Deltas as Coupled Socio-Ecological Systems

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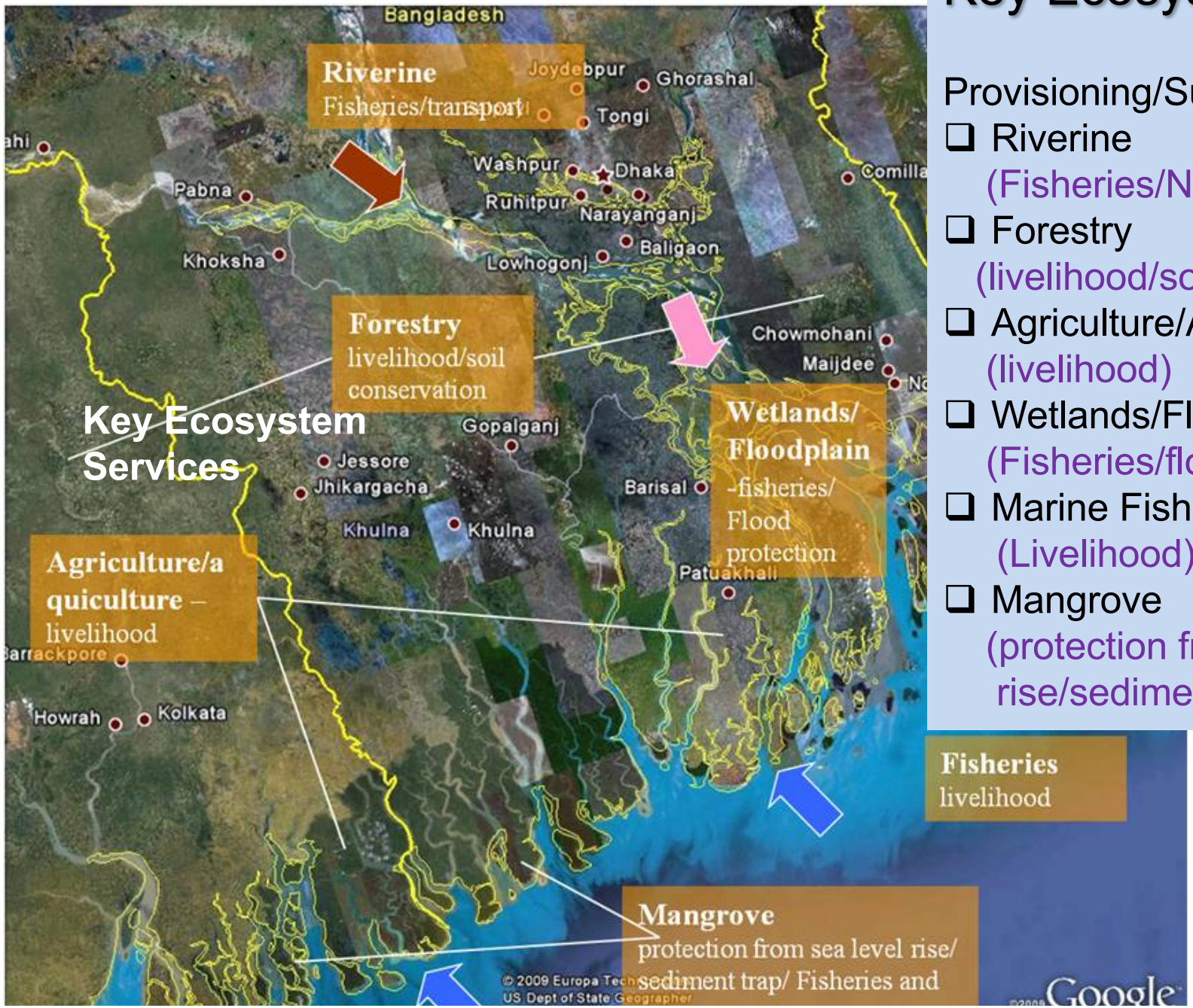
Boulder, CO

Plan

- Introduction
- Bio-physical and socio-economic components for coastal Bangladesh
- Integration: Delta Dynamic Integrated Emulator Model (ΔDIEM)
- Illustrative results
- Concluding remarks

Nile delta

Ecosystem Services/Activities in GBM delta



Key Ecosystem Services:

Provisioning/Supporting:

- ❑ Riverine
  (Fisheries/Navigation)
- ❑ Forestry
  (livelihood/soil conservation)
- ❑ Agriculture/Aquaculture
  (livelihood)
- ❑ Wetlands/Floodplains
  (Fisheries/flood protection)
- ❑ Marine Fisheries
  (Livelihood)
- ❑ Mangrove
  (protection from sea level rise/sediment trap/fisheries)

Ecosystem Services for Poverty Alleviation (ESPA)

ESPA is a £40 million international research programme on this issue in developing countries.

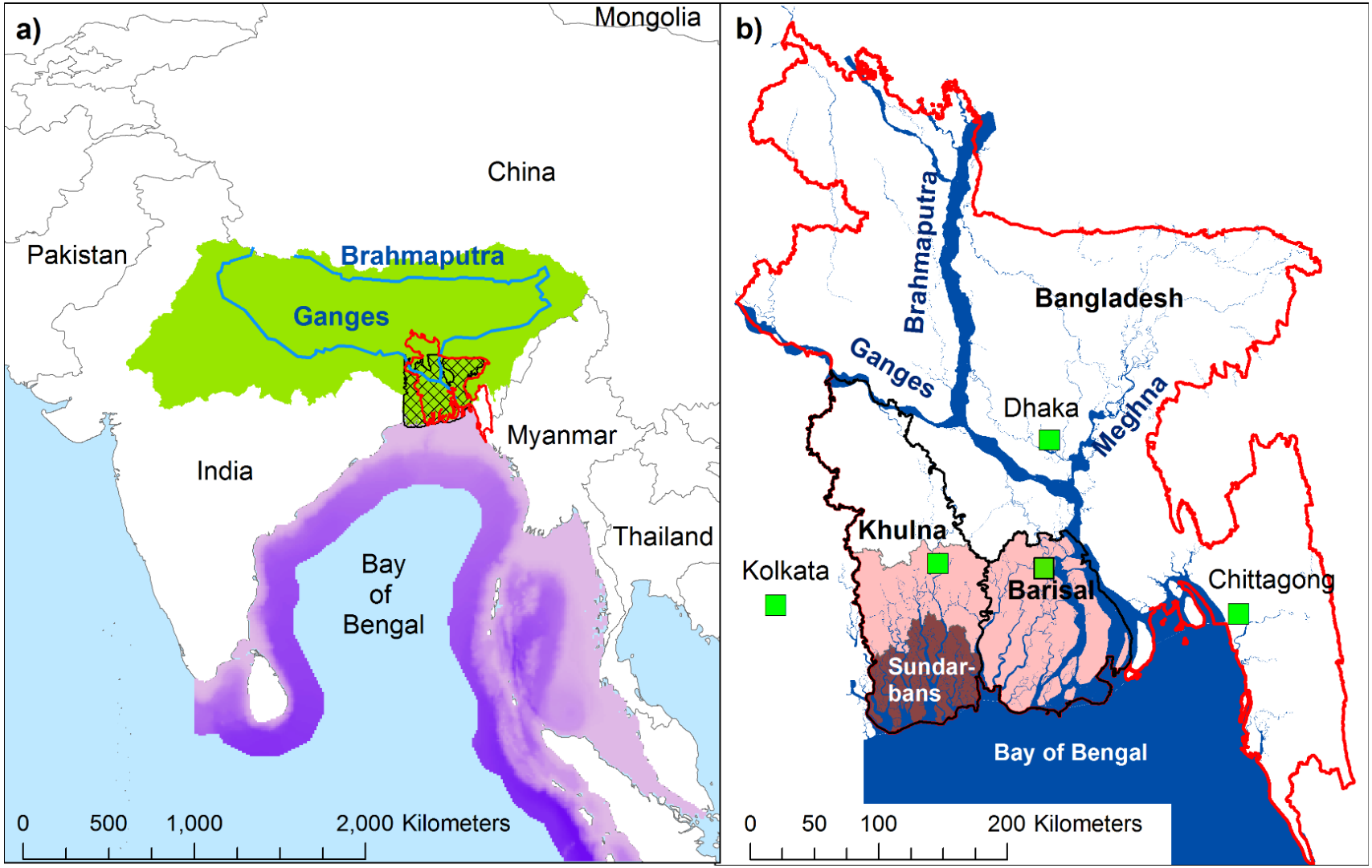
ESPA is explicitly interdisciplinary, linking the social, natural and political sciences and promotes systems thinking of social and ecological systems.

ESPA Deltas ("Assessing Health, Livelihoods, Ecosystem Services And Poverty Alleviation In Populous Deltas") was the largest ESPA Consortium Grant
(Duration: 2012 to 2016)

Active ESPA Deltas Continuation working with Planning Commission, Government of Bangladesh

ESPA Deltas Project

Assessing Health, Livelihoods, Ecosystem Services And Poverty Alleviation In Populous Deltas – Ganges-Brahmaputra-Meghna (GBM) Delta



Source: http://dx.doi.org/10.1016/j.ecss.2016.08.017

The ESPA Delta Consortium

21 partners and about 100 members from a range of disciplines

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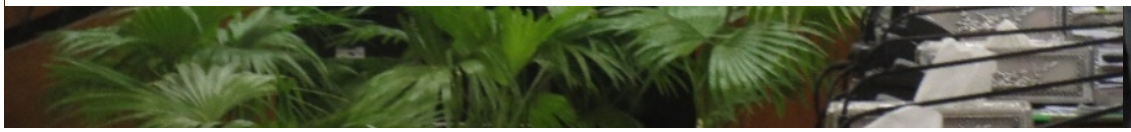
Strategic Partner: General Economic Division, Planning Commission



Deltas
stem services
verty alleviation

ESPA Deltas: Overarching aim

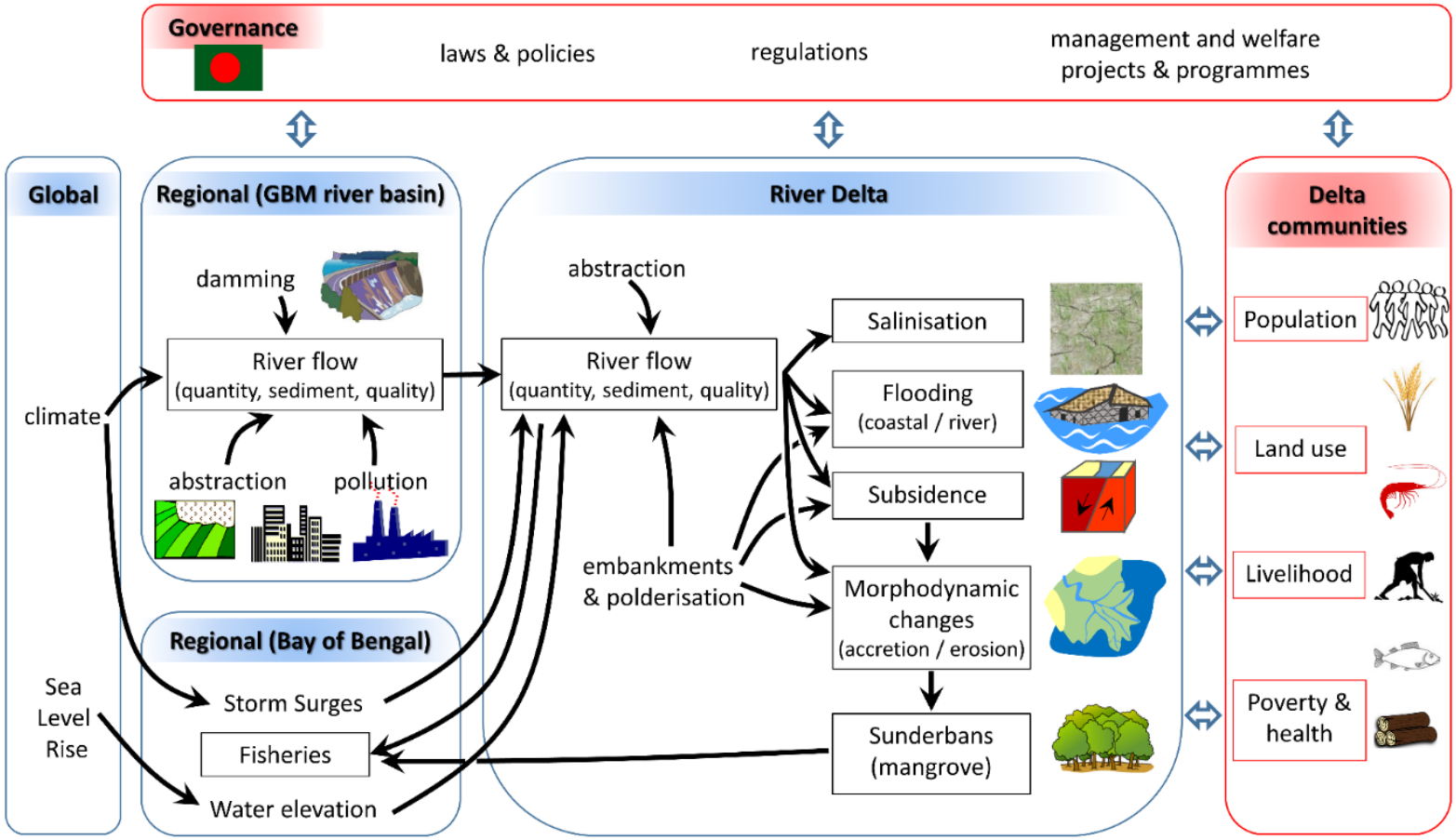
To provide policy makers with the knowledge and tools to enable them to evaluate the effects of policy decisions on ecosystem services and people's livelihoods

Vision: Link science to policy at the landscape scale

Engagement: With national level policy processes that impact at a community level

Key biophysical factors

and links to governance and socio-economic factors



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The Approach

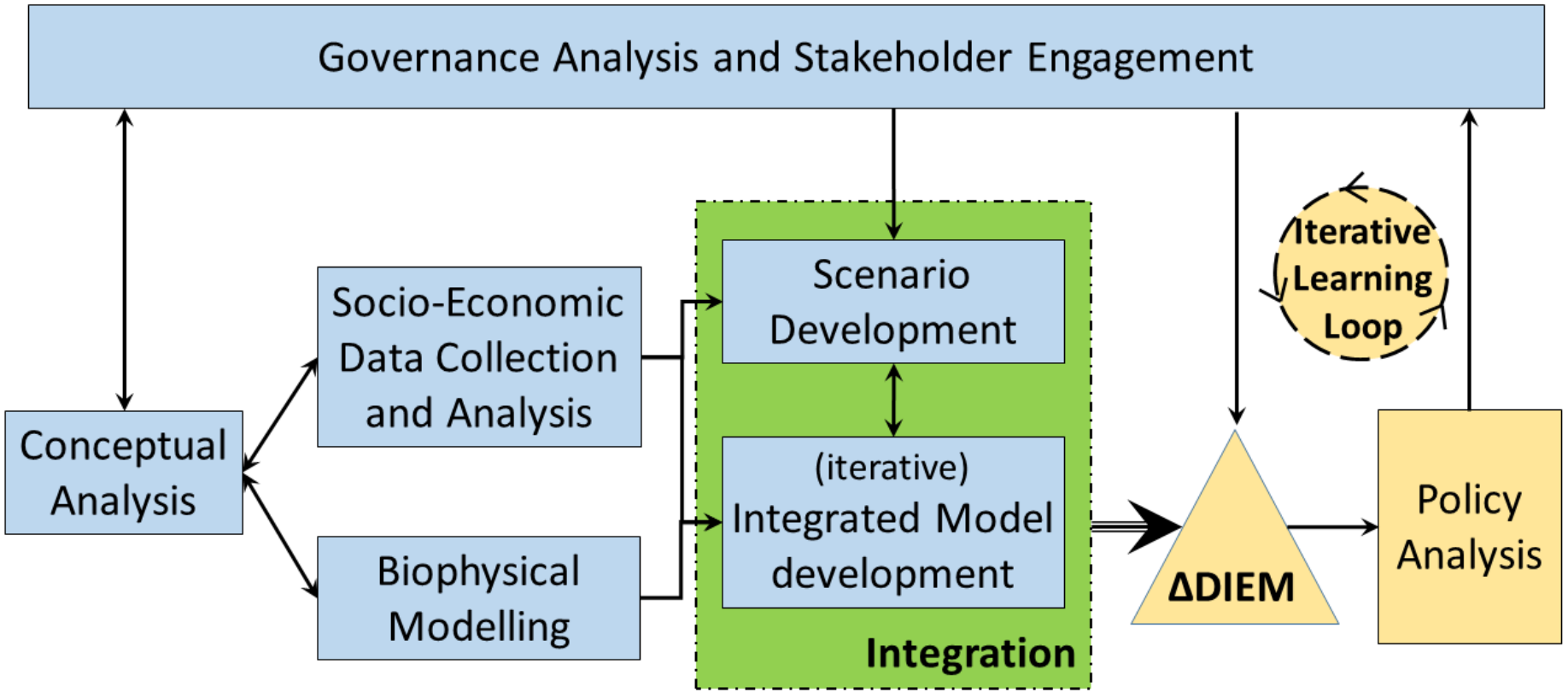
Analysis of present and future ecosystem services and human livelihoods in coastal Bangladesh requires:

- integration of the social, physical and ecological dynamics of deltas
- identification and quantification of the mechanisms by which the system components interact to produce human well-being

Hence, the Project:

- applied participatory techniques to engage stakeholders to identify issues, develop scenarios and discuss results
- determined which physical and biological processes affect life, livelihoods, health and mobility
- analysed and quantified these relationships
- developed a predictive model to analyse scenarios and explore possible futures

The Approach



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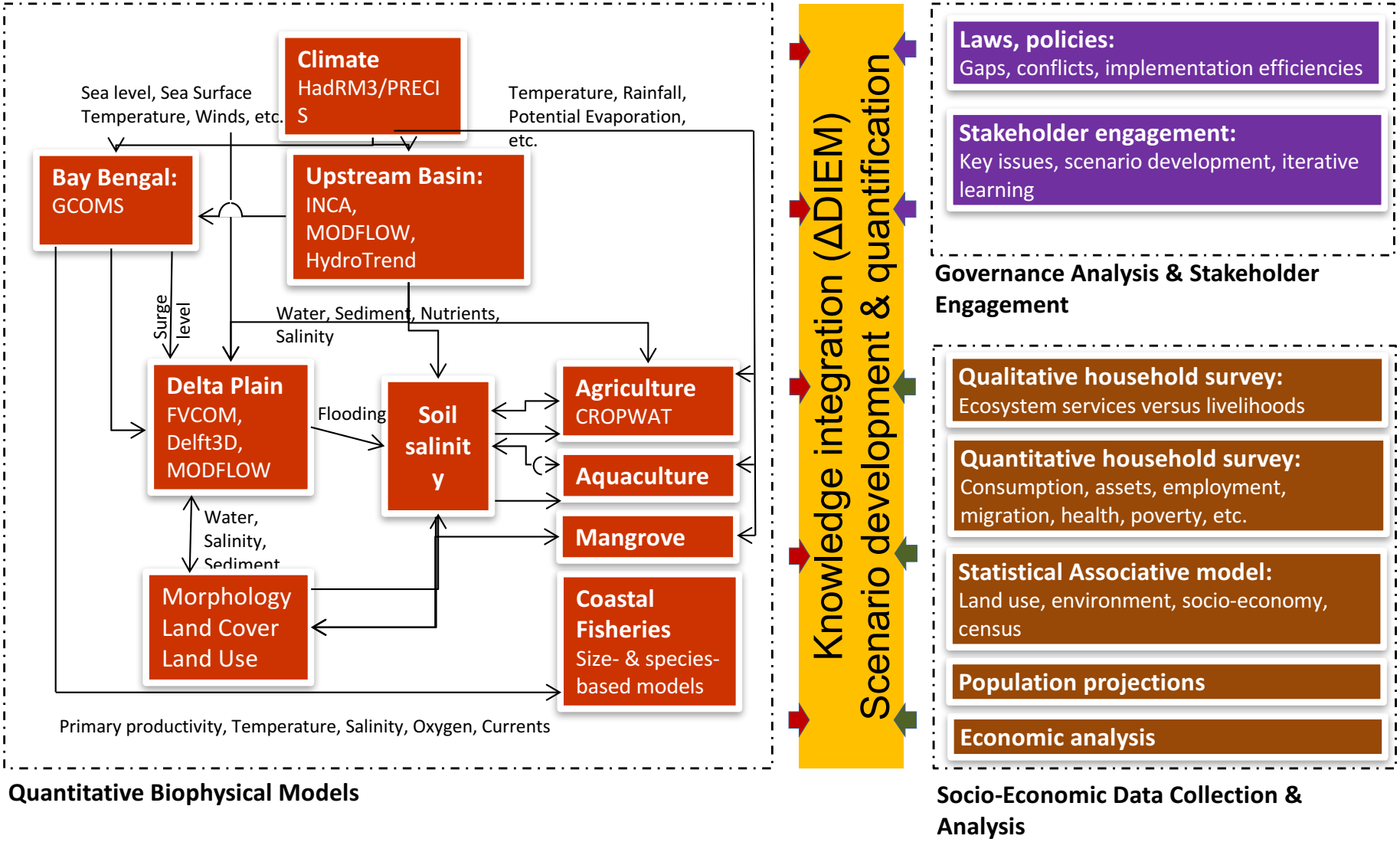
ESPA Deltas: Components



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Delta Dynamic Integrated Emulator Model (ΔDIEM)

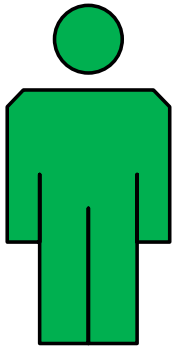
- Interdisciplinary tool
  - environment
  - socio-economy
  - demography
  - governance

- Builds on
  - high fidelity models,
  - secondary data
  - ESPA Deltas household survey (1486 households, three times over a year)
  - expert knowledge (ESPA Deltas team, stakeholders)

- Meta-model
  - harmonises scales & methods
  - fully coupled
  - 'quick' running time

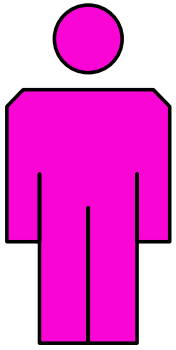
The participants in ΔDIEM development

Five main groups of participants



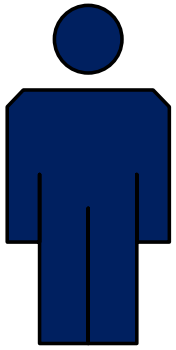
Stakeholders

50+ agencies



Households

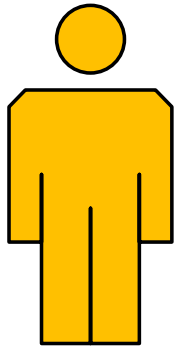
1486 surveyed households



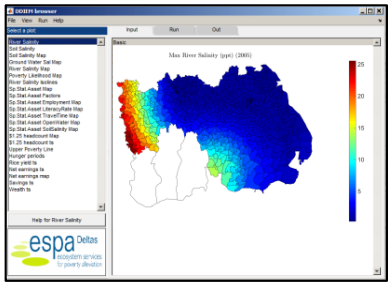
ESPA Deltas team

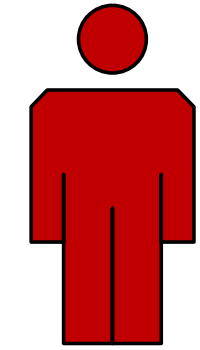
~100 specialists

- Climate
- Demography
- Agriculture
- Oceanography
- Fisheries
- Mangroves
- Social science
- Economics
- Water resource management



Integrators





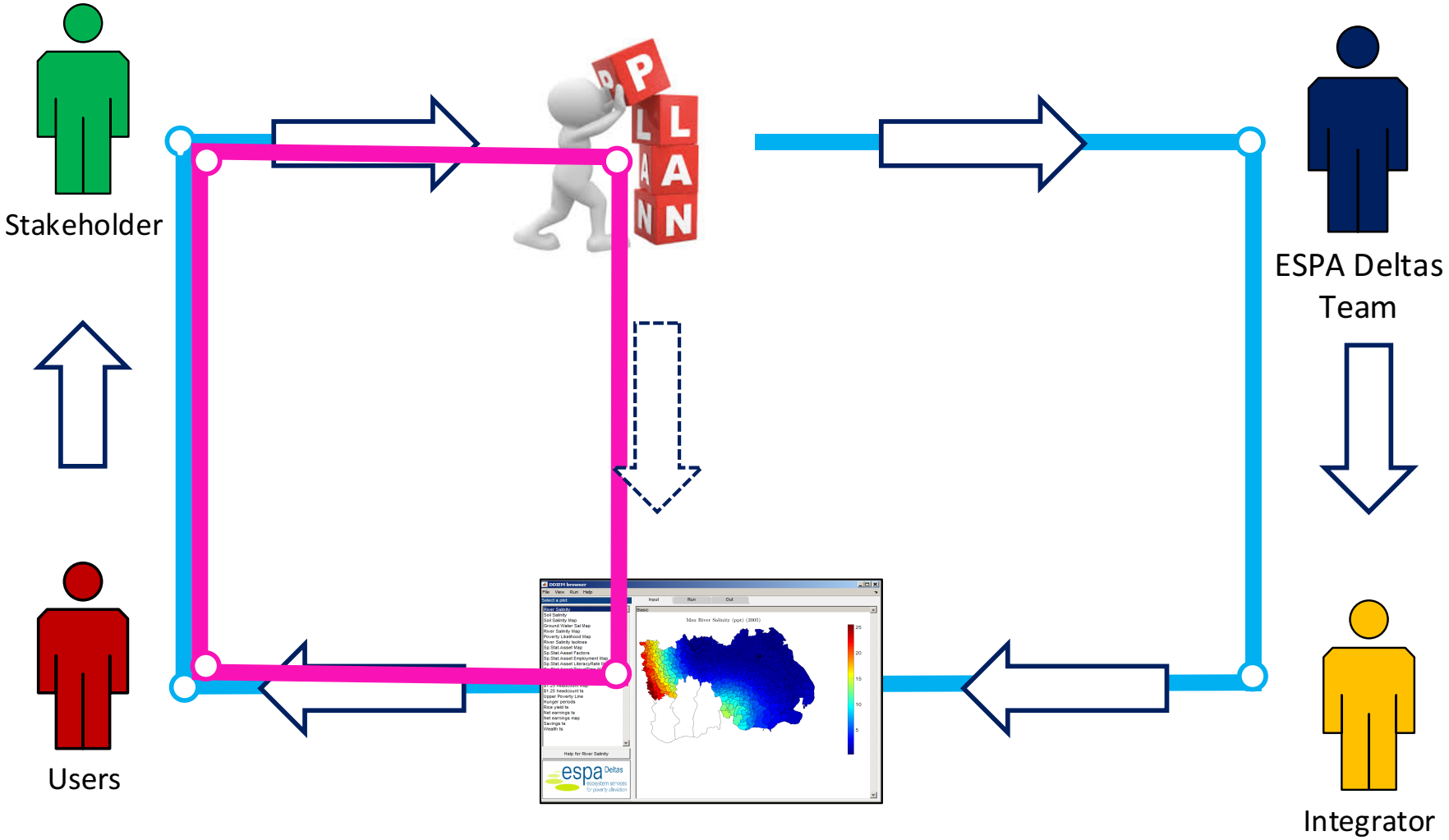
Users

Delta Dynamic Integrated Emulator Model (ΔDIEM)

Iterative learning

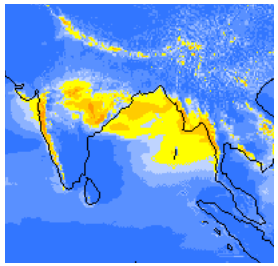
Long iteration route that involves seeking advice from a broader team

Shorter iteration, running ΔDIEM with different inputs, SSPs,…



ΔDIEM – Main Inputs

Climate



-precipitation
-temperature
-evaporation

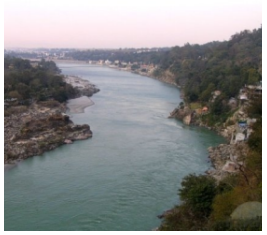
Hazards

-cyclone
-storm surge

Demography

-life expectancy
-fertility rate
-migration rate

Hydrology



-discharge
-sediment

Levees/Polder

-location
-height
-drainage rate

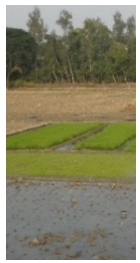
Economy

-market price
-cost of farm inputs
-wages

Bay of Bengal

-mean sea level
-(subsidence)

Ecosystem Services



-agriculture
-aquaculture
-fisheries
-mangroves

Governance

-subsidies
-land use planning
-infrastructure planning

ΔDIEM – Main Outputs

Coastal hydrology

- water elevation
- inundated area
- inundation depth

Salinisation

- river salinity
- groundwater salinity
- union-wise soil salinity
- crop productivity

Livelihoods

- fish catches
- net earnings from
  - farming,
  - aquaculture &
  - fishing

Wellbeing, Poverty & Health

I. Household outputs:

a) Bayesian statistical module:

- asset-based relative poverty indicator

b) Process-based module:

- economics (income, costs/expenses, savings/assets)
- relative wealth-level
- calories / protein intake / BMI
- monetary poverty indicators

II. Regional economic outputs

- sectoral output (tons, BDT)
- GINI
- GDP/capita
- income tax revenue
- household debt level

Delta Dynamic Integrated Emulator Model (ΔDIEM)

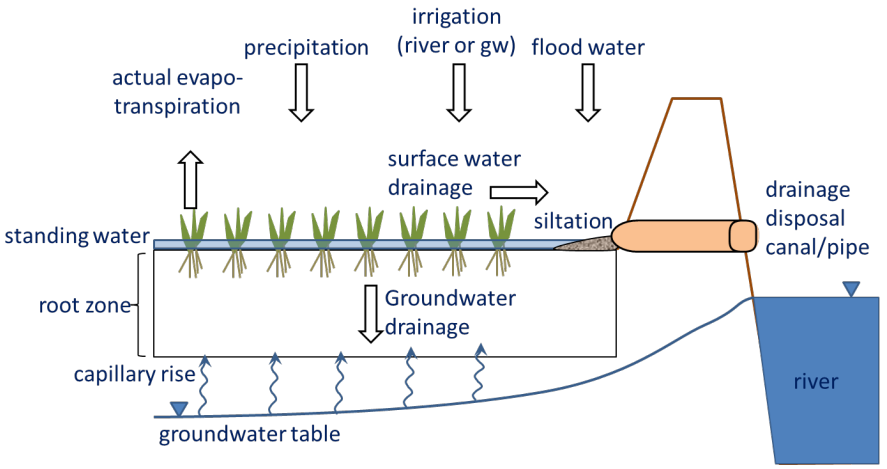
Bio-physical environment emulation is based on high fidelity models

- Climate (Met Office Hadley Centre)
- Hydrology (INCA, Delft-3D, FVCOM, MODFLOW-SEAWAT)
- Bay of Bengal (POLCOMS-GCOMS, fisheries species model)
- Mangrove (SLAMM, Markov chain & cellular automata model)

Own development

- Statistical emulation method of complex numerical models
- Regional soil salinity model
- Extended FAO CROPWAT model

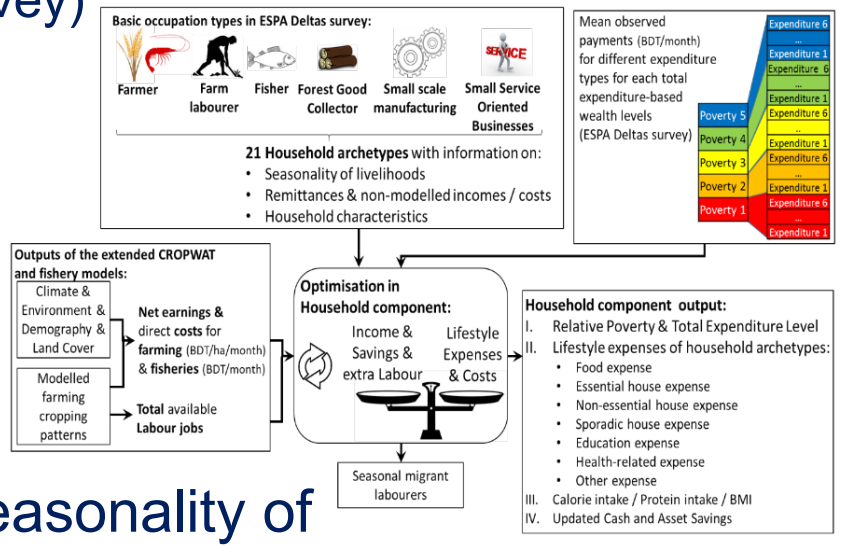
Soil salinity conceptual model



Delta Dynamic Integrated Emulator Model (ΔDIEM)

The novel household component is built on

- primary data (ESPA Deltas household survey)
- secondary data (BBS, HIES)
- expert knowledge



Key features:

- 30+ household archetypes based on seasonality of livelihoods
- economic decisions (i.e. coping strategies including loans)
- poverty/health indicator outputs

Delta Dynamic Integrated Emulator Model (ΔDIEM)

Verification:

- programming bugs
- ΔDIEM outputs vs. high fidelity simulator outputs
- coupled ΔDIEM outputs: make sense?

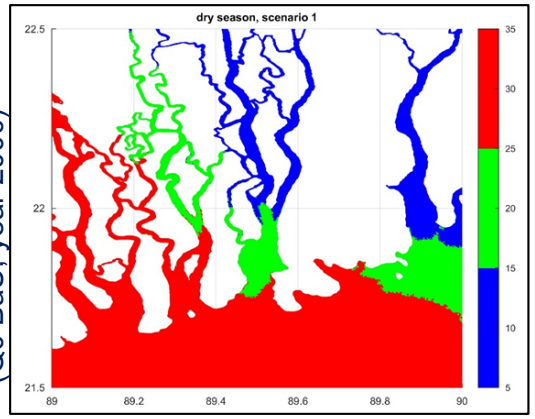
Validation:

- ΔDIEM outputs vs. other datasets (spatially / temporally)

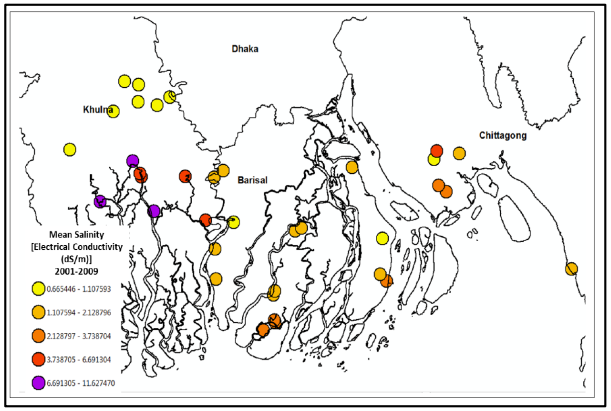
Delta Dynamic Integrated Emulator Model (ΔDIEM)

Verification / Validation (some examples)

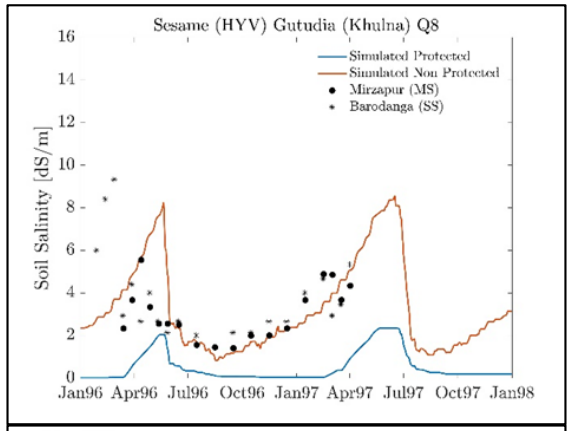
FVCOM results (Q0 BaU, year 2000)



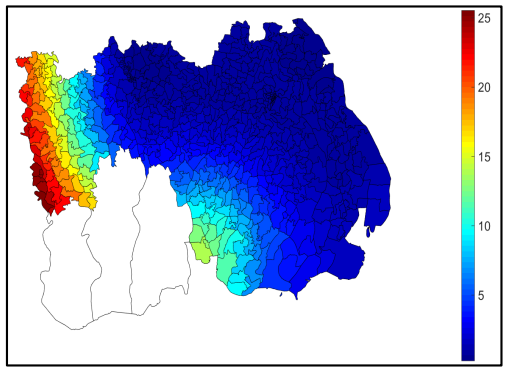
Observed soil salinity (SRDI, 2012; average monthly for 2001-2009)



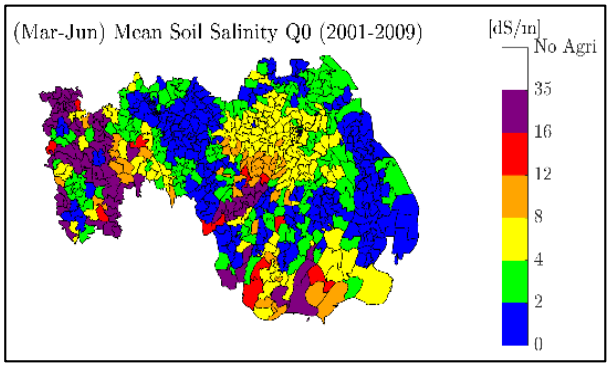
soil salinity under Sesame Observed: Mondal et al. (2001)



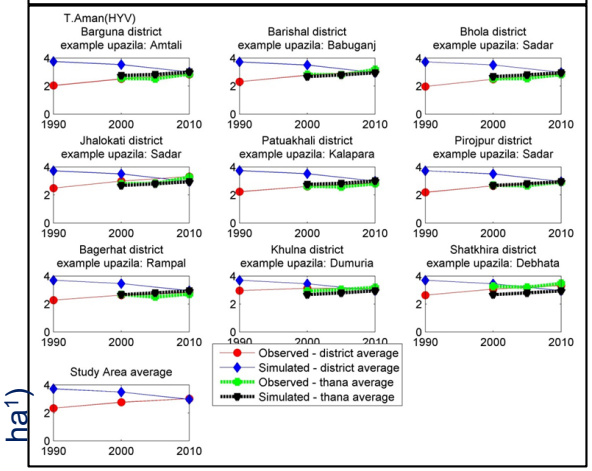
ΔDIEM emulated Union level (BaU, Q0, year 2005)



ΔDIEM simulated Union level (BaU, Q0, year 2005)



Observed vs. simulated T. Aman (HYV) yield (tons ha^{-1})



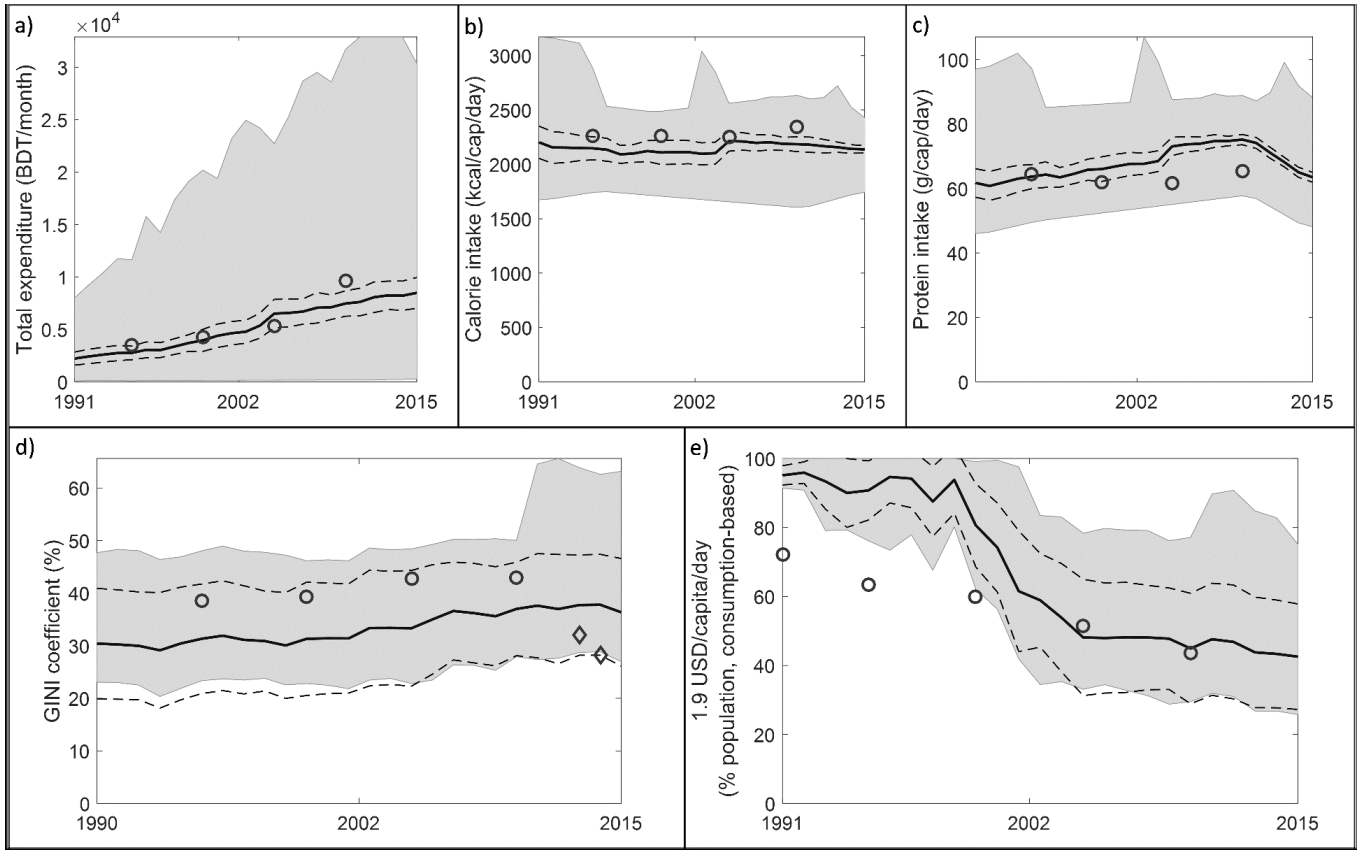
Delta Dynamic Integrated Emulator Model

Verification / Validation

- Black lines: simulated mean study area values,
- Shaded area: min-max simulated range within the study area,
- grey dots and diamonds: observations.

Observations:

a) BBS (2011) HIES, Table 4.4
b) BBS (2011) HIES, Table 5.3
c) BBS (2011) HIES, Table 5.4
d) dots: rural inequality: Ferdousi and Dehai (2014), Diamonds: national inequality - UNDP (http://hdr.undp.org/en/content/income-gini-coefficient)
e) World Bank: People living on less than $1.90 a day (http://povertydata.worldbank.org/poverty/country/BGD)



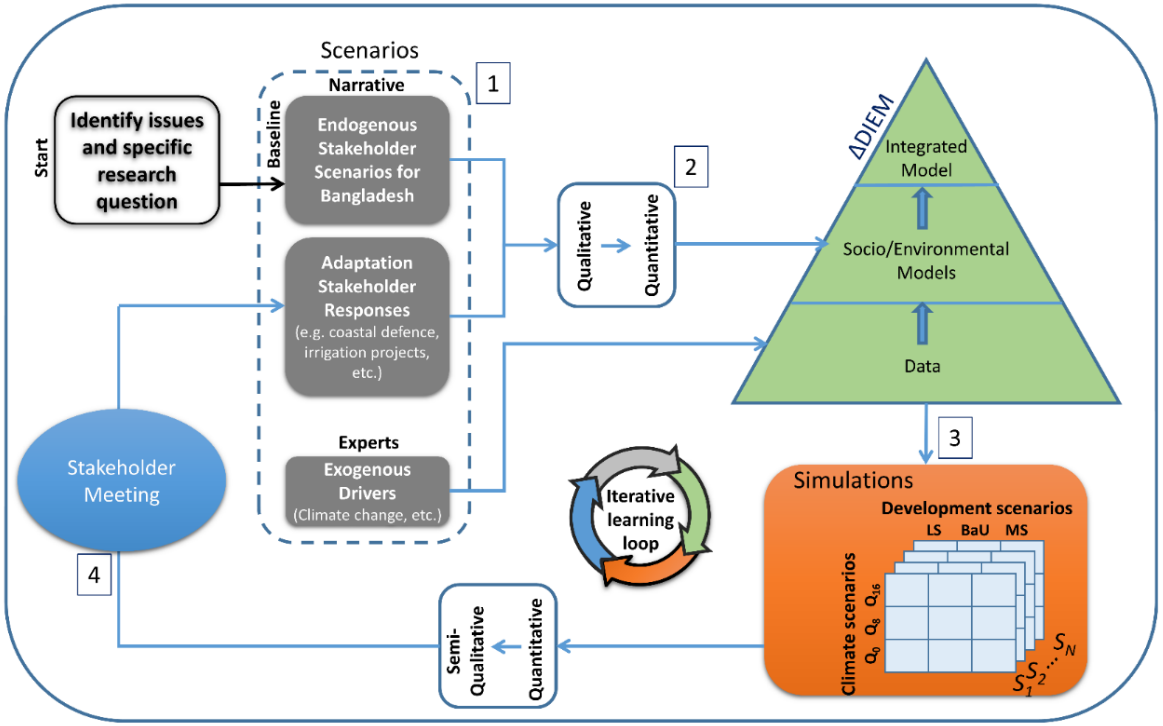
Scenario Framework and Participatory Methods

(Iterative Learning Loop)

SRES A1B (RCP 6.0 - 8.5) By 2050

Development Scenarios

	Less Sustainable (LS)	Business As Usual (BAU)	More Sustainable (MS)
Q_0			X Q0MS
Q_8		X Q8BAU	
Q_{16}	X Q16LS		



Key observations on stakeholder engagement

- A workshop can be no more than a day
- Narratives are a key communication device

Source: http://dx.doi.org/10.1016/j.ecss.2016.08.017

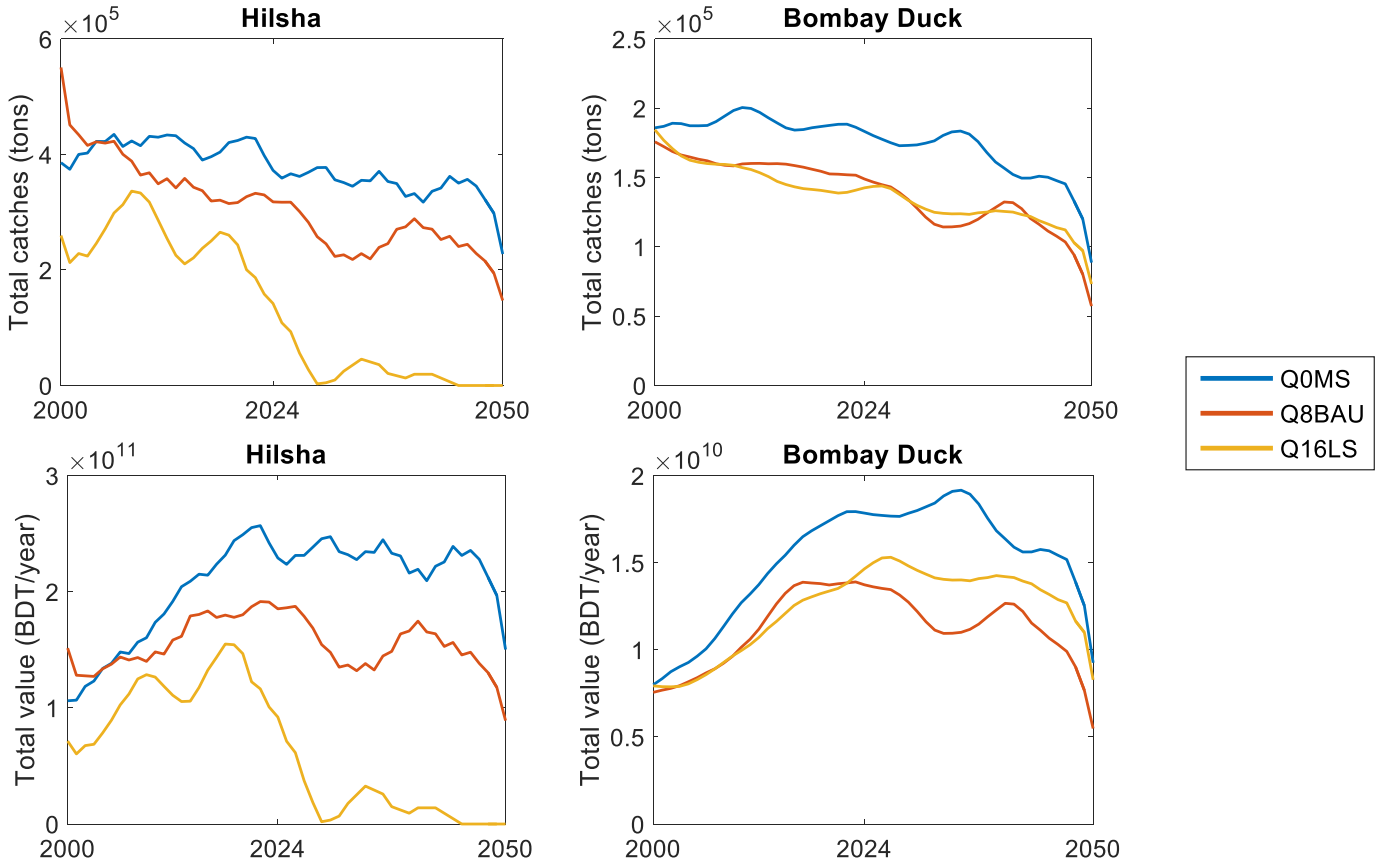
Scenario Examples

- Climate, sea level and subsidence
- Cropping patterns
- Land cover
- River flow and nutrient inputs (from INCA model)
- Fisheries (from PML models)
- Economic growth
- Demography
- Etc.

(i) Fisheries Scenarios – from PML models

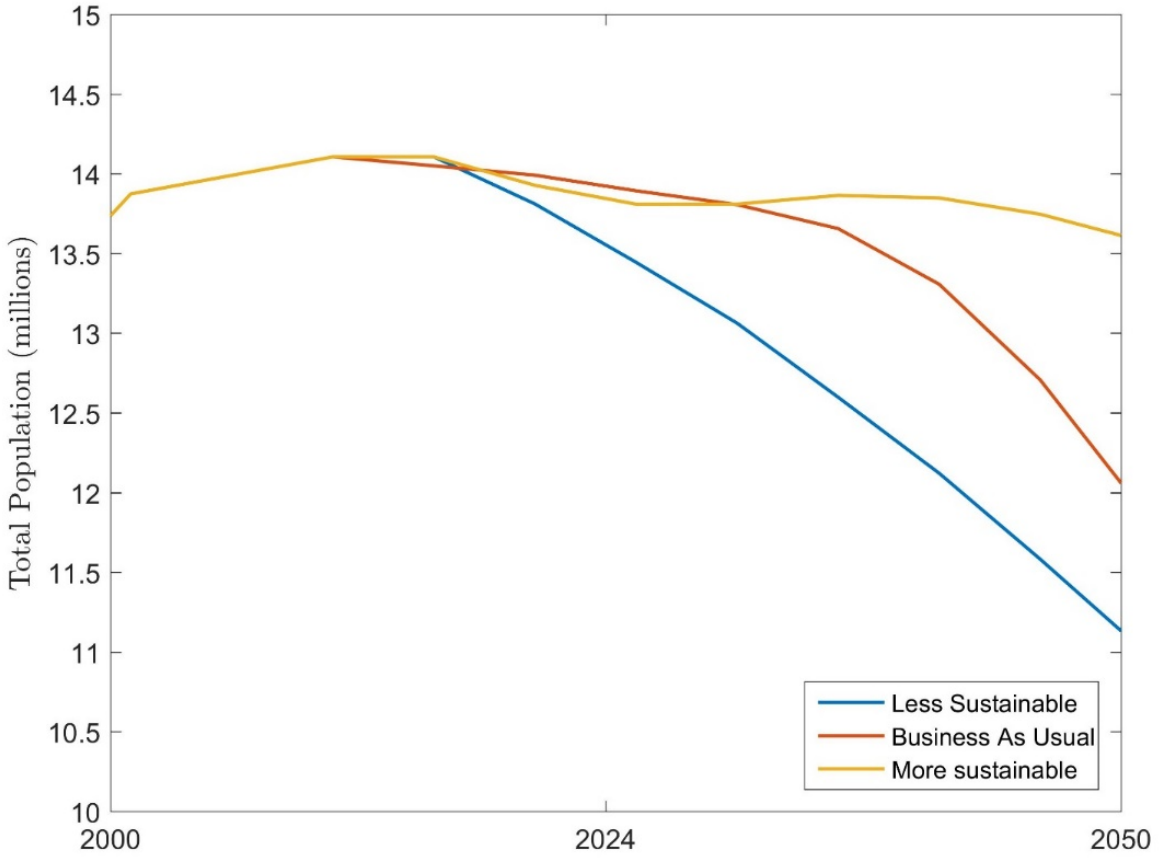
Bay of Bengal total catches and values

Current catches are not sustainable, but significant fisheries can be sustained with appropriate management



(ii) Demographic scenarios of study site

Population of study area is expected to decline under all scenarios



(iii) Economic scenarios

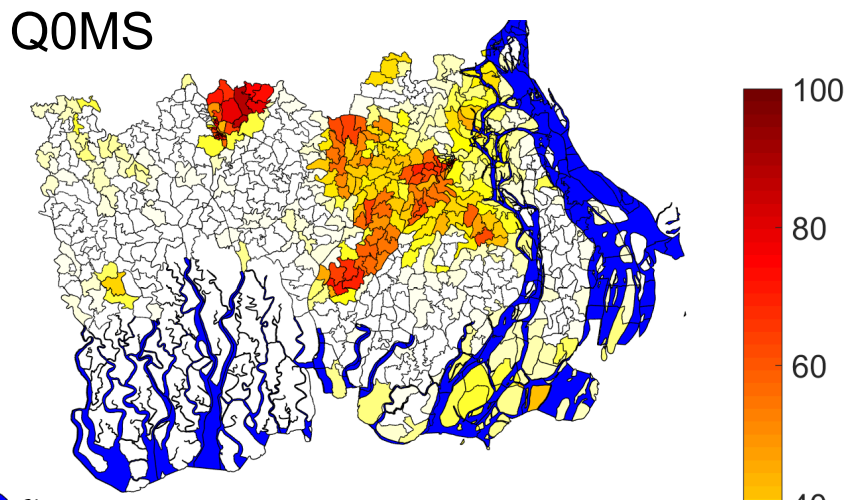
- Percentage change in ΔDIEM Economic Input Variables by 2030
- No further change after 2030

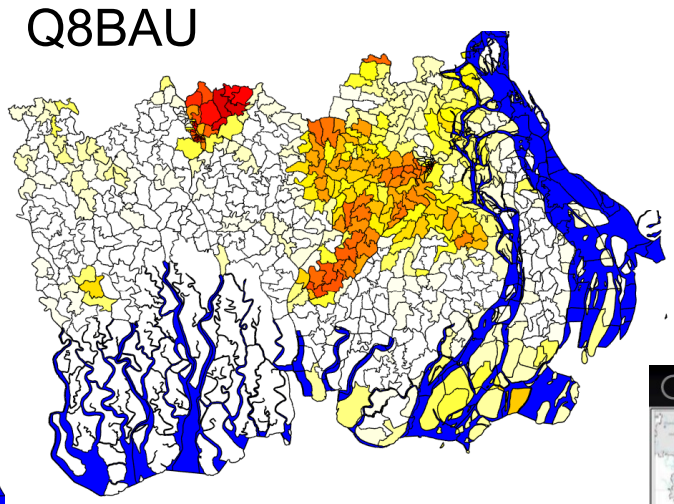
Economic input variable	Less Sustainable	Business As Usual	More Sustainable
Cost of agriculture (seed, pesticide, fertiliser types)	0	10	20
Cost of aquaculture (feed, post larvae, fishling)	20	10	0
Cost to keep livestock/poultry, fishing, Forest collection	0	10	20
Land rent cost (farming)	0	10	20
Cost to do Services & Manufacturing business	20	0	-20
Market (selling) price of agriculture crops	0	10	20
Market (selling) price of fish	30	10	20
Market (selling) price of aquaculture crops (shrimp)	0	10	20
Income from forest goods (honey, fruits, timber, etc.)	-20	-10	0
Income from Manufacturing, Services and Livestock/Poultry	65	110	165
Remittances (BDT/month)	20	30	40
Household expenses	0	10	20
Daily wage (without food) (BDT/day)	0	10	30
Cost of diesel (BDT/gallon)	0	10	20
Employment rate (% population)	0	10	30
Literacy rate (% population)	2	4	8
Children in school (% population)*	2	5	10
Travel time to major cities *	-10	-30	-50
USD/BDT exchange rate & PPP exchange rate*	0	0	0

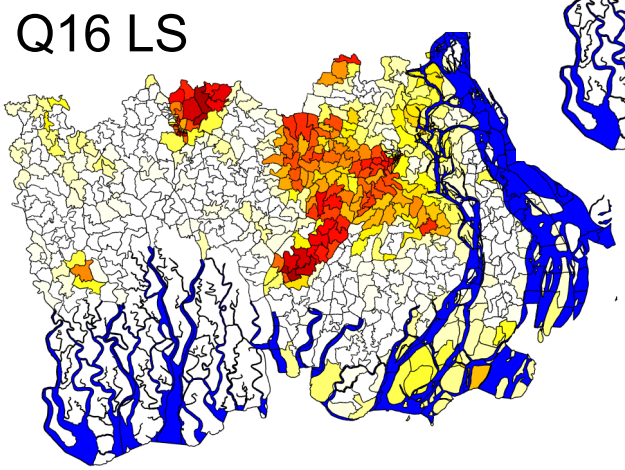
Illustrative Results

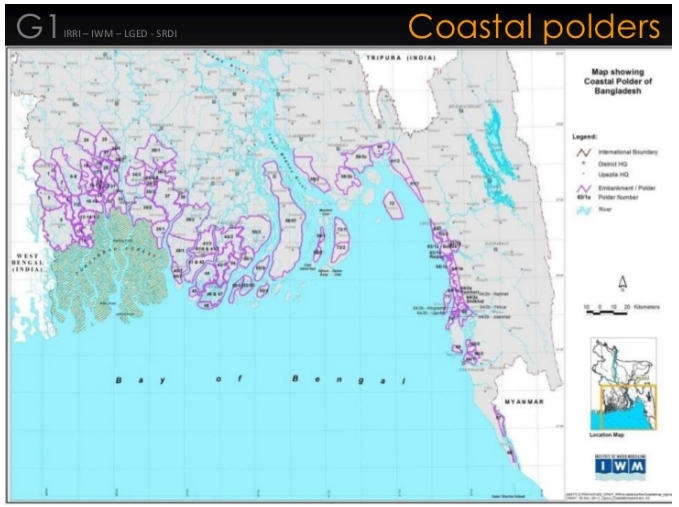
Inundated area at end of monsoon

15 September 2050, Across scenarios, (% of union area)



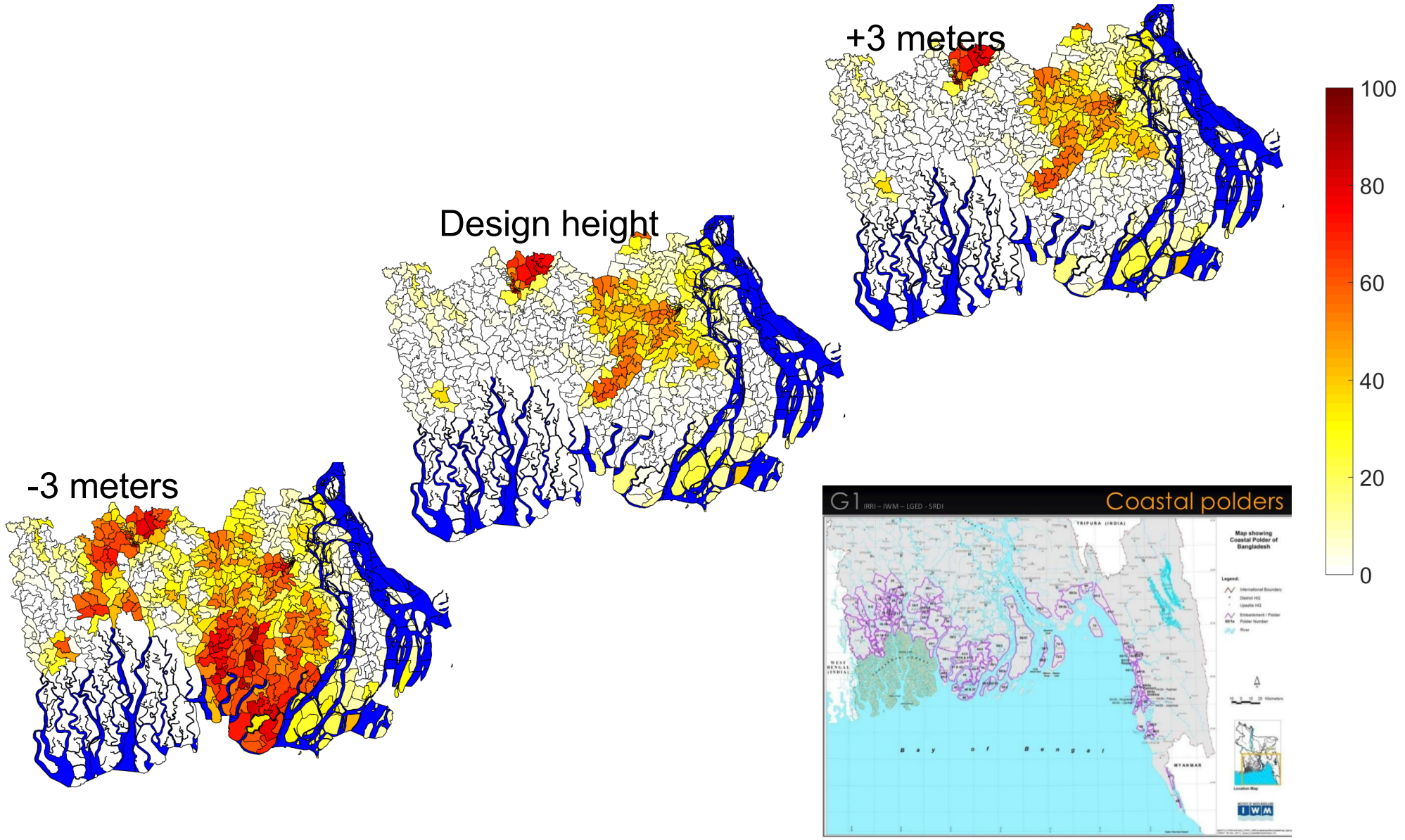






Inundated area at end of monsoon

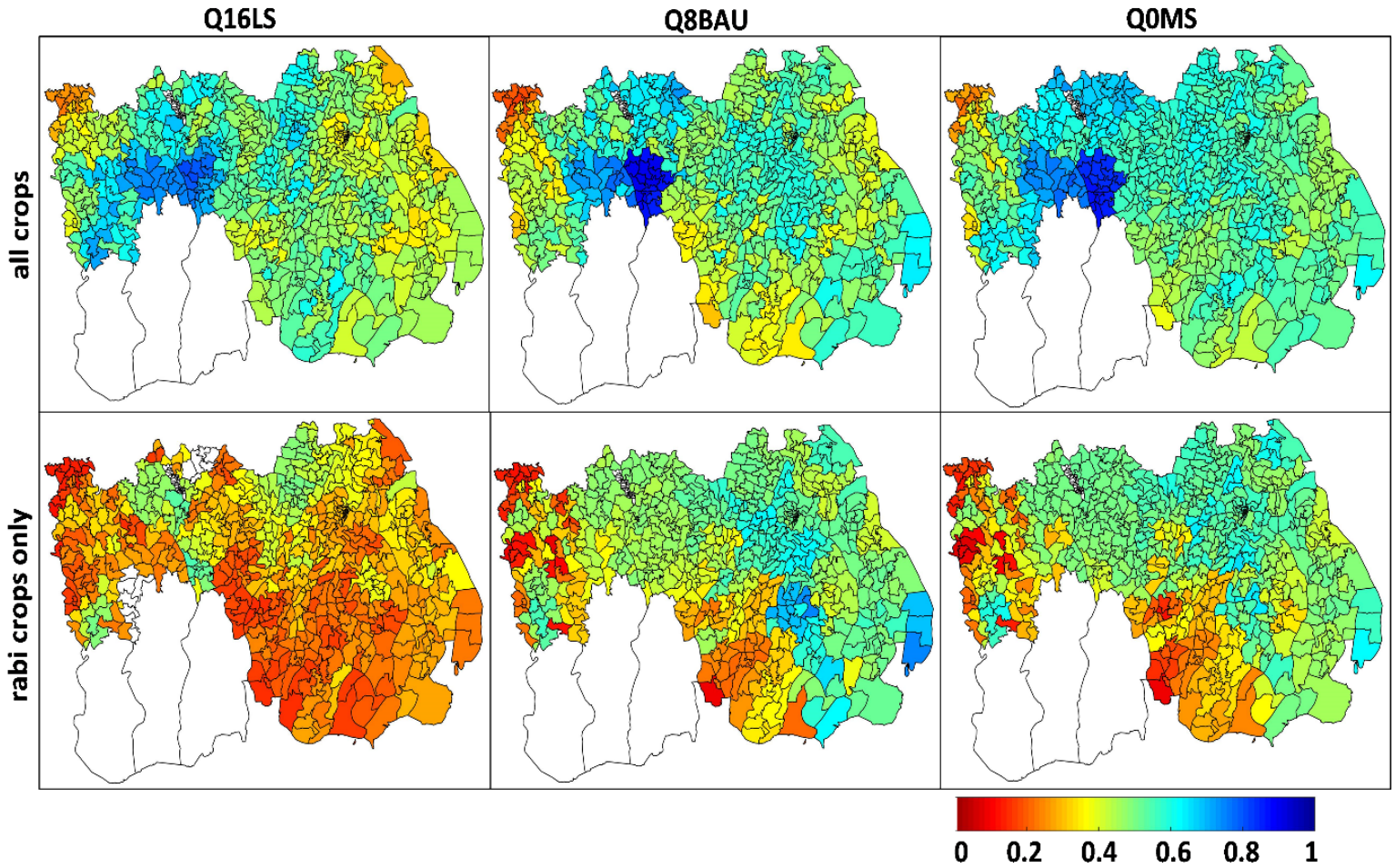
15 September 2050, Q8BAU changing dike height, (% of union area)



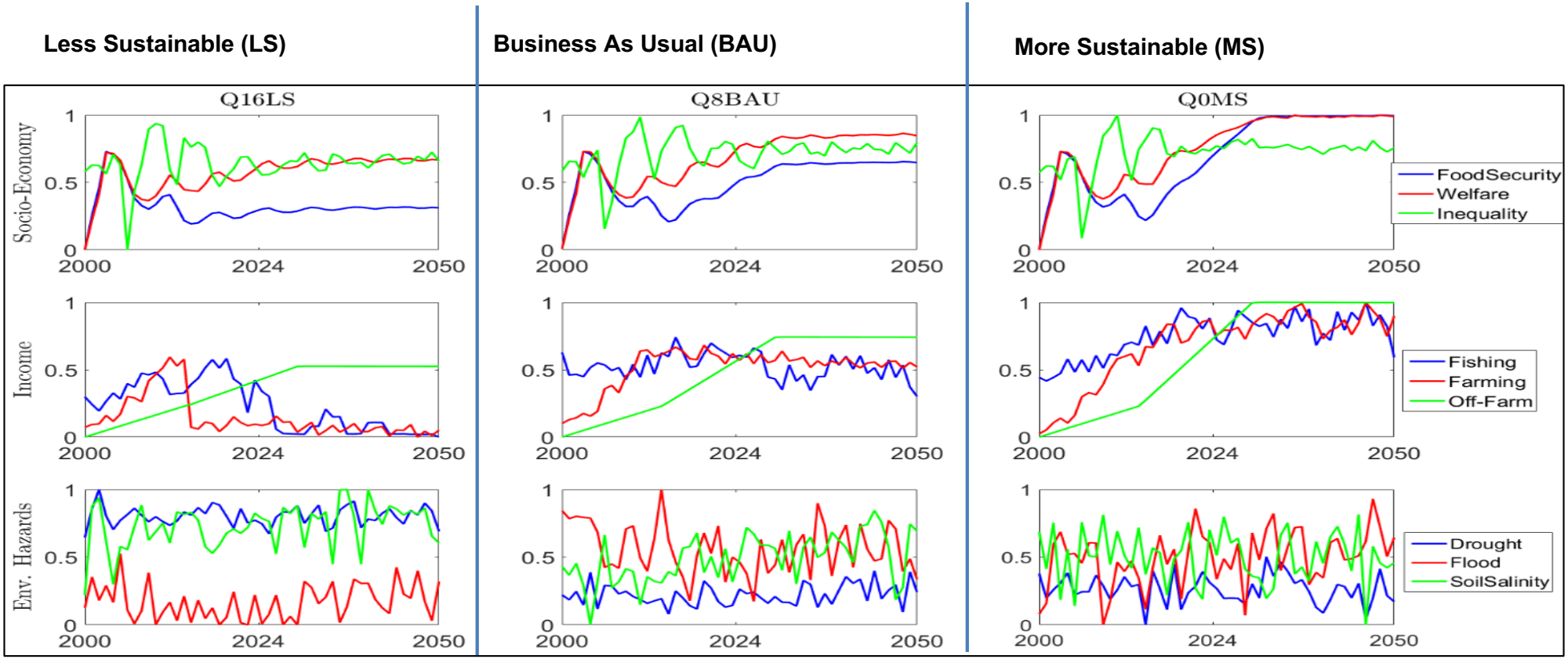
Crop yield in 2050 (fraction)

mean across all crops and seasons

- Higher yield and more salt tolerant crops perform better
- Crop variety depends on the development scenario.



Provisioning Ecosystem Services
Socio-economic situation



Inter-annual variability

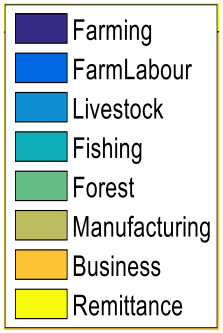
Greatest for environmental hazards; Moderate for provisioning ecosystem services;

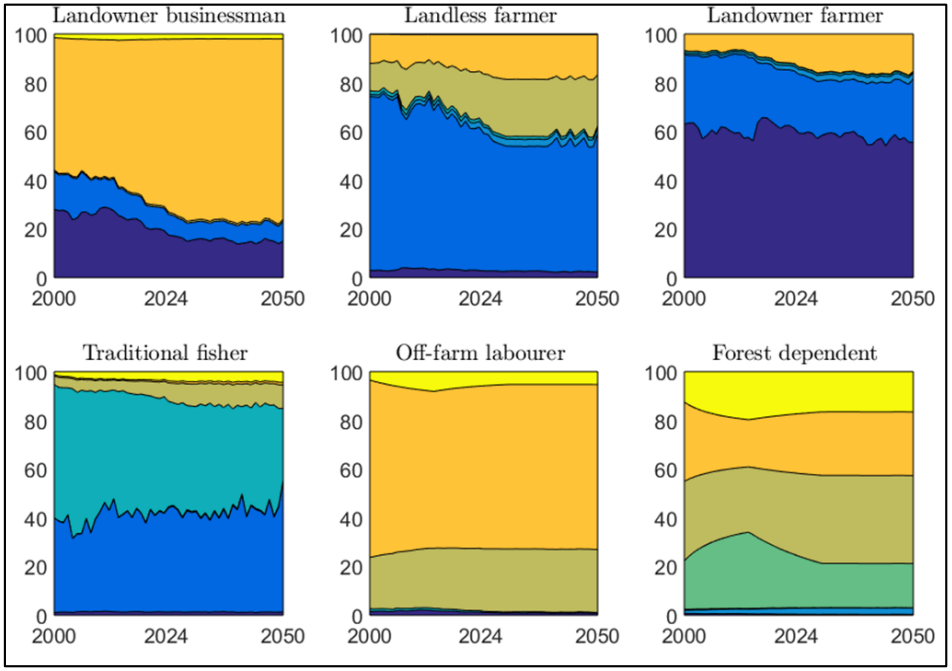
Minimal for socio-economic indicators

Dominance of livelihoods (Q_0BAU)

Six examples from the 37 archetypes

- Ecosystem Service-based livelihoods decline in importance over time for all household types.
- Small farm owners and fishers rely less on Ecosystem Services.
- Importance of business and manufacturing incomes increases.

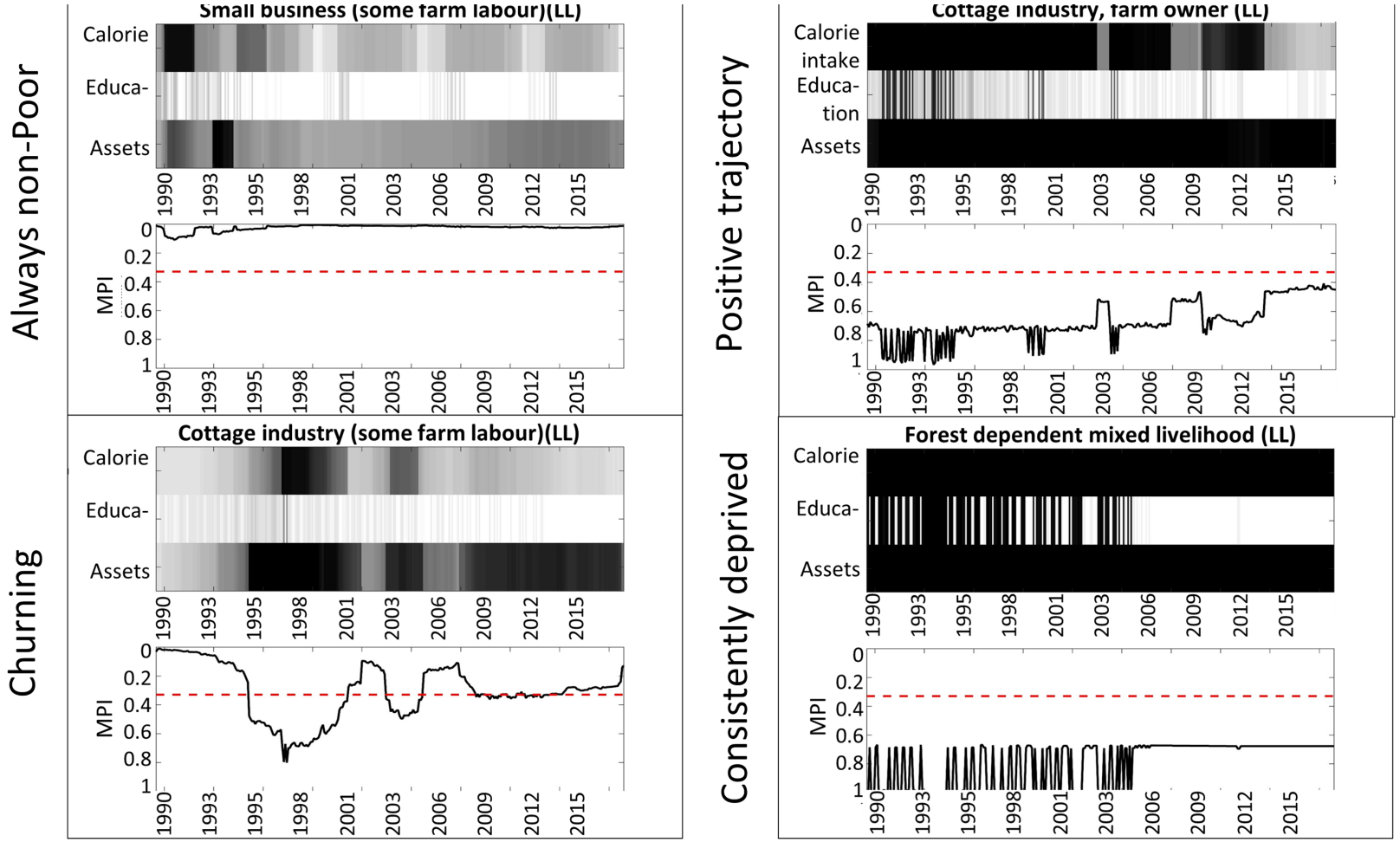




Selected archetypes

- **Business-Business-Business (Land Owner Businessman).** Fairly balanced income distribution; ends up relying heavily on off-farm business activities
- **Farming-Farming-Farming (Landless farmer).** Pond-based aquaculture and farm labour provide the bulk of their income
- **Farming-Farming (Large Land Owner farmer).** Large land to sustain wellbeing; extra income from occasional farm labour & business activities
- **Fishing-Fishing-Fishing (Landless traditional fisher).** Fishing and livestock provides livelihood with increasing limited fishing income
- **Business-Manufacturing-Business (Landless Off-farm labourer).** Only do off-farm activities,
- **Forest Dependent.** Does both ES-based and off-farm activities with no significant change in income dominance.

Multidimensional Poverty Index (MPI) Trajectories



Source: Lazar and Adams, in review

Stakeholder Engagement
General Economic Division, Dhaka
16 September 2015
An ongoing process from the beginning of the project: (1) Issue Identification; (2) Scenario development; (3) Policy exploration

Bangladesh Delta Plan 2100

ESPA Deltas Final Event

Bangladesh 30/31 October 2016

Science-Policy interaction in adaptive delta planning
Sharing key features of Bangladesh Delta Plan 2100 and ESPA Deltas Project

Goals:

- Research into Use,
- Linkage with BDP 2100,
- Potential use of ESPA deltas results in BDP 2100

Summary Outcomes:

- Policy intervention can be assessed using the developed tool (ΔDIEM)
- ΔDIEM can be adjusted to judge investment decision both in the short and long term basis

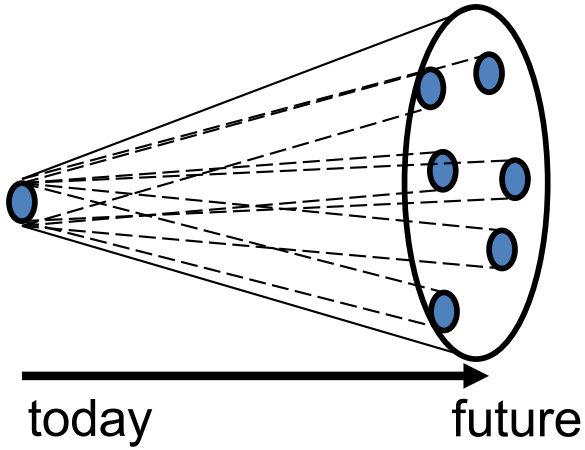
ESPA Deltas Continuation 2017-2018

Southampton, UK, 17 May 2017

Delta Dynamic Integrated Emulator Model (ΔDIEM)

Examples of management and policy strategies that can be analysed with ΔDIEM

- renegotiated Farakka treaty
- Ganges Barrage
- changing polder heights
- land zoning policies
- new potential crops
- subsidies for farming
- guaranteed crop price for farmers
- restrictions on off-shore fishing
- new loan types



Different national policies (REACH Project)

- Raise polders
- Managed retreat
- Unplanned retreat
- Build elevation (tidal river management)

Concluding Thoughts

- This work provides a new linked model and data framework for thinking about the future of coastal Bangladesh
- The modular approach allows incremental improvement
- The participatory approach adopted was a key element to engagement with stakeholders – giving local ownership
- Understanding uncertainty/sensitivity is an ongoing process
- Three key results for coastal Bangladesh (to 2050)
  - Future is more influenced by human choices/policy interventions than climate change
  - Ecosystem services diminish as a proportion of the economy with time, continuing historic trends
  - Significant poverty persists in some locations under all scenarios
- Engaging with policy questions forces consideration of human dimensions

Deltas as Coupled Socio-Ecological Systems

Robert J. Nicholls
University of Southampton

CSDMS Meeting
23-25 May 2017
Boulder, CO