Coastal Bangladesh in a Changing Climate

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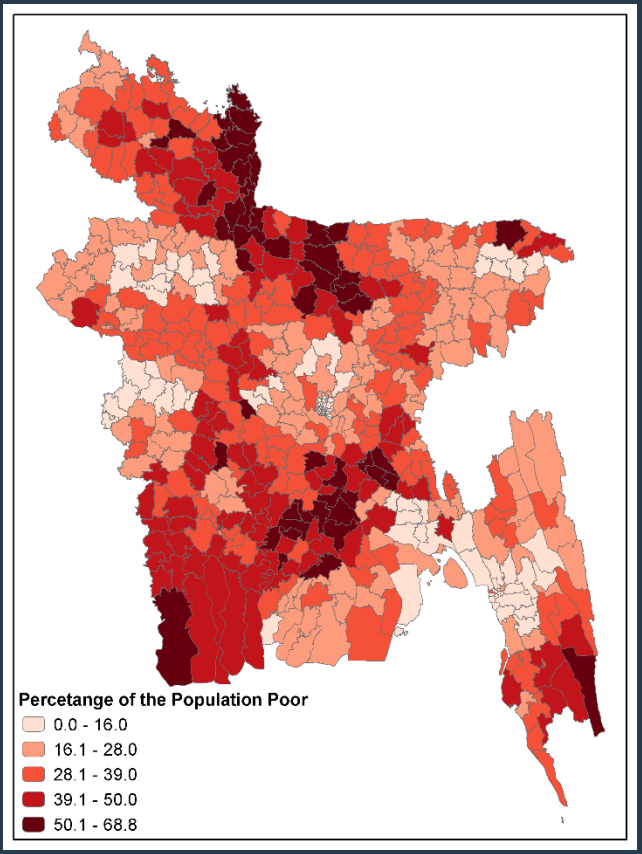
Overview

- Coastal Bangladesh
- Coastal Bangladesh in a Changing Climate
  - Cyclones – Risk of Inundation
  - River Salinity – Scarcity of Drinking Water, Water for Irrigation, Loss of Fish Habitat
  - Soil Salinity – Adverse Impact on Agriculture
- Implications for Environment and Poverty
- Adaptation Measures
- Message to Policy Makers

Poverty Map of Bangladesh
2010

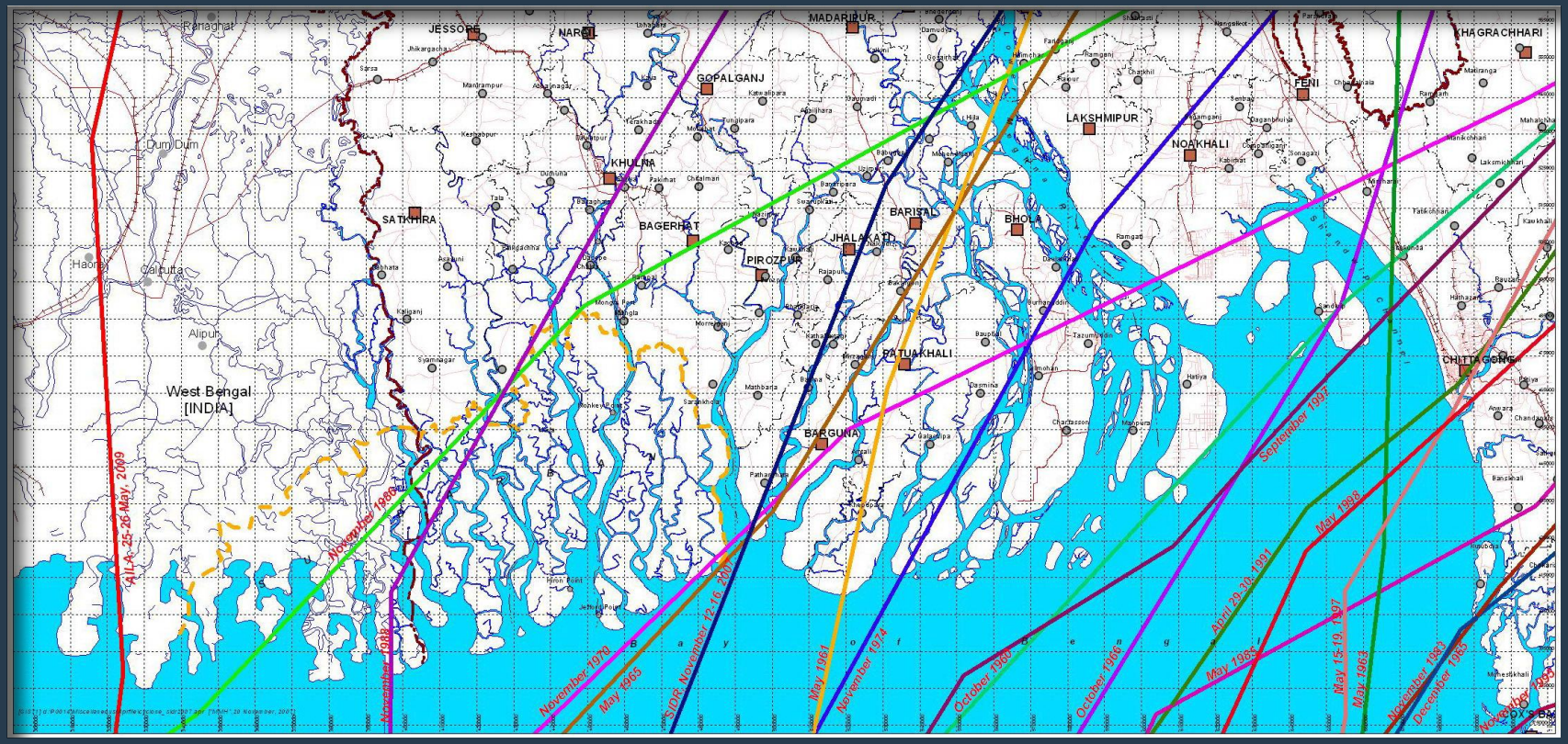


- 43.2 million people in Bangladesh live in poverty.
- 24.4 million extremely poor do not meet the basic needs of food expenditure.

Bangladesh: Coastal Region

- 19 districts (and 148 sub-districts).
- Accounts for 32% of the land area of Bangladesh and 26% population in Bangladesh (sustains livelihood of more than 37 million).
- High incidence of poverty: 11.8 million poor in 2010.
- Cyclones struck 154 times during 1877 and 1995, and 5 severe cyclones struck between 1995 and 2014.
- On average, severe cyclones strike Bangladesh every three years-producing storm surges that can reach heights of 10 m.
- High river and soil salinity in the southwest coastal region are apparent.

Major Cyclones in Bangladesh (1960 – 2009)



- Risk spans the entire coastline

Aftermath of Cyclone Roanu
May 21, 2016

- Storm surge is the biggest threat to lives and properties.
- Typical cyclone storm surge height ranges from 1.5m to 9m.
- Surge heights excess of 10m or more are not uncommon.

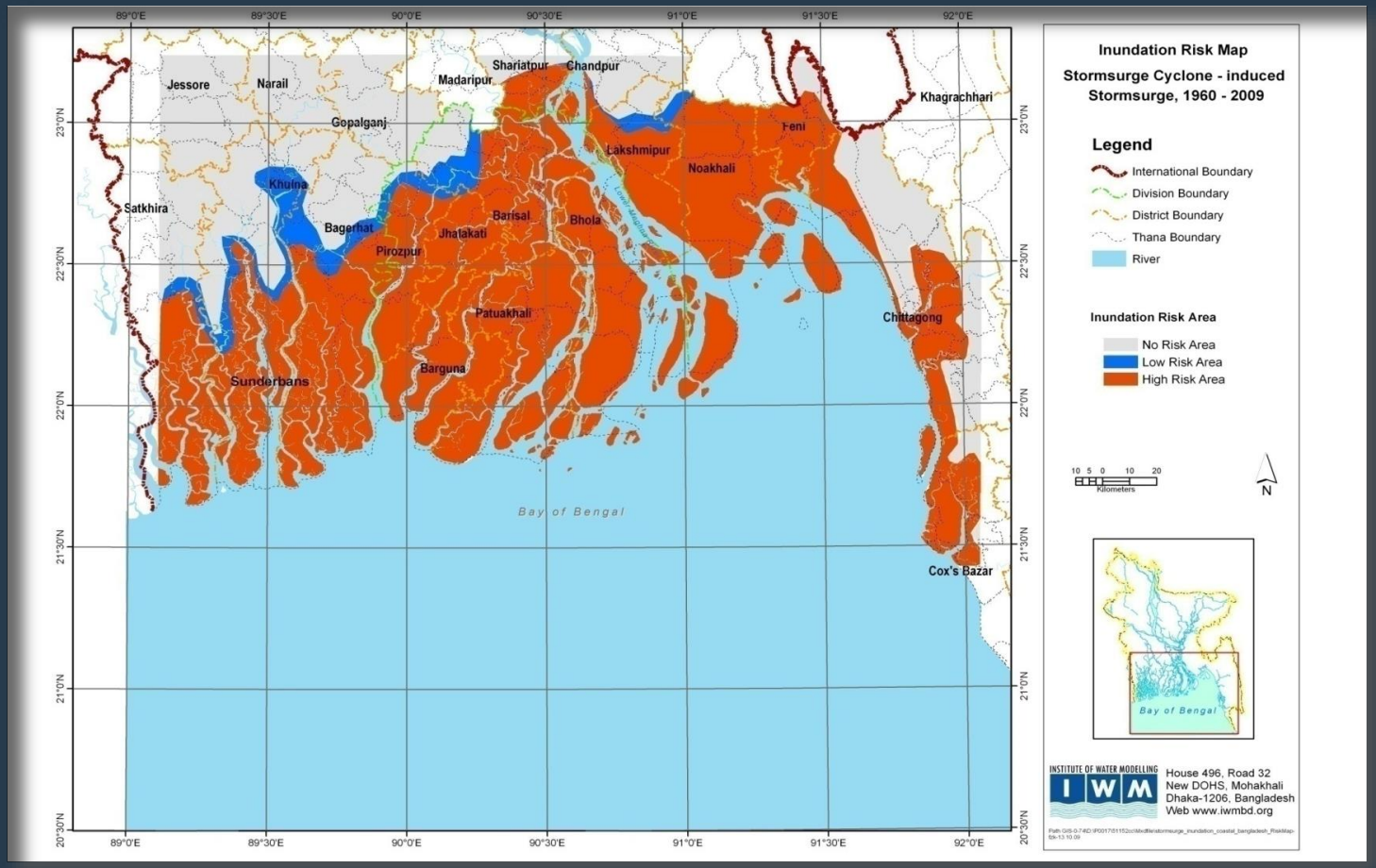
Image: European Pressphoto Agency

Demarcation of Inundation Area

Baseline Scenario: 19 historical cyclone tracks with actual observed meteorological parameters (*Maximum wind speed; radius of influence, cyclone tracks, forward speed and direction and central and neutral pressure*).

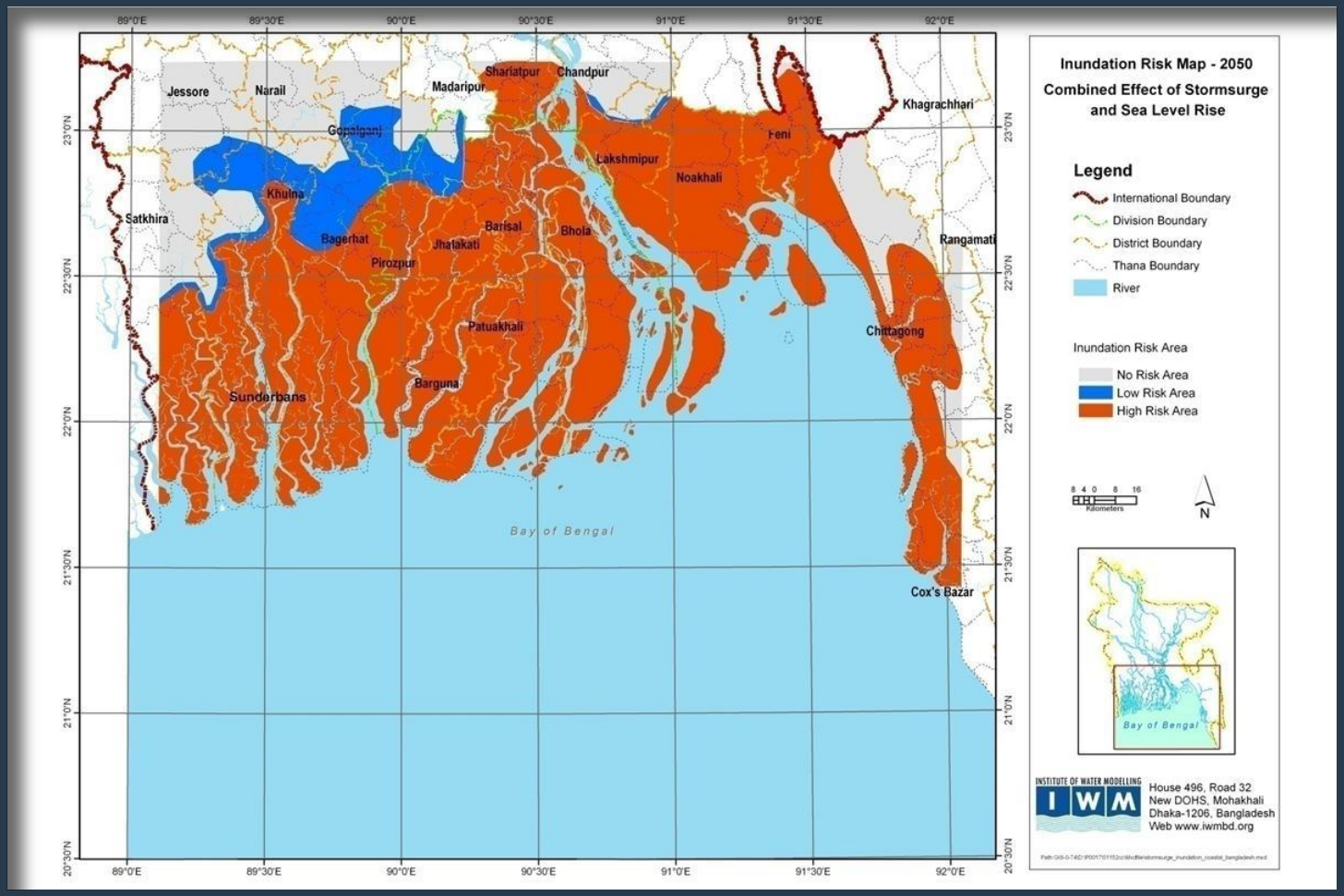
Climate Change Scenario: Five cyclone tracks to span the coast line, meteorological parameters as Sidr for the artificial track, 10% increase in wind speed, 27 cm sea level rise, Land fall at high tide.

Storm Surge Inundation Area under Baseline
(2050 without Climate Change)

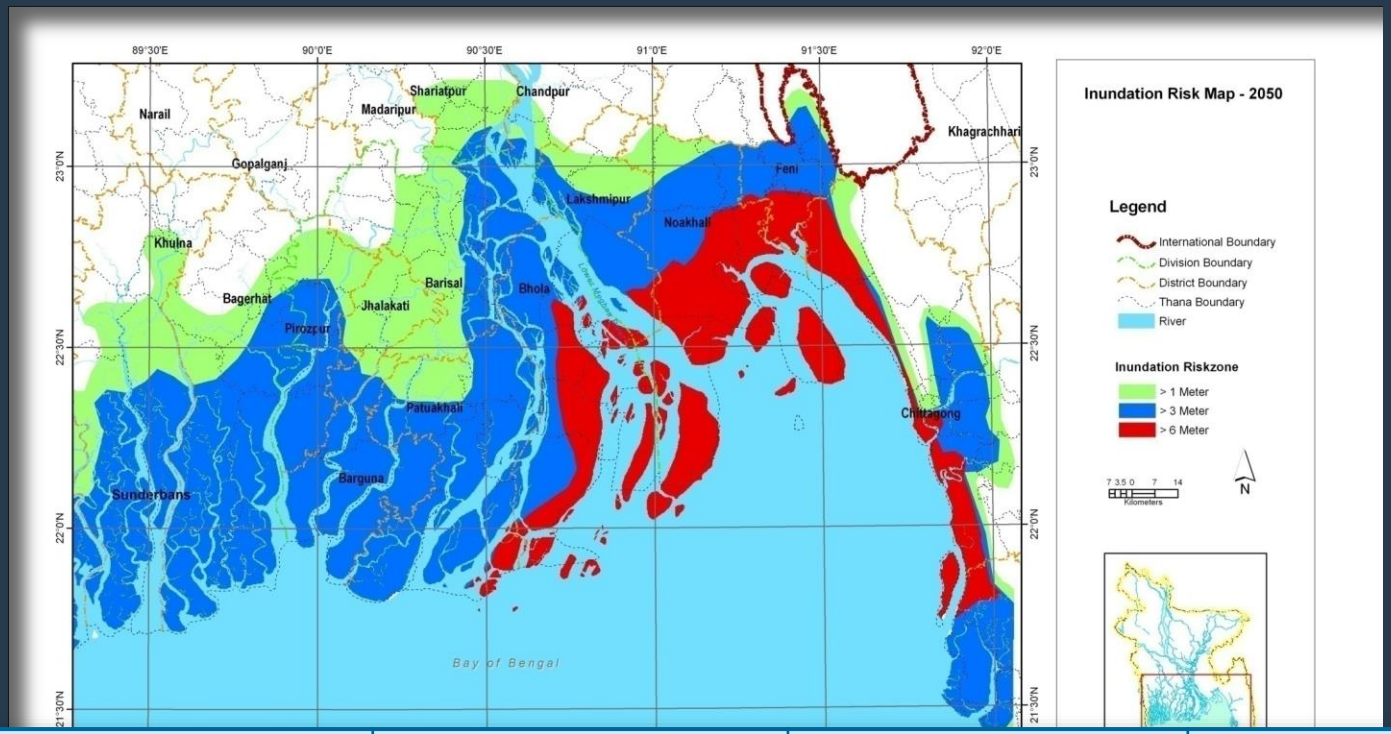


- Bay of Bengal model based on MIKE 21 Hydrodynamic modeling system has been used.

Storm Surge Inundation Area under Baseline
(2050 in a Changing Climate)

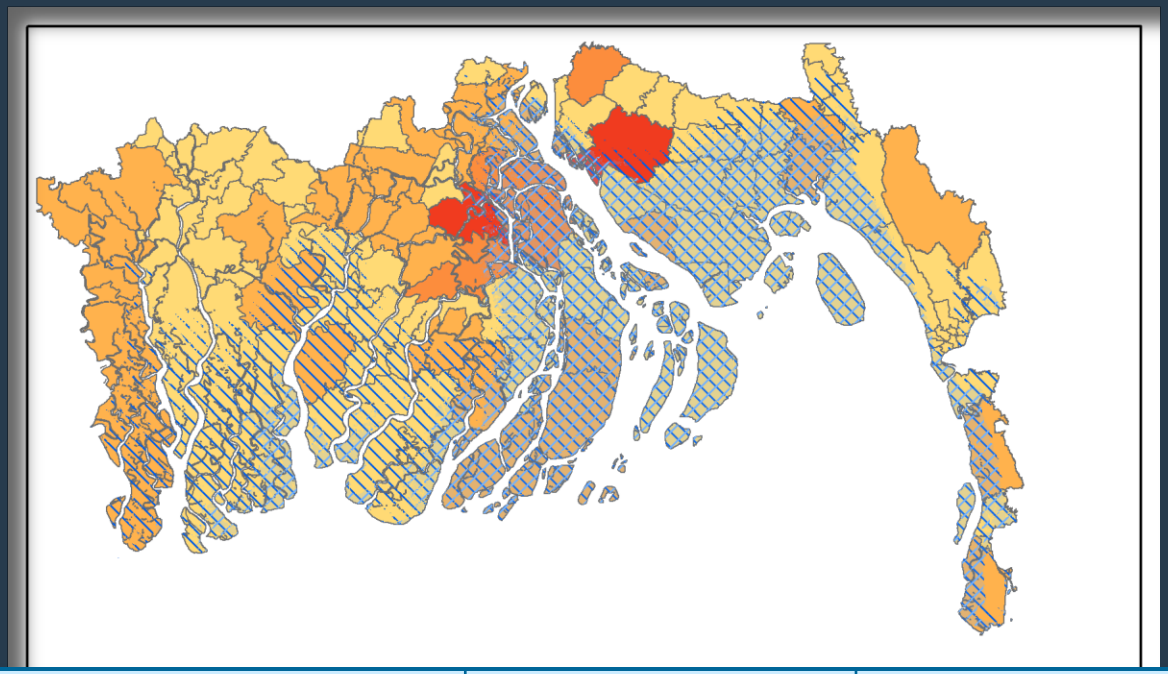


High Risk Area in a Changing Climate 2050



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



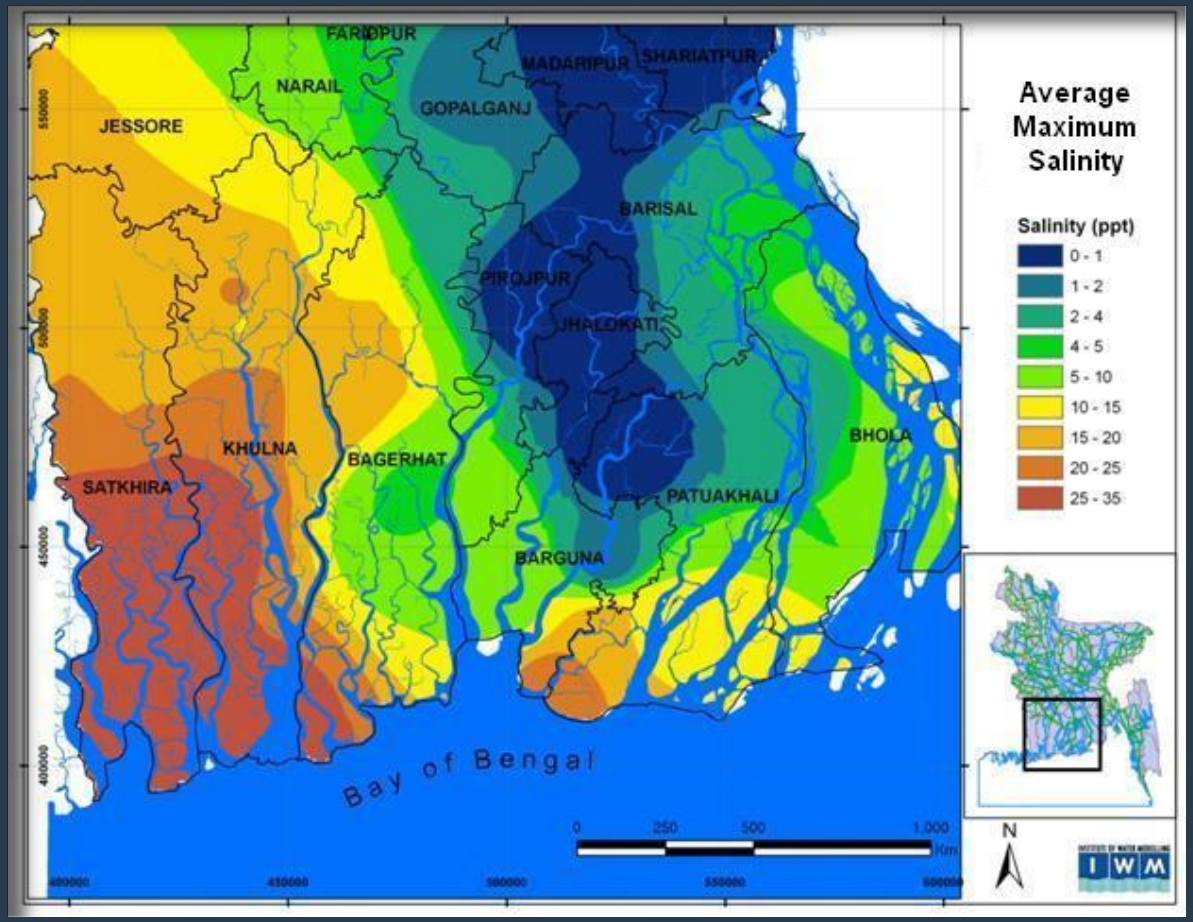
	Total population	Poor
Current situation	15.4 million	4.3 million
Future (2050)	16.8 million	5.3 million
Change from the current situation to 2050	+ 9%	+ 22%

River Water Salinity in the Coastal Region

- 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 of the southwest coastal zone are highly saline.
- Scarcity of drinking water and water for irrigation in the southwest coastal region are apparent and serious.

River Salinity in the Southwest Region

Spatial variation of maximum river salinity during 2011-2012

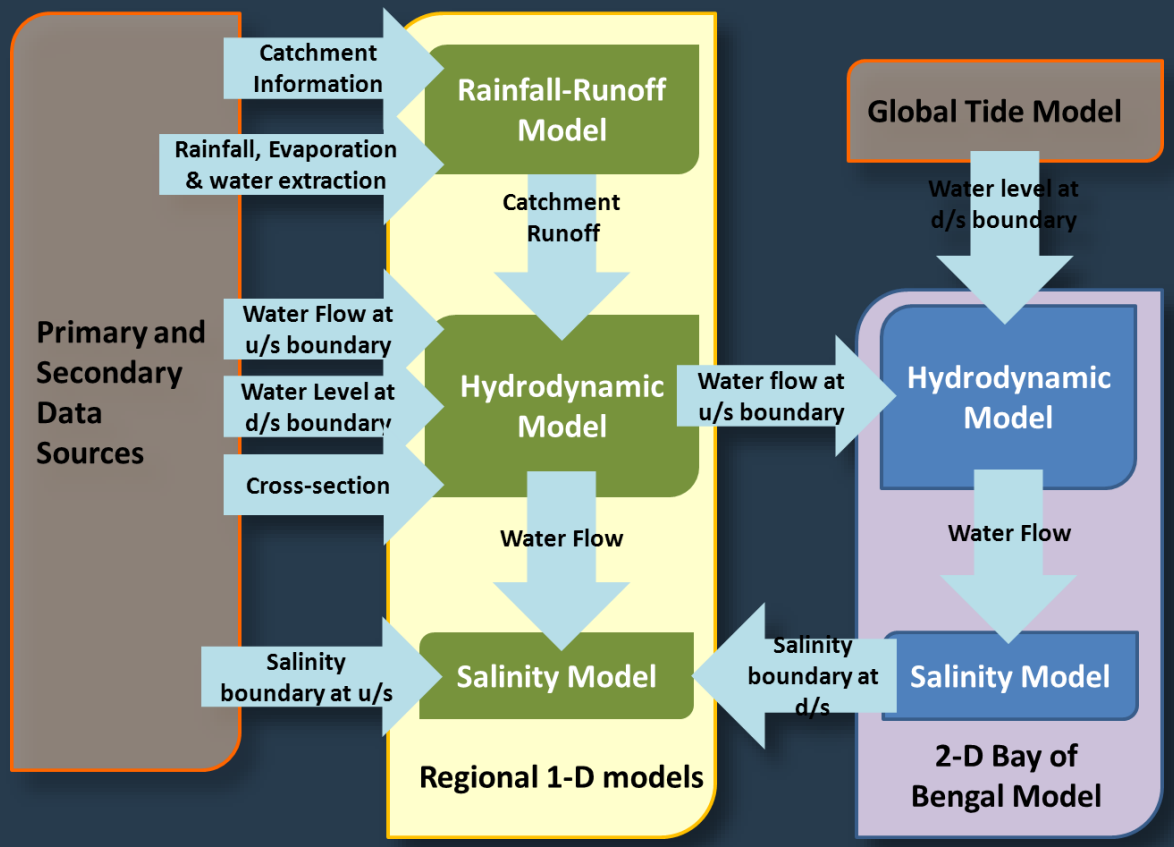


Source: IWM, 2013

River Salinity Modeling: Conceptual Framework

- River water salinity in coastal Bangladesh depends on:
  - Volume of freshwater discharges from the upstream river systems
  - Surface water runoff from rainfall
  - Salinity of the Bay of Bengal near the coast, and
  - Tidal dynamics of the coastal river system

River Salinity Modeling



u/s: upstream boundary d/s: downstream boundary of a river

Source: IWM, 2013

River Water Salinity Modeling

1. A Rainfall-Runoff model was applied to estimate the runoff from rainfall in various watersheds of the model area.
   - Inputs: watershed characteristics, rainfall, soil moisture, irrigation & water extraction from the surface or groundwater sources in the watershed, evaporation, percolation and other losses.
   - Output: Runoff from the catchment.
2. The hydrodynamic module of the MIKE 11 model system (the Southwest Regional Model, SWRM) was used to develop the water flow and the water level in the river systems of the southwest region.
   - Inputs: rainfall runoff estimates , water flow data recorded by river gauges at the upstream end of the river, water level data from the downstream end of the river, and the cross-sectional river data.
   - Output: Water flow, water level, and flow velocity of the river systems.

River Water Salinity Modeling (Continued)

3. Bay of Bengal model based on the MIKE 21FM module of the DHI was used to simulate the salinity of the Bay of Bengal.
   - Inputs: water flow estimates from the SWRM and measured salinity at the upstream boundary , time-series water level data and constant 32ppt salinity from the DHI Global Tides Model at the downstream boundary,
   - Output: Estimates of salinity of the Bay of Bengal.

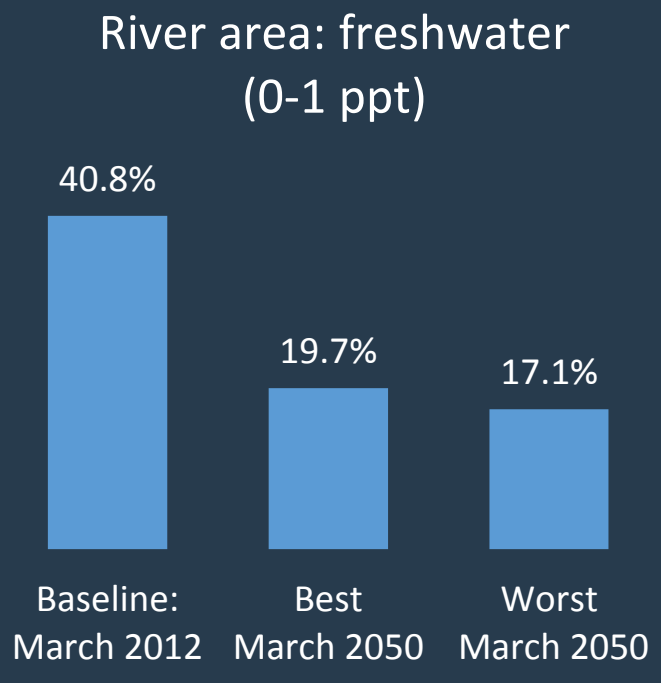
   Assumption: All 61 polders are functioning well and will not be overtopped by 2050.
4. Salinity model (the advection-dispersion module of MIKE11) is coupled with the hydrodynamic module to assess river salinity in the southwest coastal zone.
   - Inputs: Measured concentrations of salinity along the upstream boundary and estimates of salinity of the Bay of Bengal for the downstream boundary.
   - Output: Location-specific river salinity.

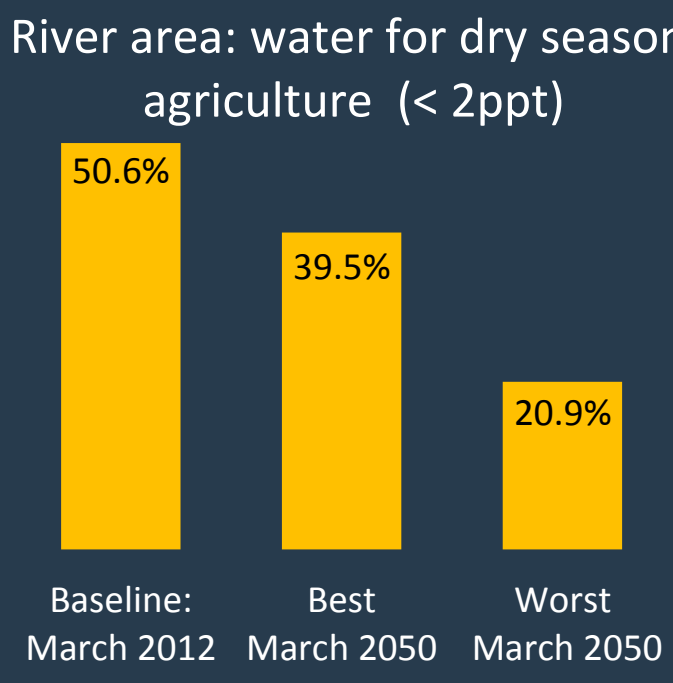
Area Estimates

Salinity classification* 1 dS = 1.75 ppt	Baseline (March 2012)	Best (March 2050)	Worst (March 2050)
Slight saline (<1 dS/m)	22 %	16 %	13 %
Slight to moderately saline (1-5 dS/m)	35 %	30 %	21 %
Moderate to high saline (5-10 dS/m)	8 %	17 %	27 %
Highly saline (>10 dS/m)	35 %	38 %	40 %

*WARPO-Bangladesh: National Water Management Plan

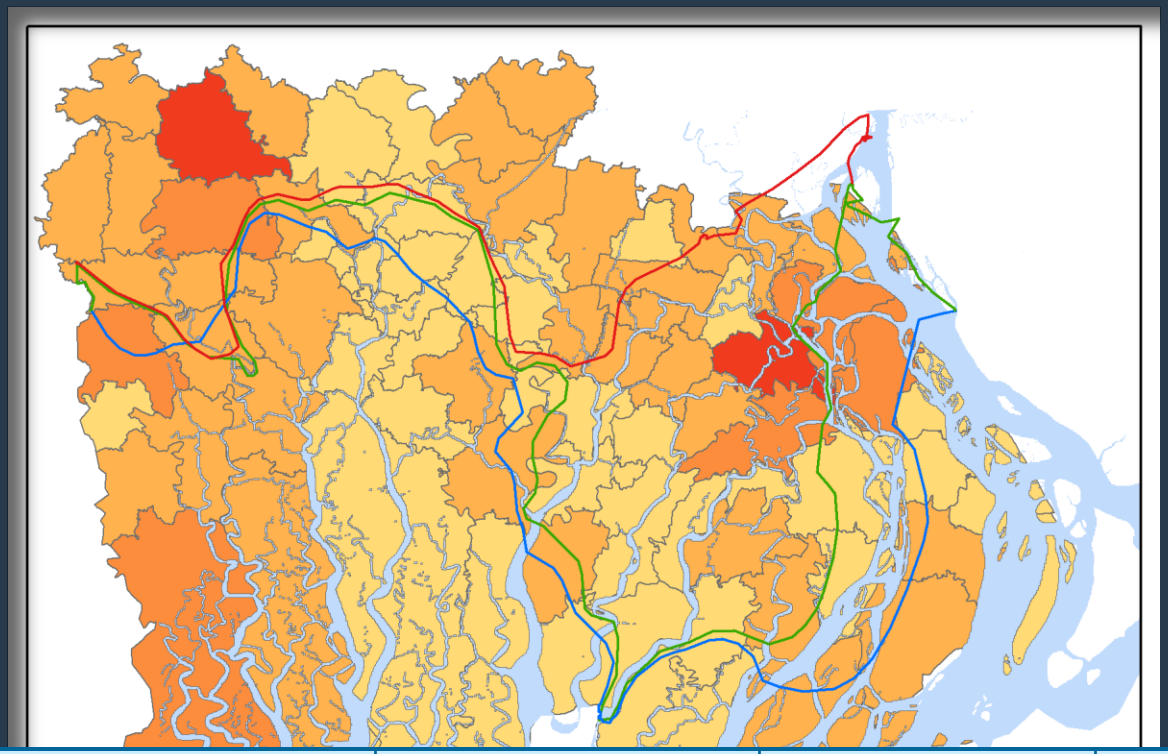
Expected Impacts





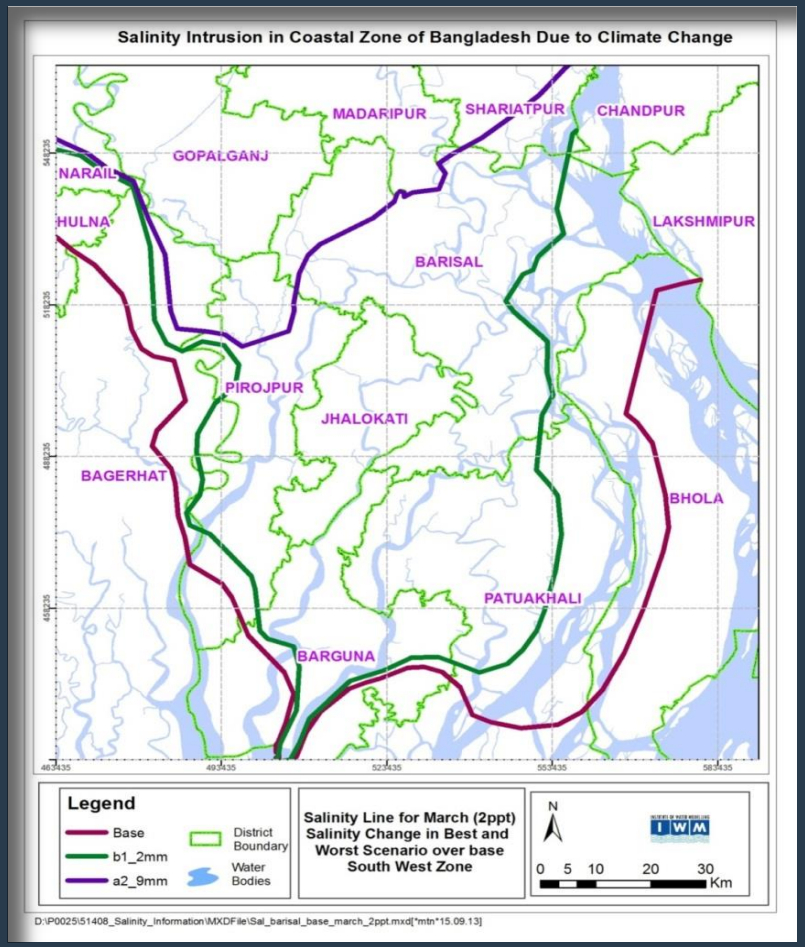
- Expected increase in river salinity is likely to impact wild habitats of fresh water fish, low-value indigenous species and nutritional intake of the poor, especially women and children.
- In Sunderbans (UNESCO Heritage site), a shift in species is expected from *Heritiera fomes* to *Ceriops decandra* and *Excoecaria agallocha*.

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 %

Illustrative Example: Scarcity of Water for Irrigation



In Barisal division, river water will no longer be usable in the Bhola Irrigation project

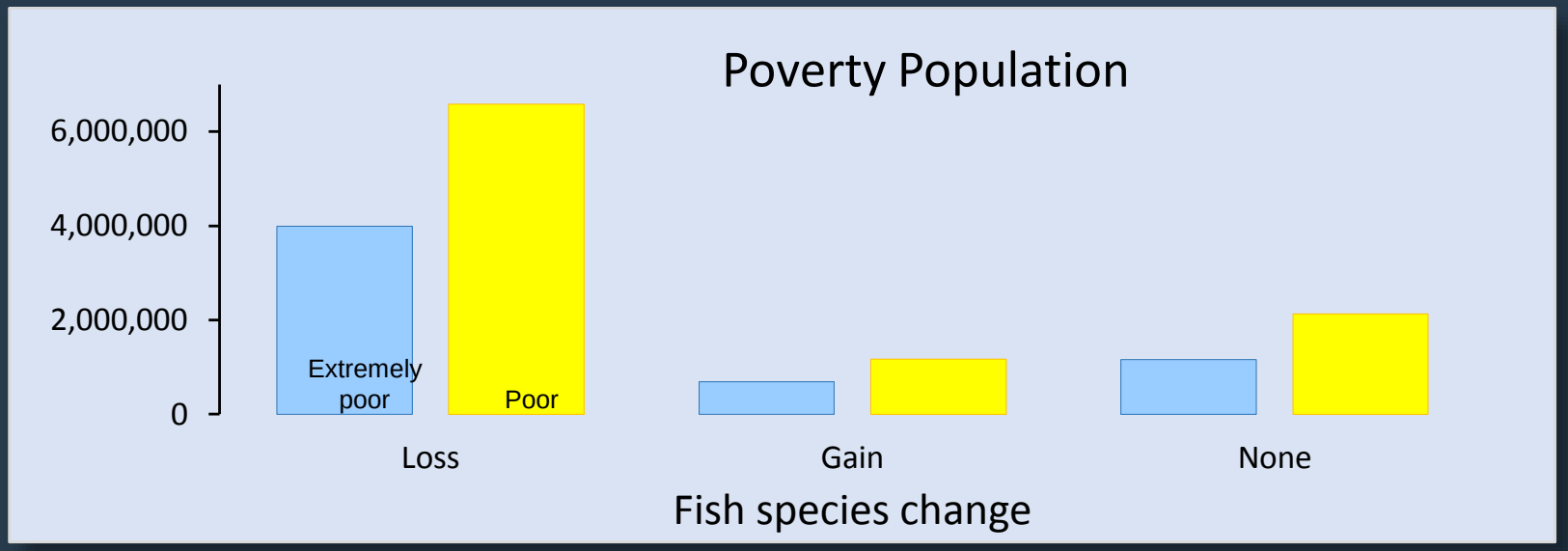
Important Source of Dietary Protein

Wild, small freshwater fish are the most common fish consumed in rural Bangladesh

Image: Pritthijit Kundu

Implications for Fish Habitats

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



- Significant impact on animal protein intake of poor women and children is expected.

Additional Impacts: Change in Mangroves

- Significant impact on mangrove species in Sunderbans (UNESCO Heritage site) is anticipated,
- A shift in species is expected from *Heritiera fomes* to *Ceriops decandra* and *Excoecaria agallocha*.
- A negative impact on standing stock of timber in the region is inevitable.
- Overall honey production is likely to increase.
- Human and wildlife conflicts in Sundarbans will increase.

Analysis is based on 14 mangrove species and mixed species.

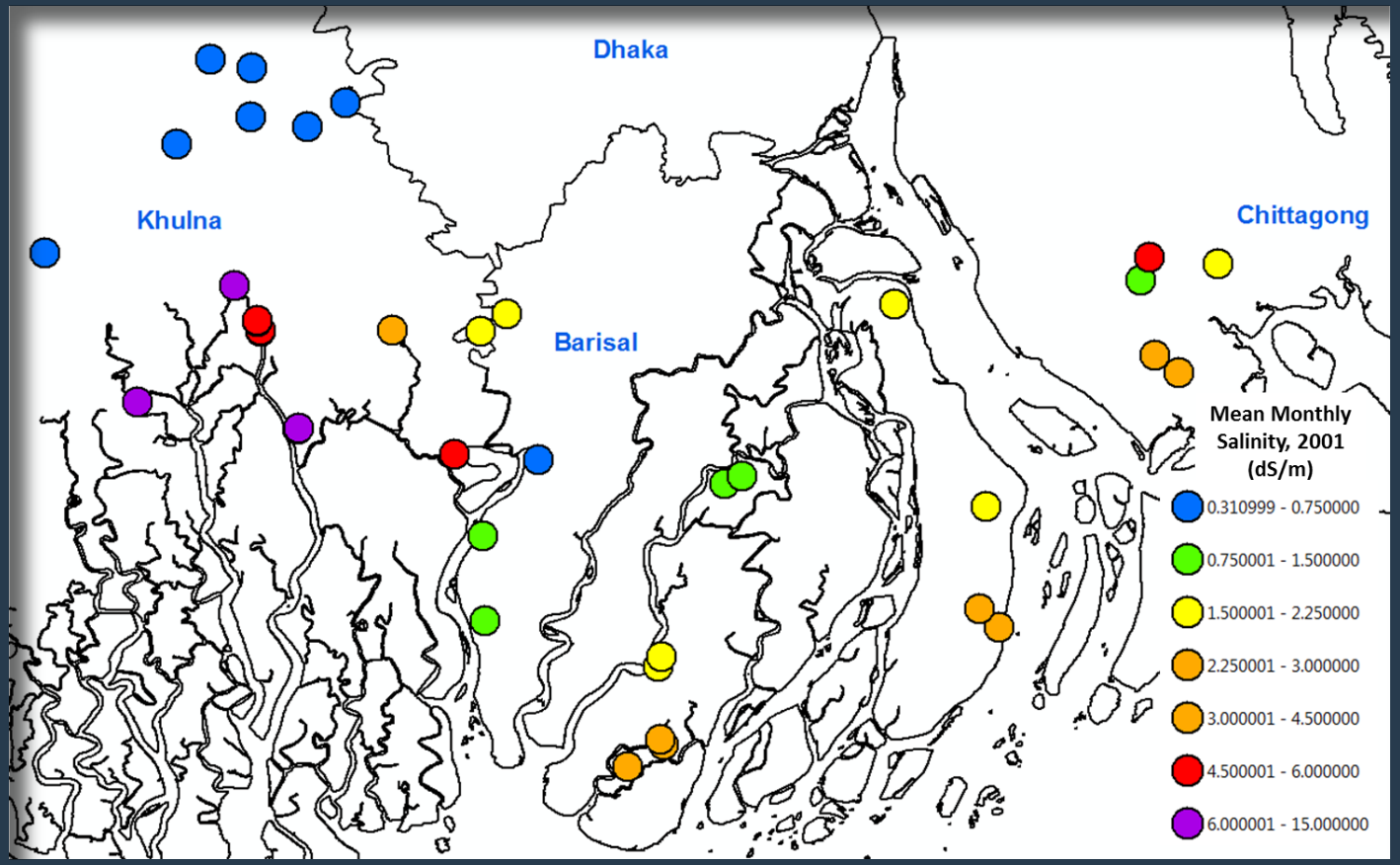
Health Implications of Increased Water Salinity

- 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.

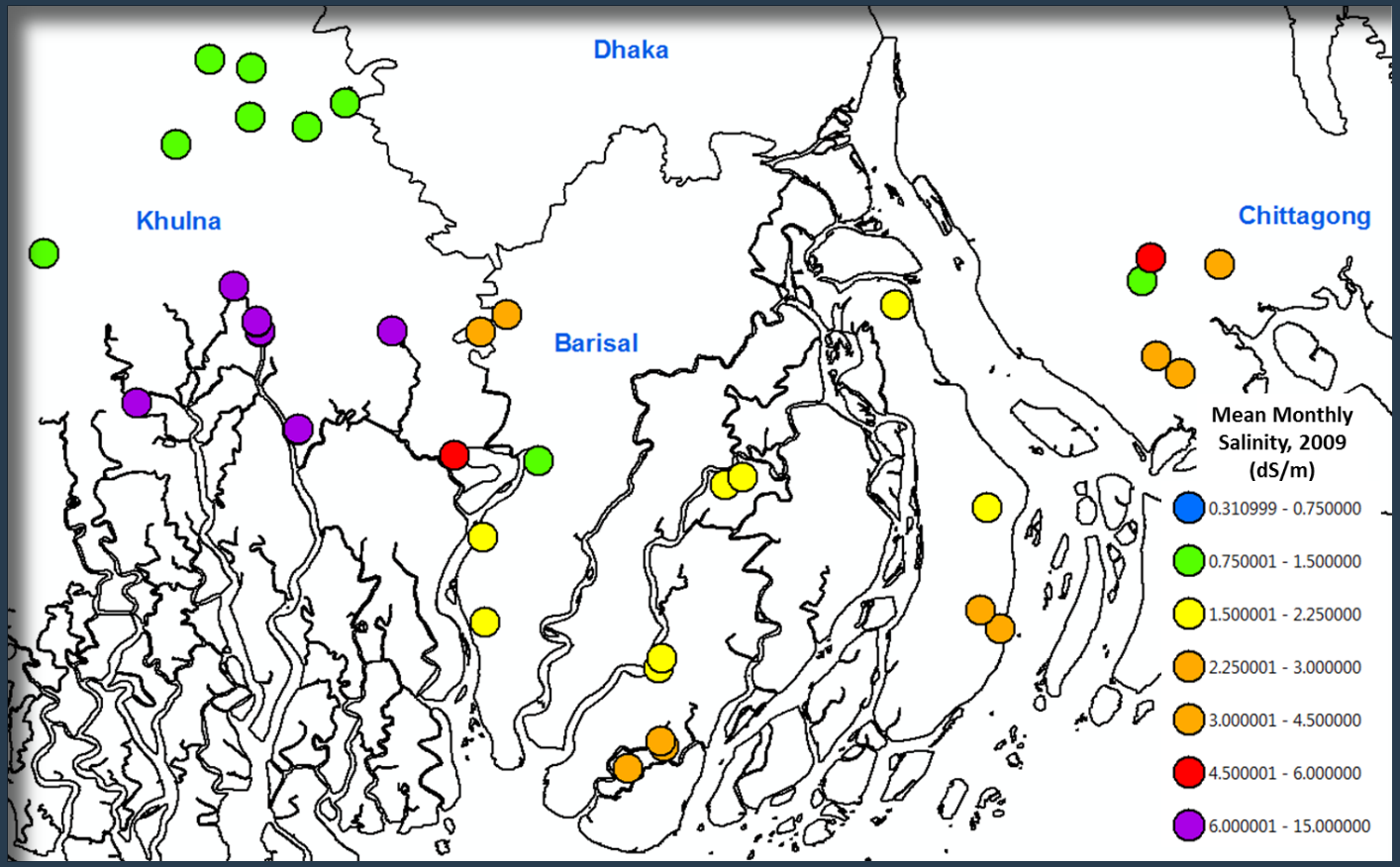
Soil Salinity in Coastal Bangladesh

2001



Soil Salinity in Coastal Bangladesh Increasing Over Time

2009



Soil Salinity Prediction: Regression Framework

$$S_{Lit} = \beta_0 + \beta_1 E_i + \beta_2 S_{Rit} + \beta_3 R_{it} + \beta_4 T_{it} + \varepsilon_{it}$$

Where, for period t:

S_{Lit}= Measured soil salinity (dS/m) at land station i

E_i = Elevation (m) of station i

S_{rit} = Distance-weighted measured salinity (ppt) at river stations within 30 km of land station i

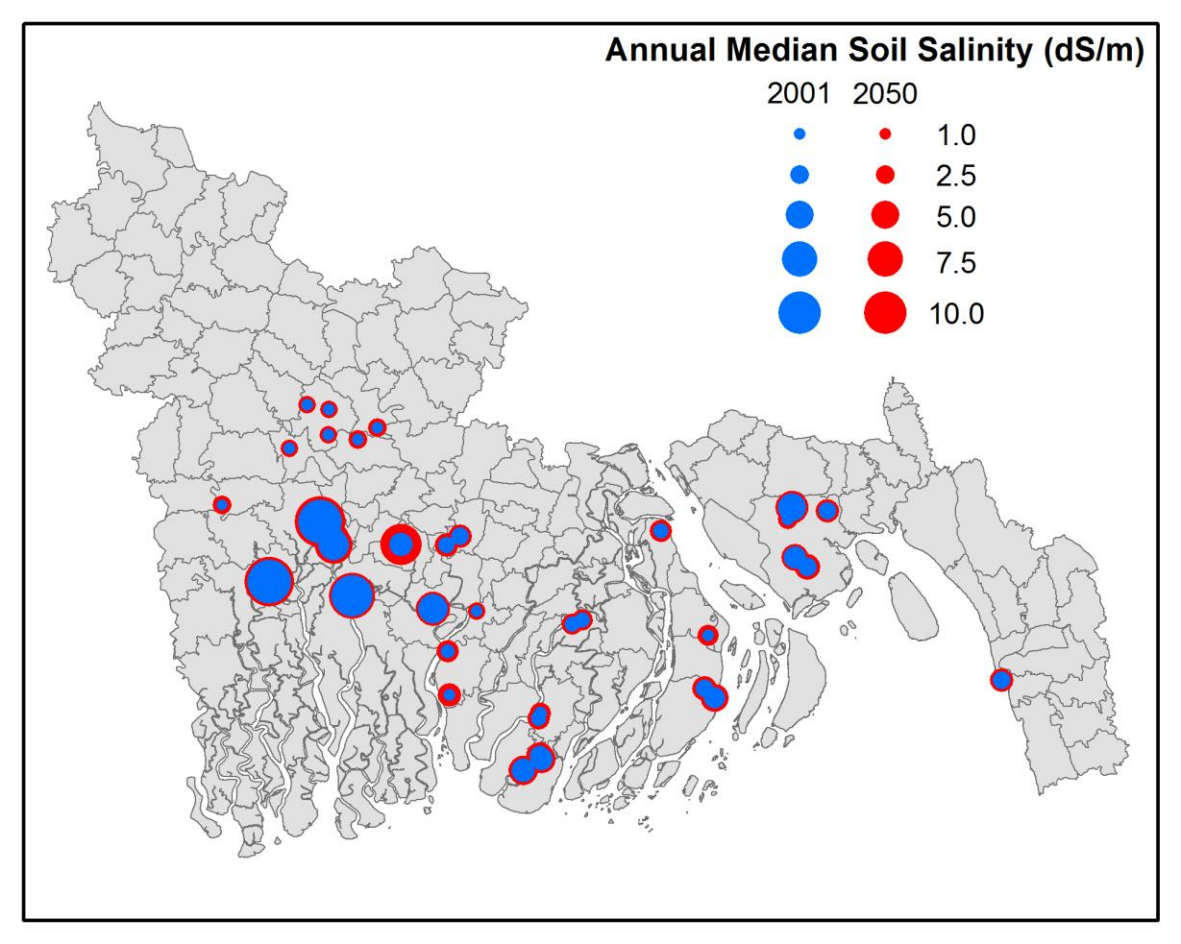
R_{it} = Measured rainfall (mm) at the Bangladesh Meterological Department (BMD) weather station nearest to land station i

T_{it}= Maximum monthly temperature (° C) at the BMD weather station nearest to land station i

ε_{it} = Random, spatially-autocorrelated error term with station and time components

Expected signs: $\beta_1, \beta_3 < 0$; $\beta_2, \beta_4 > 0$

Significant Increase in Soil Salinity by 2050



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

Soil Salinity in a Changing Climate

- By 2009, a general pattern of salinity increase is apparent. The shift continues through 2050.
- Across 41 monitoring stations
  - Median projected increase is 26.2%.
  - 25% of the stations have changes of 41.8% or higher
  - 10% have projected changes greater than 55.7%.
- 24 or more *upazila*s are expected to cross 4.0 dS/m within a few decades after 2050.

Soil Salinity and HYV Rice Yield

- Many sub-districts have already suffered large yield losses from rising soil salinity.
- Losses will be compounded by further salinity increases in the coming decades.
- Estimates suggest that HYV rice output will decline by 15.6 percent in nine coastal sub-districts where soil salinity is expected to exceed 4 deciSiemens per meter before 2050.
- Predicted change in soil salinity will lead to significant income declines from HYV rice production in many areas, including a 10.5% loss in Barisal region and 7.5% loss in Chittagong region.

Livelihood Threats and Household Responses

- Coastal families face recurring inundations from cyclonic storms.
- Degradation of natural resources from progressive salinization salinity is apparent.
- Agricultural productivity loss, loss of fresh water fish species are affecting the livelihood of coastal families adversely.
- Economic necessity drives more working-age adults to seek outside earnings in households threatened by inundation and salinization, particularly those that are relatively isolated from market centers.
- Those left behind face a far greater likelihood of extreme poverty than their counterparts in less-threatened areas.

Household Labor Allocation

$$\eta_{ij} = \beta_0 + \beta_1 T_j + \beta_2 S_j + \beta_3 C_j + \beta_4 C_j log E_j + \varepsilon_{ij}$$

Where, for household i in cluster j

η_{ij} = Household percent of resident working-age individuals (male or female)

T_j = Travel time to nearest urban center from cluster centroid (hundreds of minutes)

S_i = Average cluster soil salinity in 2011 (dS/m)

C_j = Coastal proximity dummy variable (1 if cluster is within 4 km; 0 otherwise)

E_j = Elevation of the cluster centroid (m)

$\varepsilon_{i\,t}$ = Random error term

Expected signs: $\beta 1, \beta 3 < 0$; $\beta 4 > 0$

Household Economic Welfare

$$p(Q)_{ij} = \beta_0 + \beta_1 T_j + \beta_2 S_j + \beta_3 C_j + \beta_4 C_j log E_j + \varepsilon_{ij}$$

Where, for household i in cluster j

$p(Q)_{ij}$= Probability that household i in cluster j is in the lowest national wealth quintile

T_j= Travel time to nearest market center from cluster centroid (hundreds of minutes)

S_i= Average cluster soil salinity in 2011 (dS/m)

C_j= Coastal proximity dummy variables (1 if cluster is within 4 km; 0 otherwise)

E_j= Elevation of the cluster centroid (m)

ε_{it}= Random error term

Expected signs: $\beta_1, \beta_2, \beta_3 > 0$; $\beta_4 < 0$

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.

Implications for Poverty

When salinity, inundation risk and market access are switched from their most favorable to least favorable settings,

- Reallocation of labor to outside earning opportunities leads to
  - 53% decrease in resident working-age males
  - 22% decreases in resident working-age females
  - 160% increase in the household dependency ratio -- the ratio of old and young dependents to working-age adults.
- The poverty impact is even more striking: the probability of lowest-quintile economic status rises by nearly 600%, from 8% to 56%.

Adaptation Measures for Cyclone Intensification

- Height Enhancement of Coastal Embankments
- Afforestation to Protect Sea-Facing Embankments
- Construction of Multipurpose Emergency Shelters
- Cyclone-Resistant Private Housing, Strengthening Early Warning and Evacuation System.

Potential Adaptation Measures for Ingress of Salinity

- Desalinization of Drinking Water
- Widespread use of Saline Resistant Crops
- Expansion of Tilapia Farming
- Expansion of Honey Production
- Expansion of Crab Culture
- Precautionary Measures before Construction of Buildings.

Alternative Interventions

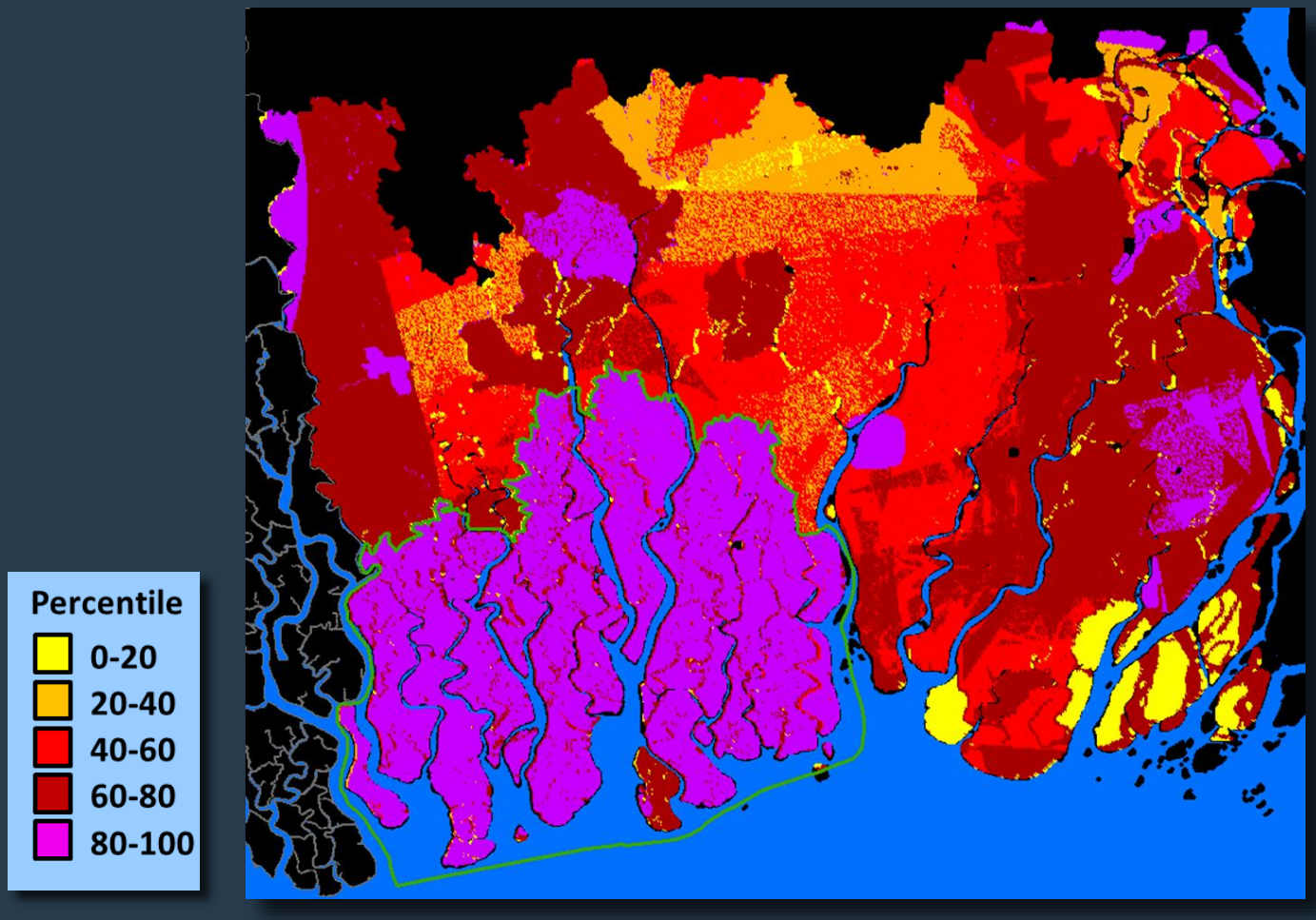
- Standard adaptation measures focus on direct compensation for welfare losses, and are necessary.

In addition,

- Reduction of travel times for isolated settlements to market centers by 2 1/2 hours (from current condition of 9 hours) would significantly improve their economic welfare.
- Benefits of increased mobility are enlarged by the threat of climate change, making such investments an attractive low-regret option.

Critical Biodiversity

Indicator based on count, threat status, endemicity and extinction probability of species



Improvement of market access should take into account critical biodiversity of the region

Recommendations

- Desalinization of water
- Expansion of honey production
- Expansion of crab culture
- Cooperative management of fishing
- Vocational training for women (e.g., training for textile industry)
- Vocational training for men (e.g., driving of commercial vehicles)
- Improvement of market access in non-critical biodiversity areas

Summary

- This research quantified the impact of inundation risk and salinization on coastal Bangladesh with and without climate change.
- Degradation of natural resources is already apparent.
- Progressive degradation of natural resources in a changing climate is imminent.
- The critical zone for inundation risk lies within 4 km of the coast, with attenuated impacts for coastal-zone households at higher elevation.
- Households threatened by inundation and salinization, particularly those that are relatively isolated from market centers respond by “hollowing out”, as economic necessity drives more working-age adults to seek outside earnings.
- Those left behind face a far greater likelihood of extreme poverty than their counterparts in less-threatened areas.

Urgent Call for Action

- With a virtual certainty that sea-level rise will continue beyond 2100 even if greenhouse gas emissions are stabilized today, families in coastal Bangladesh are already on the “front line” of climate change. Their adaptation foretells future decisions by hundreds of millions of families worldwide who will face similar threats well before 2100.

- For sustainable poverty alleviation, it is imperative for policymakers to begin planning to cope with the potential poverty trap that climate change may create. Implementation of new policies takes time. Therefore, the time is now for the policymakers and development partners to prepare and implement policies that reduce vulnerability to climate change.

Co-Researchers

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Discussion

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Q & A

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