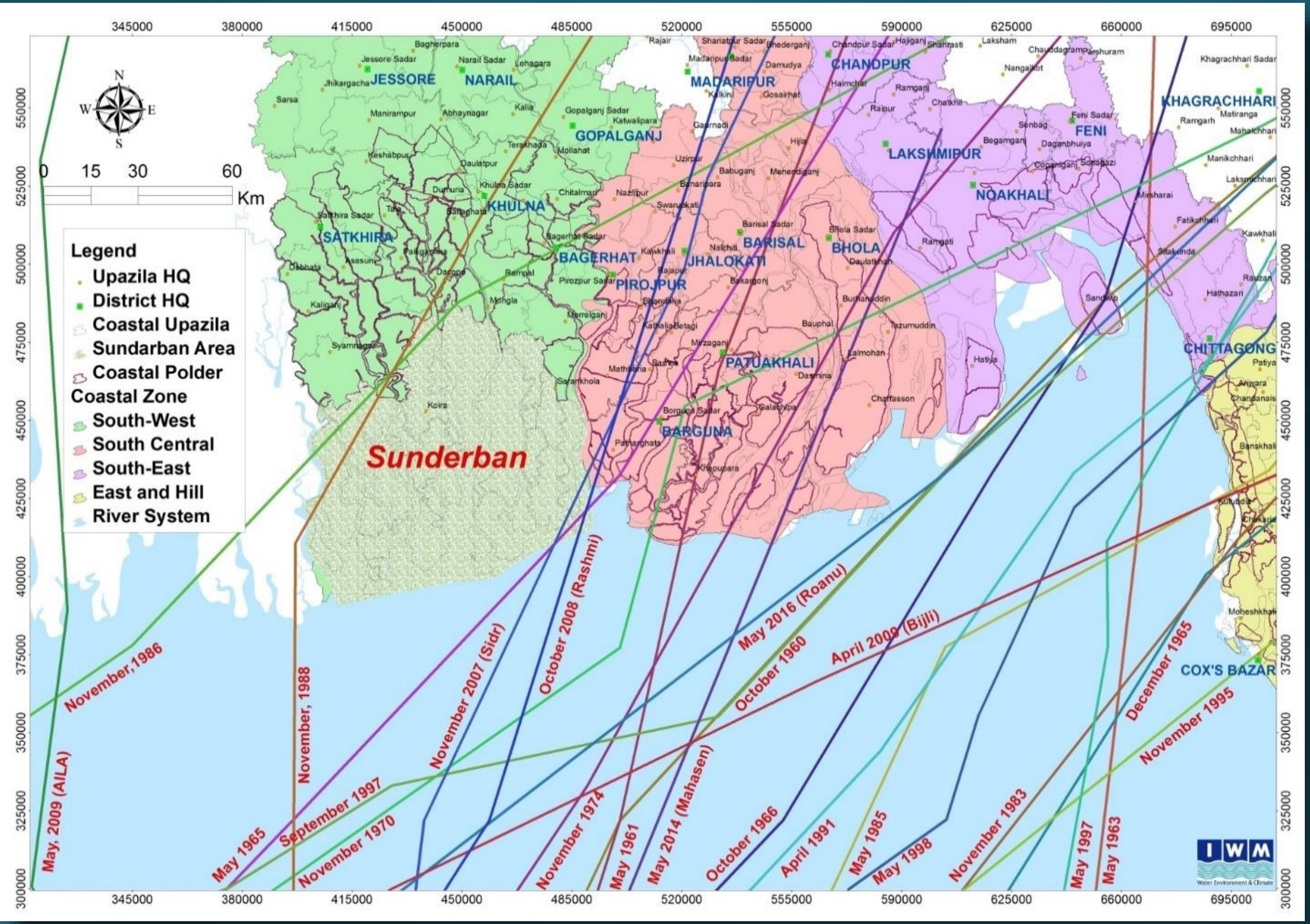
Reduced timber yield

Loss of tourism from reduced biodiversity in UNESCO Heritage Forest

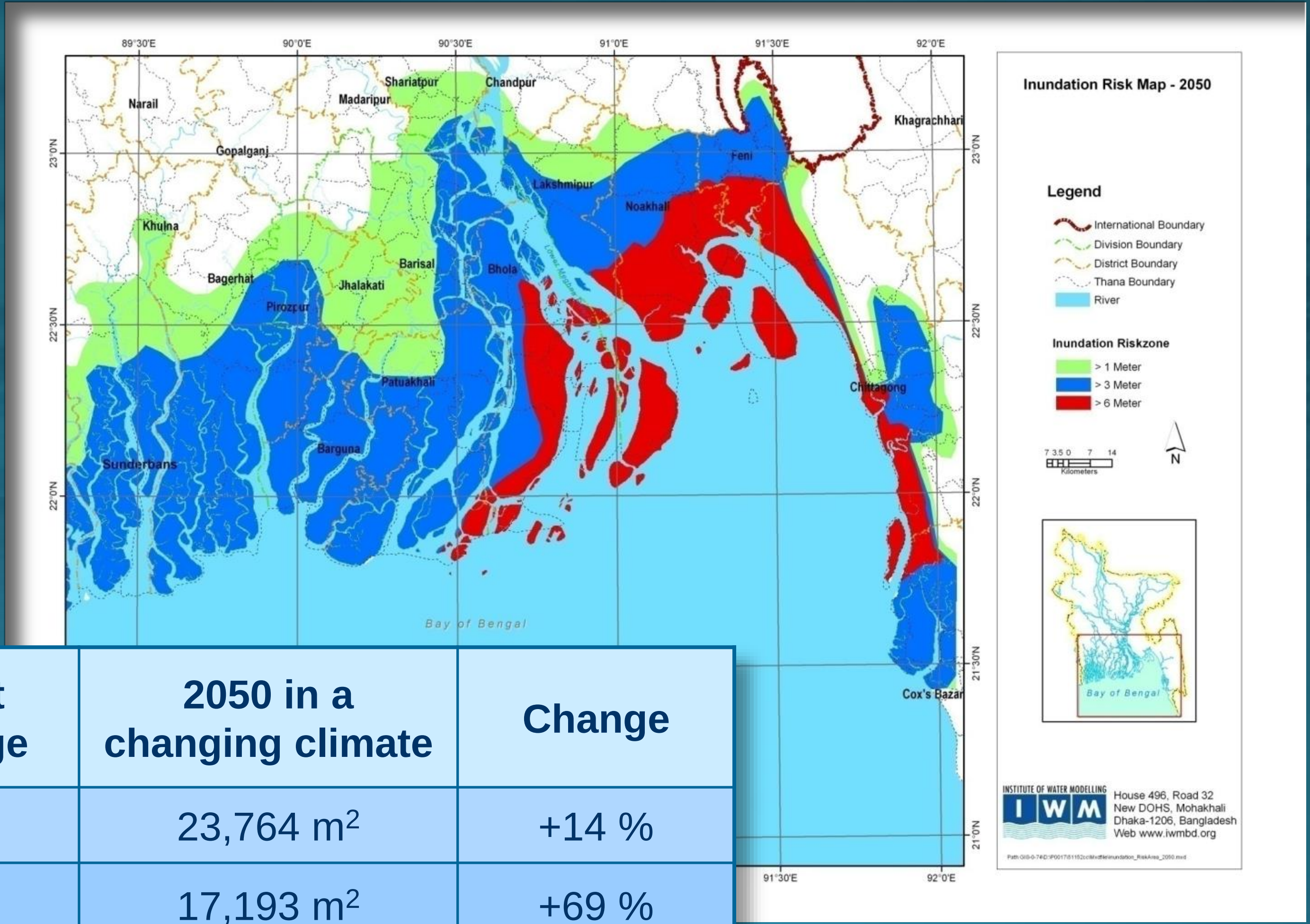
Cyclones in a Changing Climate

- Intensification of storm surges due to ocean surface temperature increase is controversial.
- Increase in the extent of inundation and increase in location-specific inundation depth due to sea level rise is certain.

Major Cyclones: 1960-2016

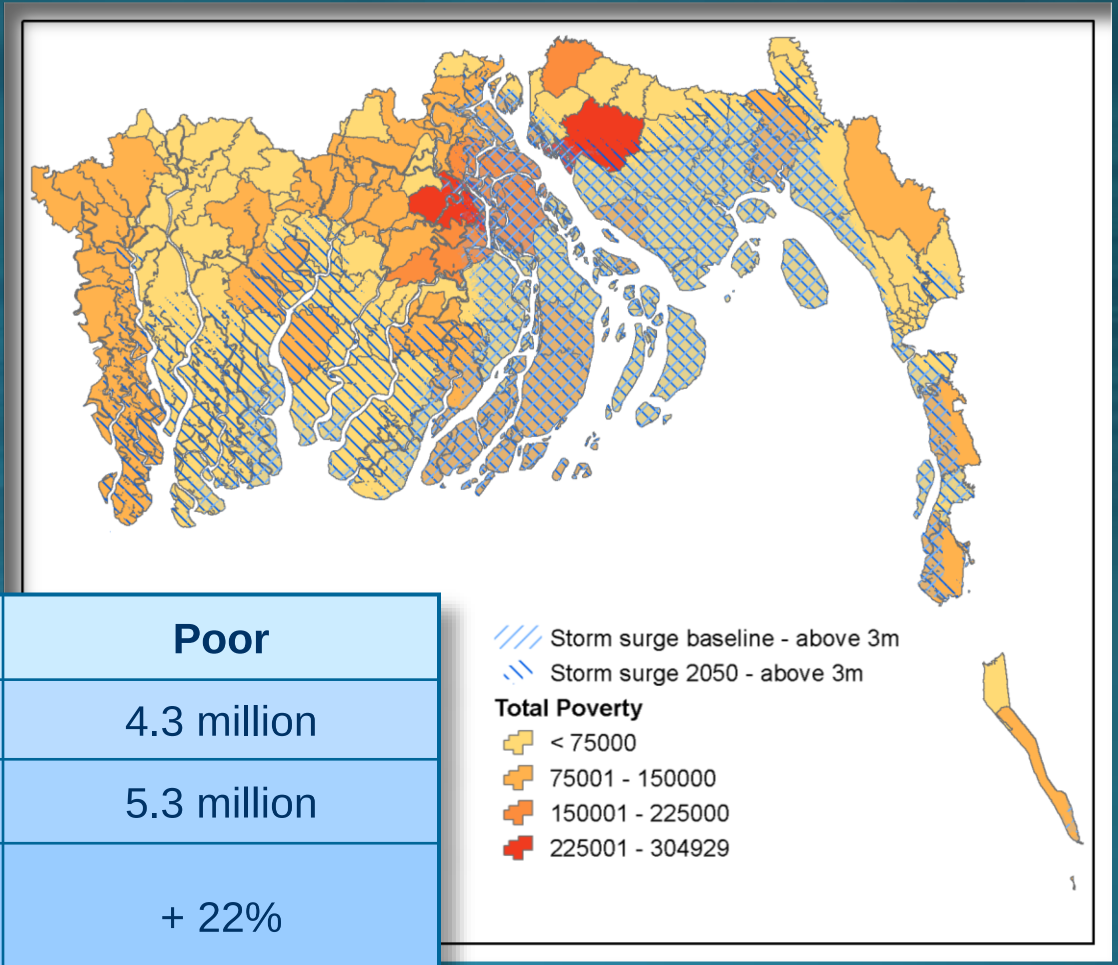


High Risk Area in a Changing Climate 2050



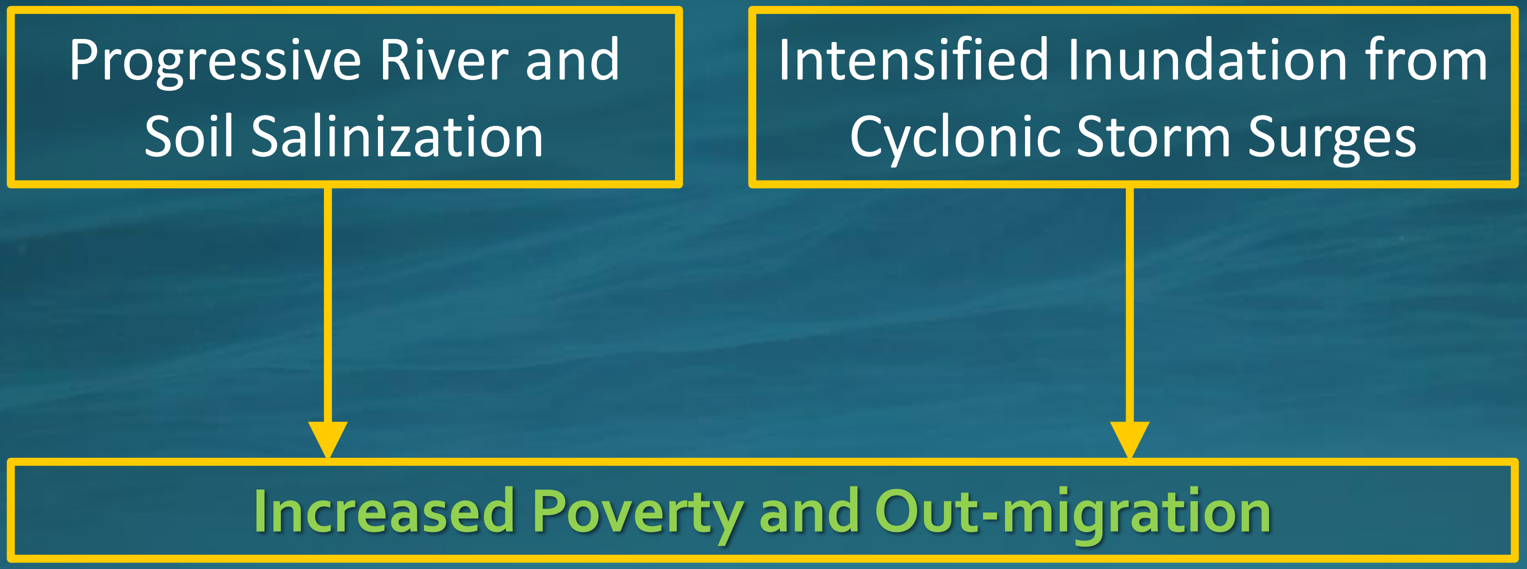
Inundation depth (m)	2050 without climate change	2050 in a changing climate	Change
1 m – 3 m	20,876 m^2	23,764 m^2	+14 %
More than 3 m	10,163 m^2	17,193 m^2	+69 %

Implications of Storm Surge for the Poor



	Total population	Poor
Current situation	15.4 million	4.3 million
Future (2050)	16.8 million	5.3 million
Change from the current situation to 2050	+ 9%	+ 22%

Multifaceted Impacts of Sea-Level Rise
Poverty and Out-migration



Livelihood Threat and Household Composition

- Households subject to high inundation and salinization threats have out-migration rates for working-age adults (particularly males), dependency ratios, and poverty incidence that are significantly higher than their counterparts in non-threatened areas.
- The critical zone for inundation risk lies within 4 km of the coast, where about 8% of the population of Bangladesh currently resides, with lesser impacts observed for coastal-zone households at higher elevations.

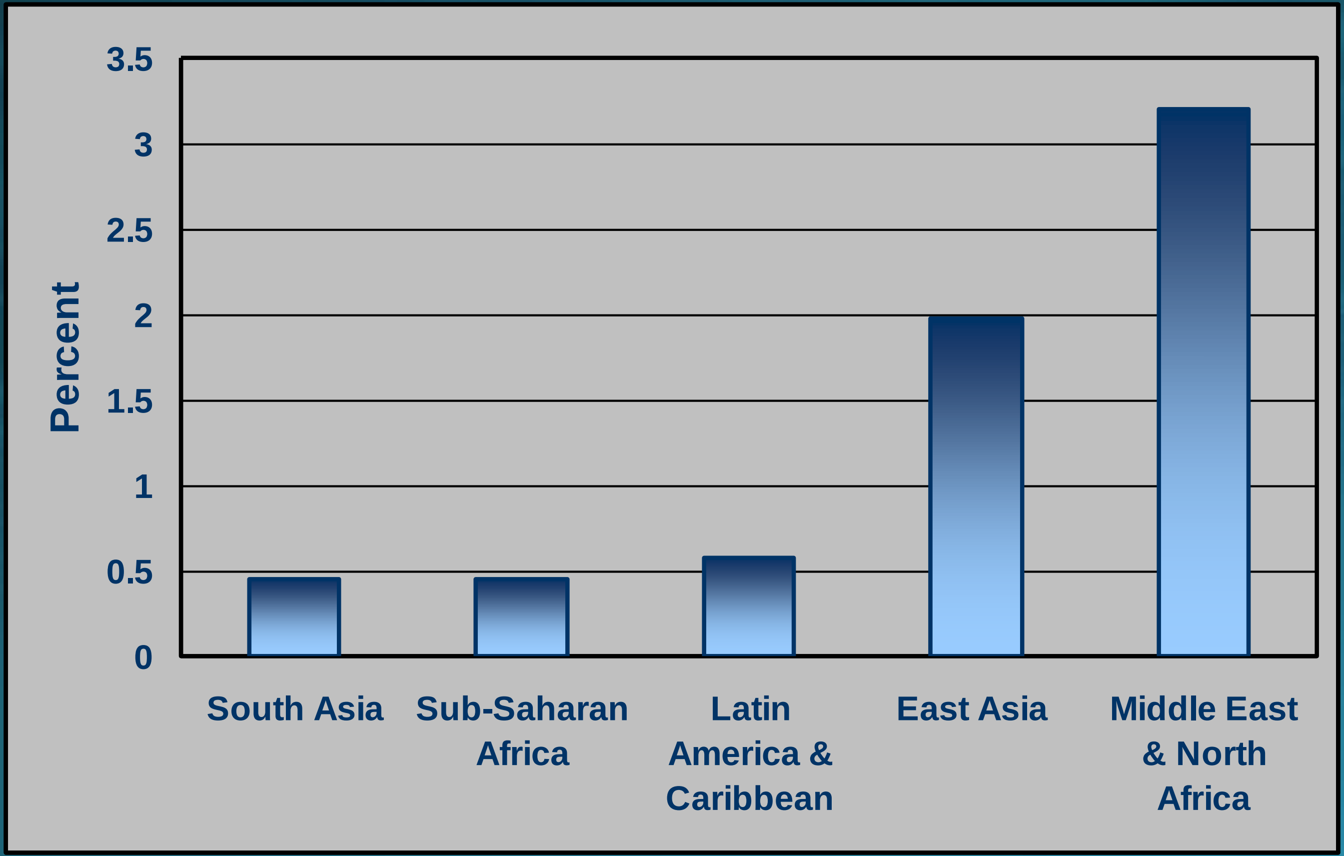
Impact : Total Population

1 Meter Sea Level Rise

East Asia & Pacific	37.2 million
Middle East & North Africa	8.3 million
South Asia	5.9 million
Latin America & Caribbean	2.9 million
Sub-Saharan Africa	2.1 million
Total	56.4 million

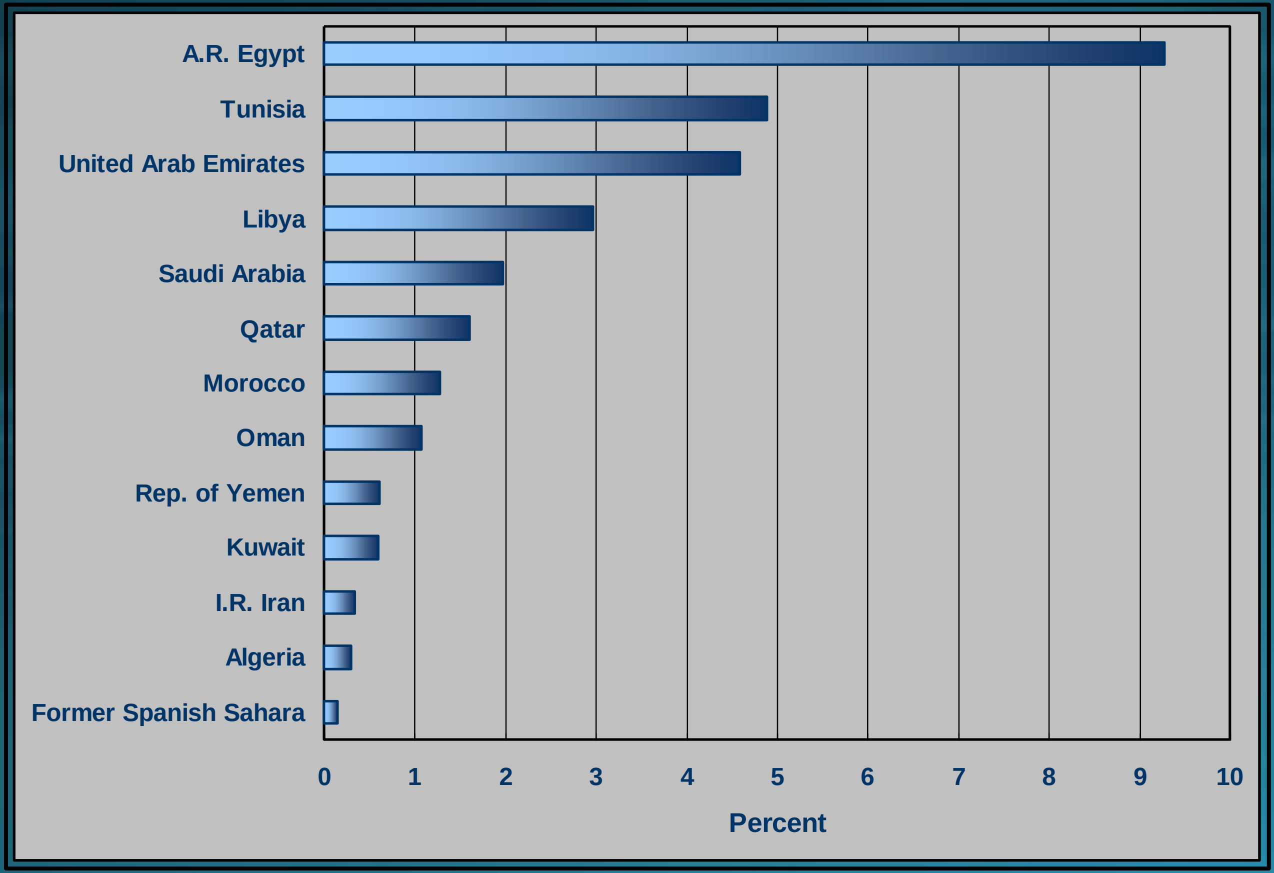
Percent Impact : Population

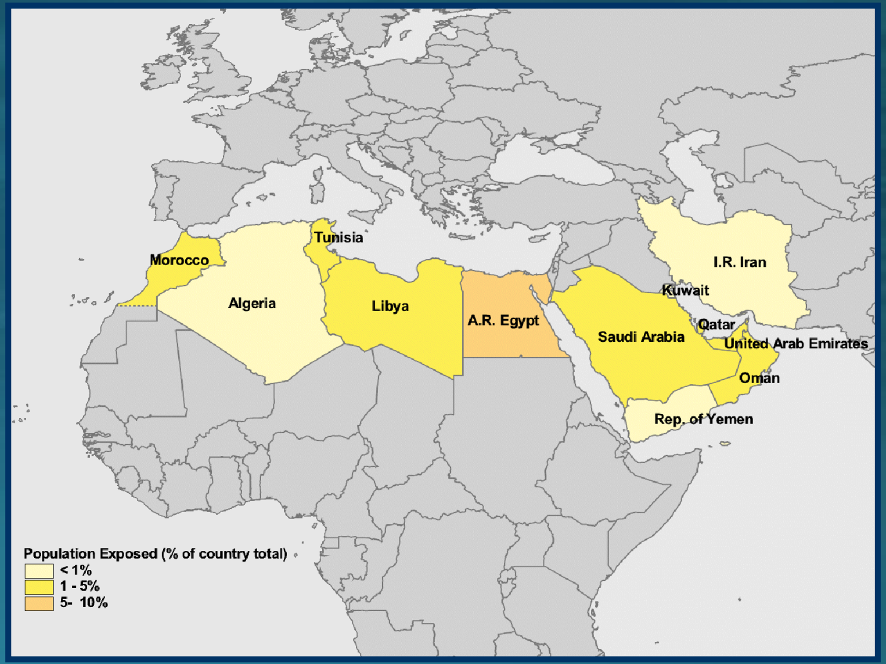
1 Meter Sea Level Rise



Percent Impact : Population

Middle East & North Africa





Nile Delta - 2000

Nile Delta - 2000

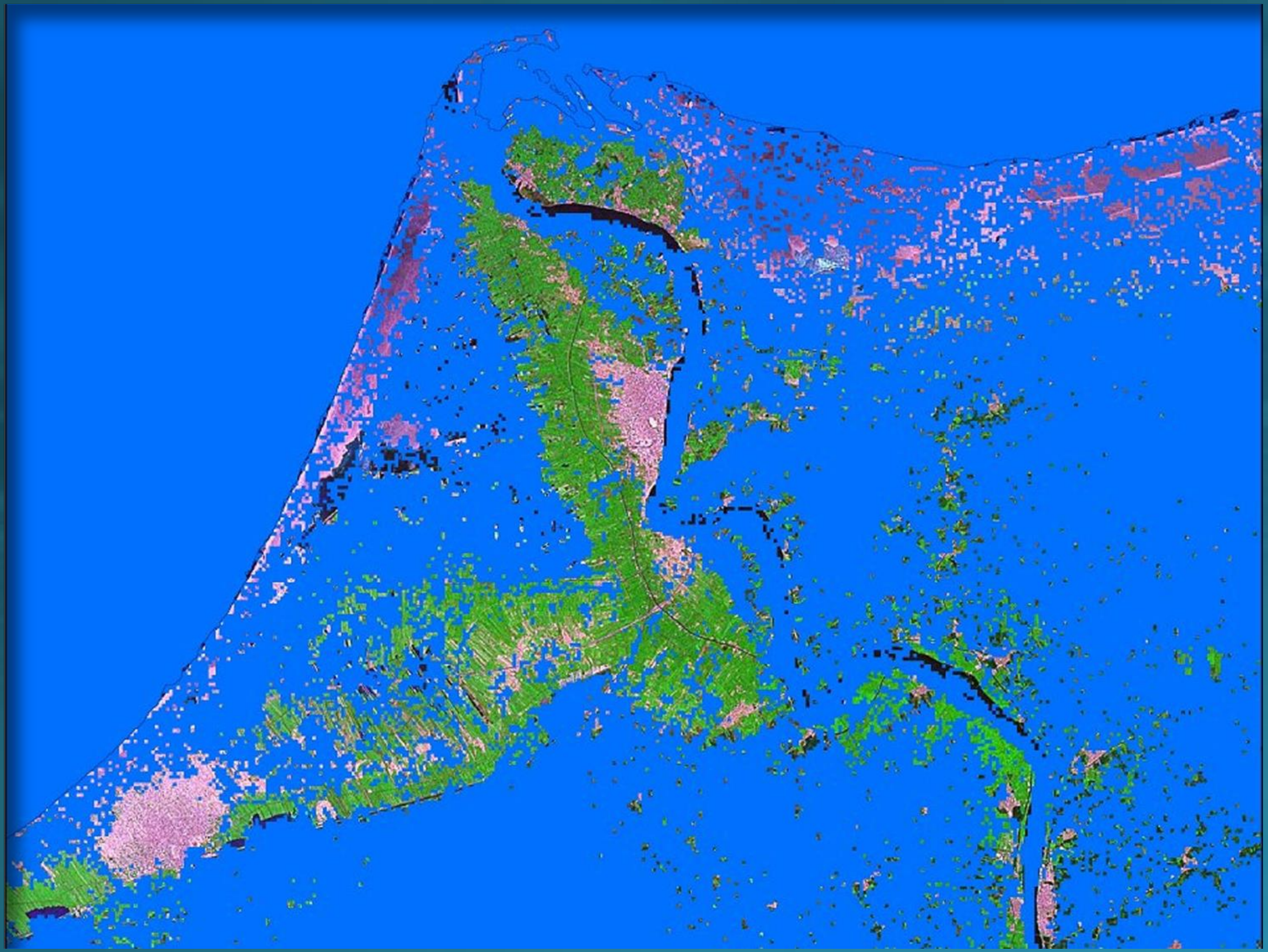
Nile Delta – 1 m Sea Level Rise

Nile Delta

Nile Delta - 1990

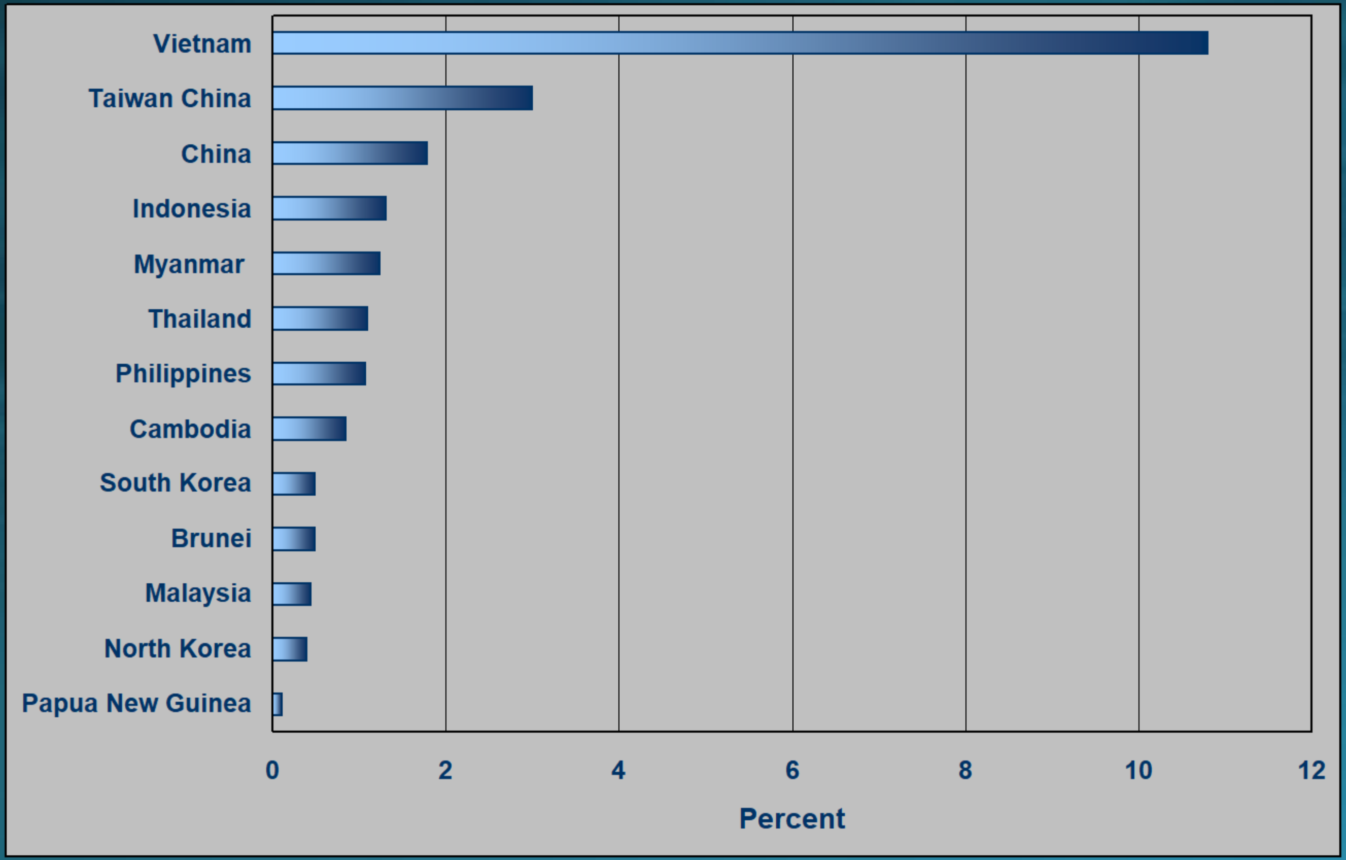
Nile Delta - 2000

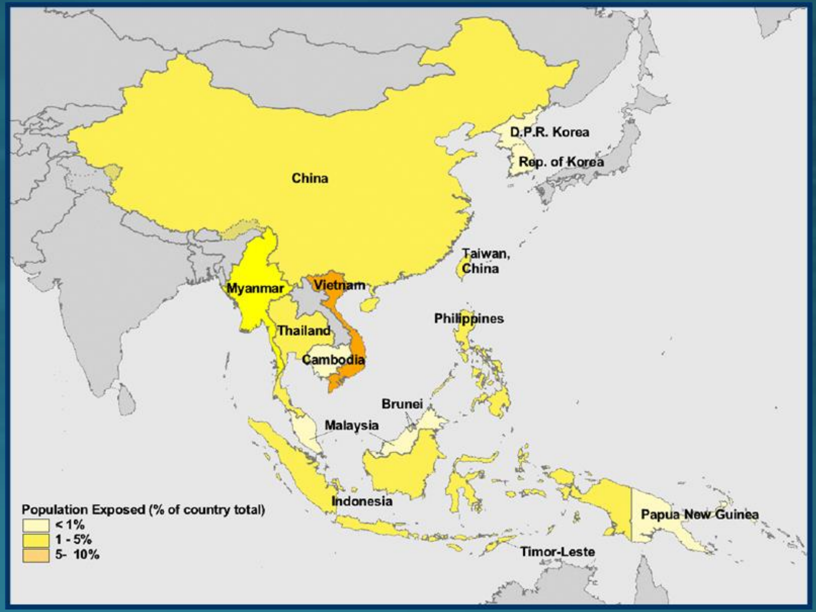
Nile Delta – 1 m Sea Level Rise



Percent Impact : Population

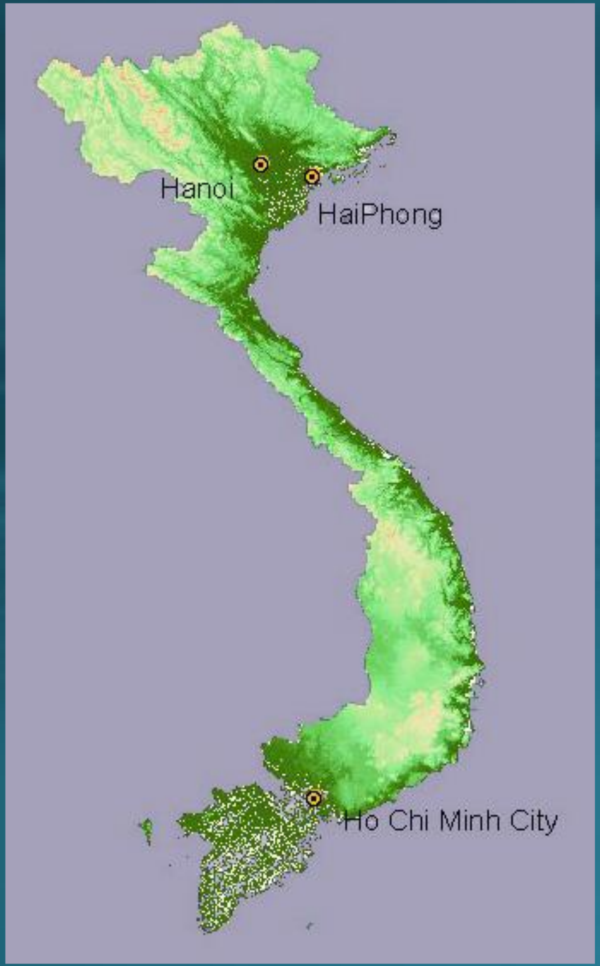
East Asia & Pacific



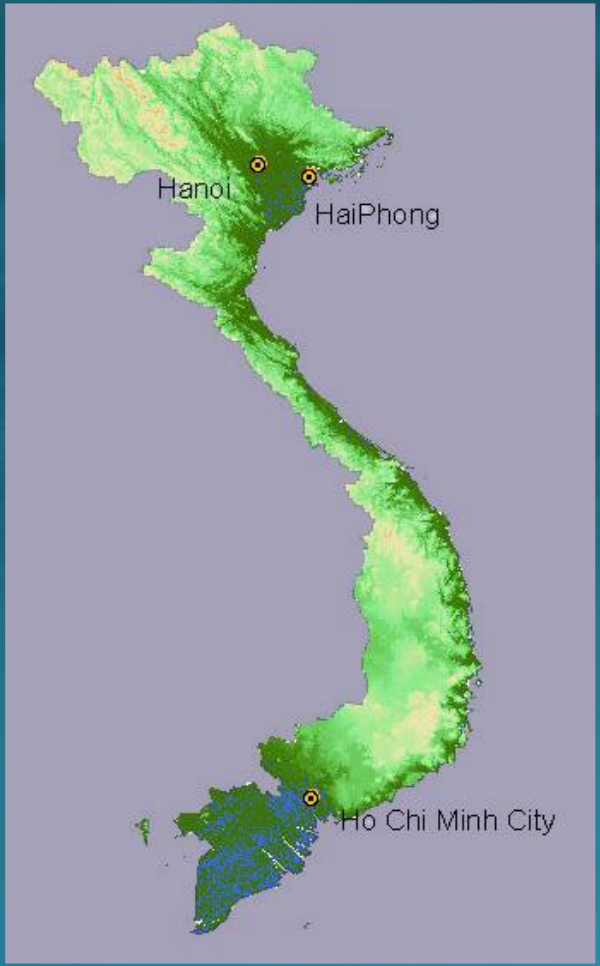


Vietnam

Present



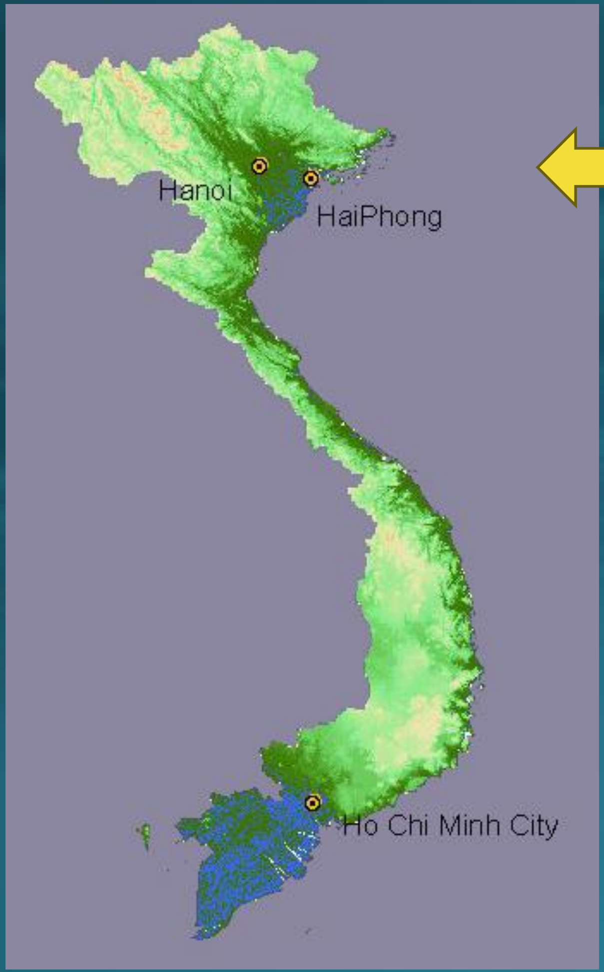
1 m Sea Level Rise



Vietnam 1 m Seal Level Rise	Country Total	Impacted	% of Total
Area (km^2)	328,535	16,977	5.17
Population (10^3)	78,137	8,437	10.8
GDP (10^6 US$)	154,787	15,805	10.21
Urban Areas (km^2)	5,904	634	10.74
Agricultural Land (km^2)	192,816	13,773	7.14
Wetlands (km^2)	46,179	13,241	28.67

Vietnam

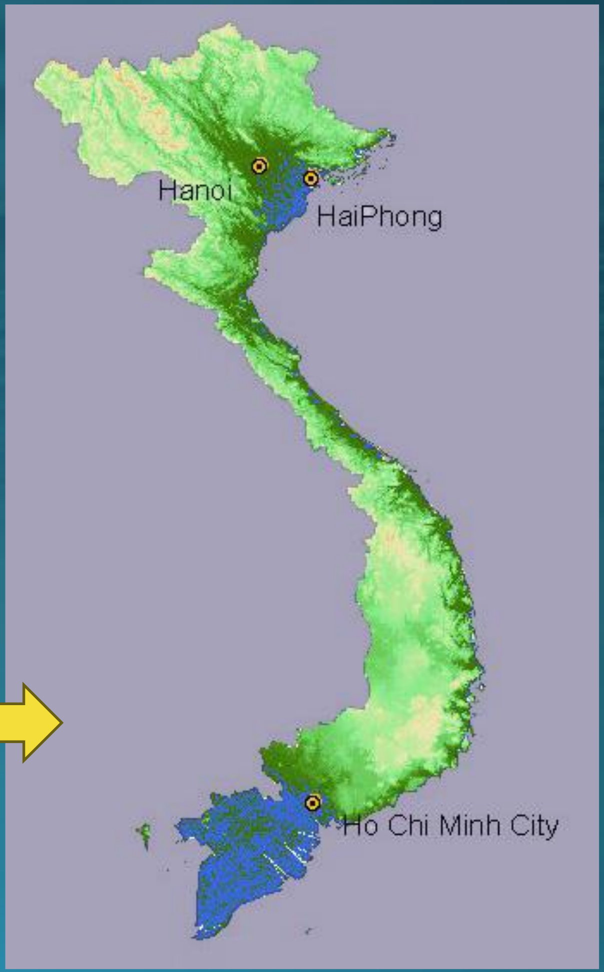
2 m Sea Level Rise



Vietnam 2 m Seal Level Rise	Country Total	Exposed	% of Total
Area (km^2)	328,535	28,090	8.55
Population (10^3)	78,137	14,036	17.96
GDP (10^6 US$)	154,787	25,522	16.49
Urban Areas (km^2)	5,904	1,095	18.55
Agricultural Land (km^2)	192,816	23,641	12.26
Wetlands (km^2)	46,179	22,527	48.78

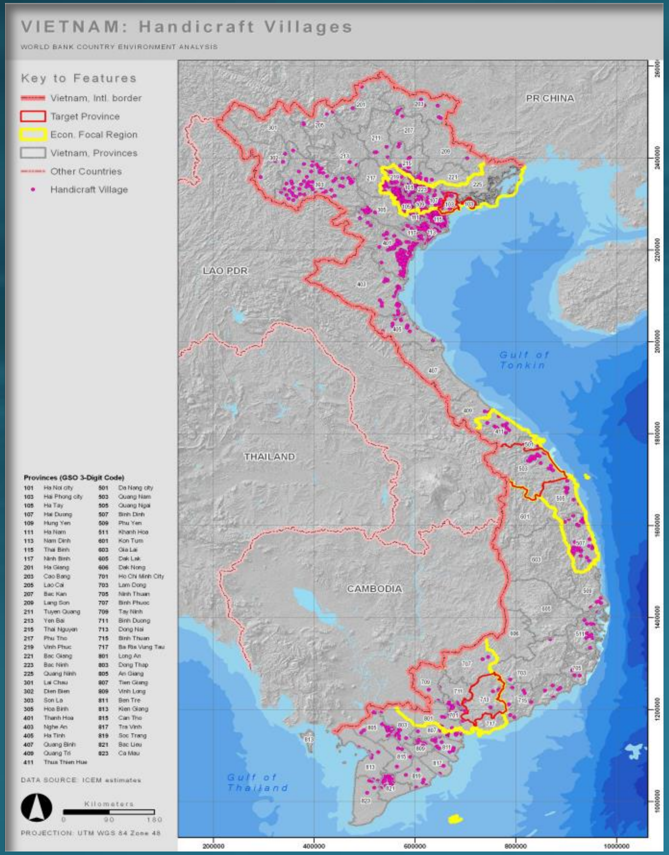
Vietnam 3 m Seal Level Rise	Country Total	Exposed	% of Total
Area (km^2)	328,535	28,860	11.83
Population (10^3)	78,137	2,003	25.60
GDP (10^6 US$)	154,787	37,419	24.17
Urban Areas (km^2)	5,904	1,584	26.83
Agricultural Land (km^2)	192,816	33,064	17.15
Wetlands (km^2)	46,179	31,094	67.33

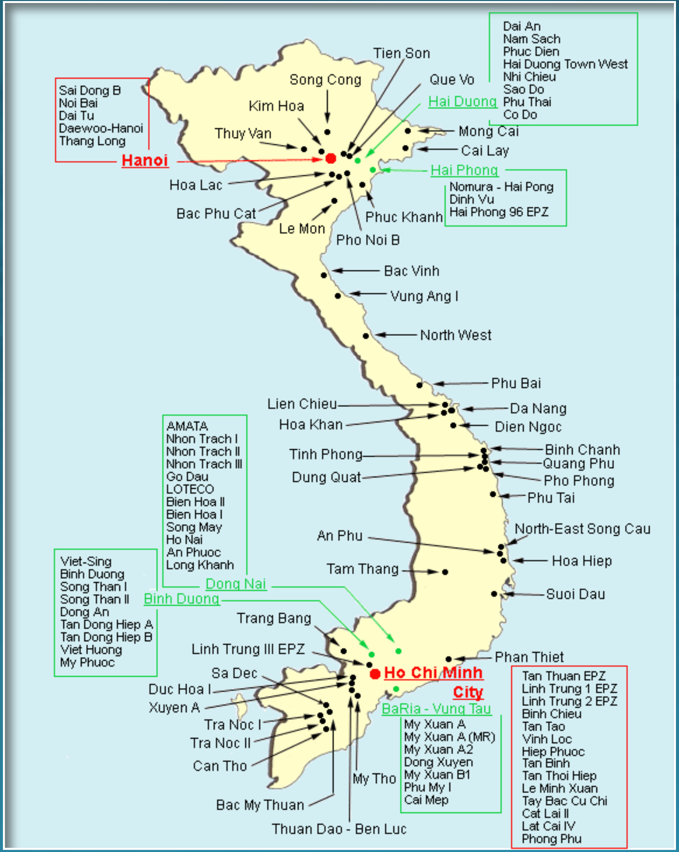
3 m Sea Level Rise



Impact: Industry

Almost all industrial parks in the South and a significant portion of handicraft villages in the North would go under water.





Adaptation to Sea-Level Rise

Adaptation to Sea-Level Rise

- Adaptation must be location-specific.

  Adaptation Alternatives:
  1. Hard Protection
  2. Sediment-based Protection
  3. Nature-based Protection
  4. Other Adaptation Measures/ “Accommodation”
  5. Hybrids
- A one-size-fits-all approach will not work.

Hard Protection: Built Structures on/near the Edges of the Ocean

Examples: Seawalls, Breakwater, Embankments, Dikes, Surge Barriers

- Commonly found in Northwest Europe, East Asia & around many coastal cities and deltas

Advantages:

- If properly maintained, provide predictable protection & work well for protecting densely populated areas.

Disadvantages:

- Costly to build and maintain
- Alter the hydrodynamic and morphodynamic patterns
- Lock-in to a development pathway in which development intensifies behind higher and higher defenses.
- Social conflicts between those favoring protection and those being negatively affected.

Sediment-based Protection

Examples: Beach & Shore Nourishments, Dune Management

Advantages:

- Preserve and encourage tourism.

Disadvantages:

- Seabed dredging of sand and gravel can have negative impacts on marine ecosystems such as seagrass meadows and corals.
- Nourishment practices on sandy beaches may have drawbacks for local ecosystems.
- Social conflicts between those favoring protection and those being negatively affected

Nature-based Protection

Examples: Mangroves, Coral Reef

Mangroves

Advantages:

- Reduce impacts of disasters, e.g. cyclone-induced storm surges
- Reduce coastal erosion
- Provide habitats for biodiversity.
- Positive impacts on livelihoods of coastal inhabitants.
- Adaptation with mitigation co-benefits.

Disadvantages:

- Land requirement / Require land and land may not be available.

Other Adaptation Measures: "Accommodation"

Examples from our Ganges-Brahmaputra Delta Study:

- Rainwater Harvesting
- Local Water desalinization plants
- Saline Resistant Seeds for Agriculture
- Saline Resistant Crops
- Pond-based Aquaculture
- Crab Culture
- Precautionary Measures before Construction of Buildings
- Vocational training for men and women (e.g., training for textile industry, commercial vehicle driving)

Hybrid Adaptation Measures

Examples:

- Embankments with mangroves in the foreshore areas
- Cyclone shelters and mangroves
- Rainwater Harvesting and Water Desalinization Plants

Concluding Remarks

- We have no choice but to adapt to rising sea levels.
- We will have to be much more flexible in our approach to environmental uncertainty in coastal areas.
- Regional and national decision-makers will need to make hard decisions based on a cost-benefit analysis.

Research Questions of Future Interest

- Compensation for the population losing from Climate Change.
- History and Equity in Carbon Budget Allocation.
  - Who is accountable for Climate Change?
- Compensation/s for countries suffering and/or losing from Climate Change.