



Community Surface Dynamics Modelling System (CSDMS)
2014 Annual Meeting
Uncertainty and Sensitivity in Surface Dynamics Modeling
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Coupling terrestrial and marine biophysical processes with livelihood dynamics for analysis of poverty alleviation in Bangladesh

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Presentation overview

- The ESPA Deltas project
- Integration (aim & concept)
- Some preliminary results
- Handling uncertainty / model testing
- Summary



The ESPA Deltas project (<http://www.espadeltas.net/>)

(2012-16)

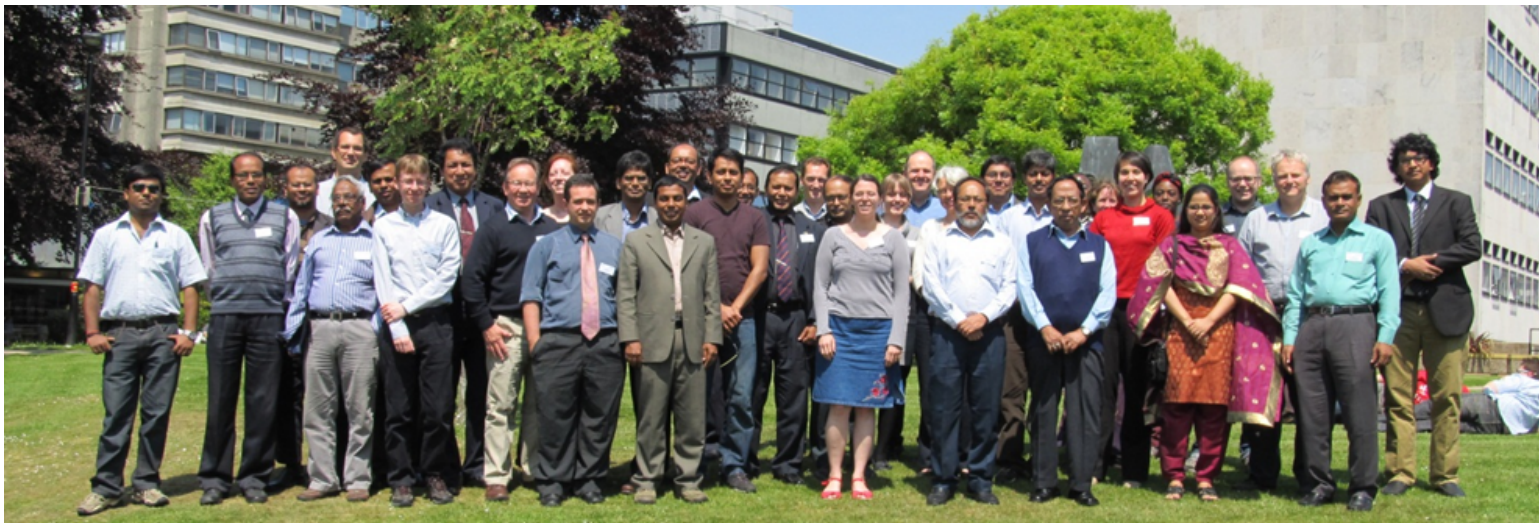
Overarching aim:

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

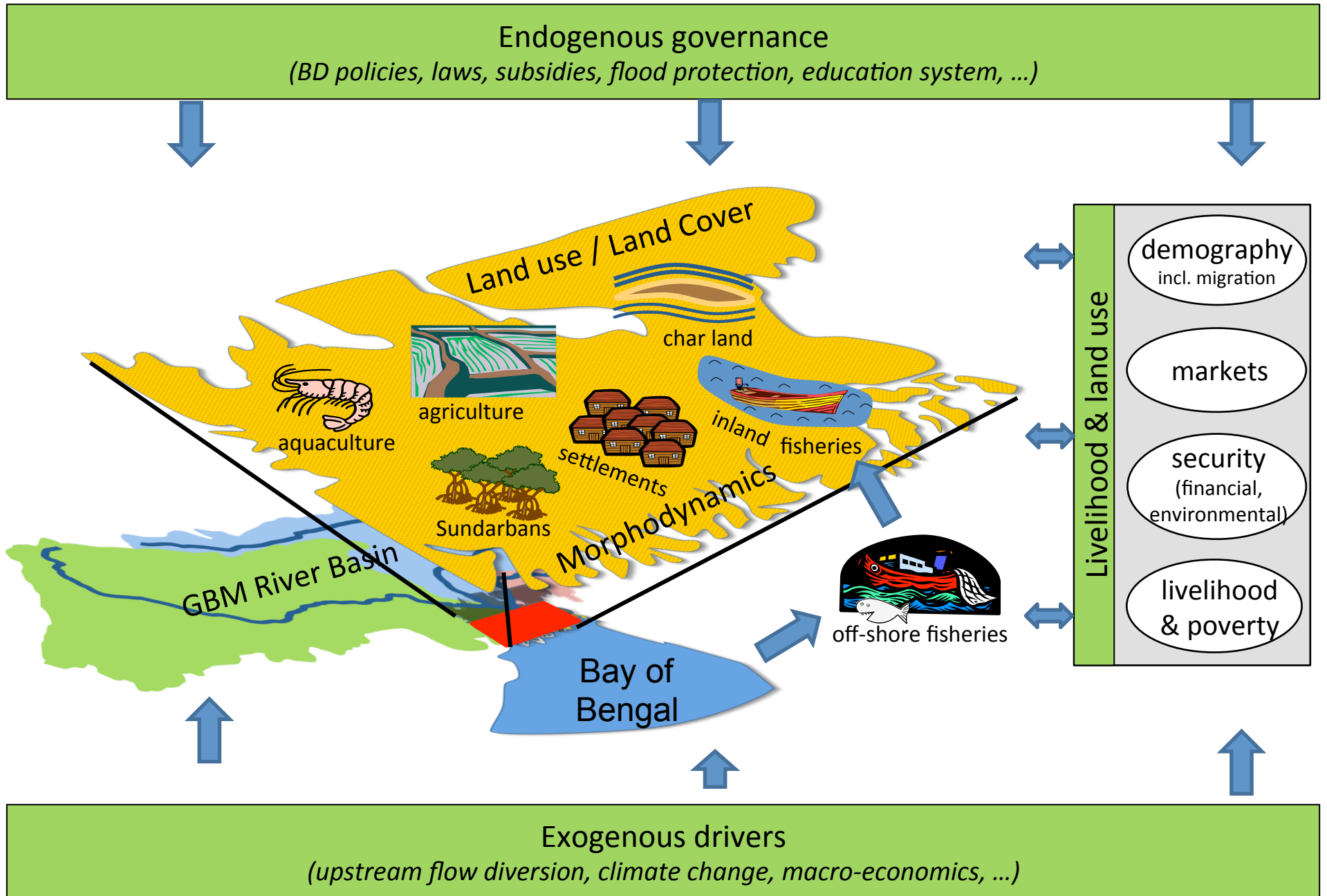
Consortium:

UK (7), Bangladesh (11), India (4)

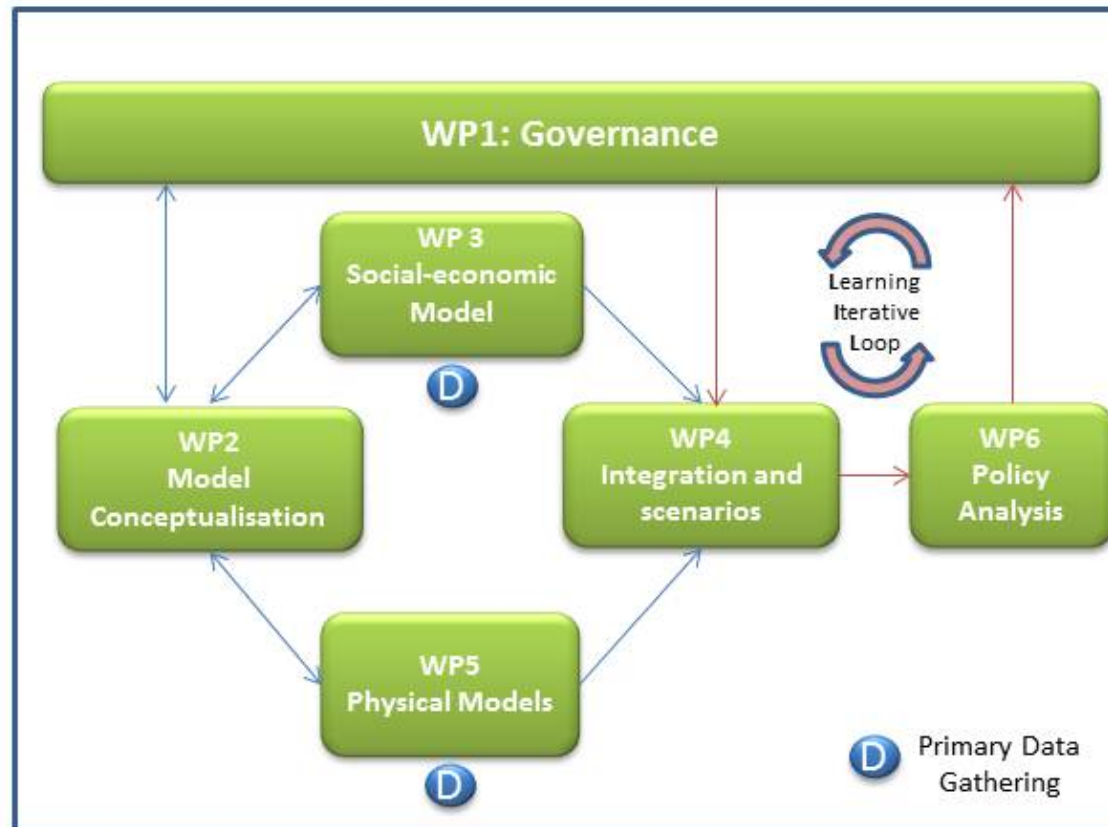
Lead partner: University of Southampton



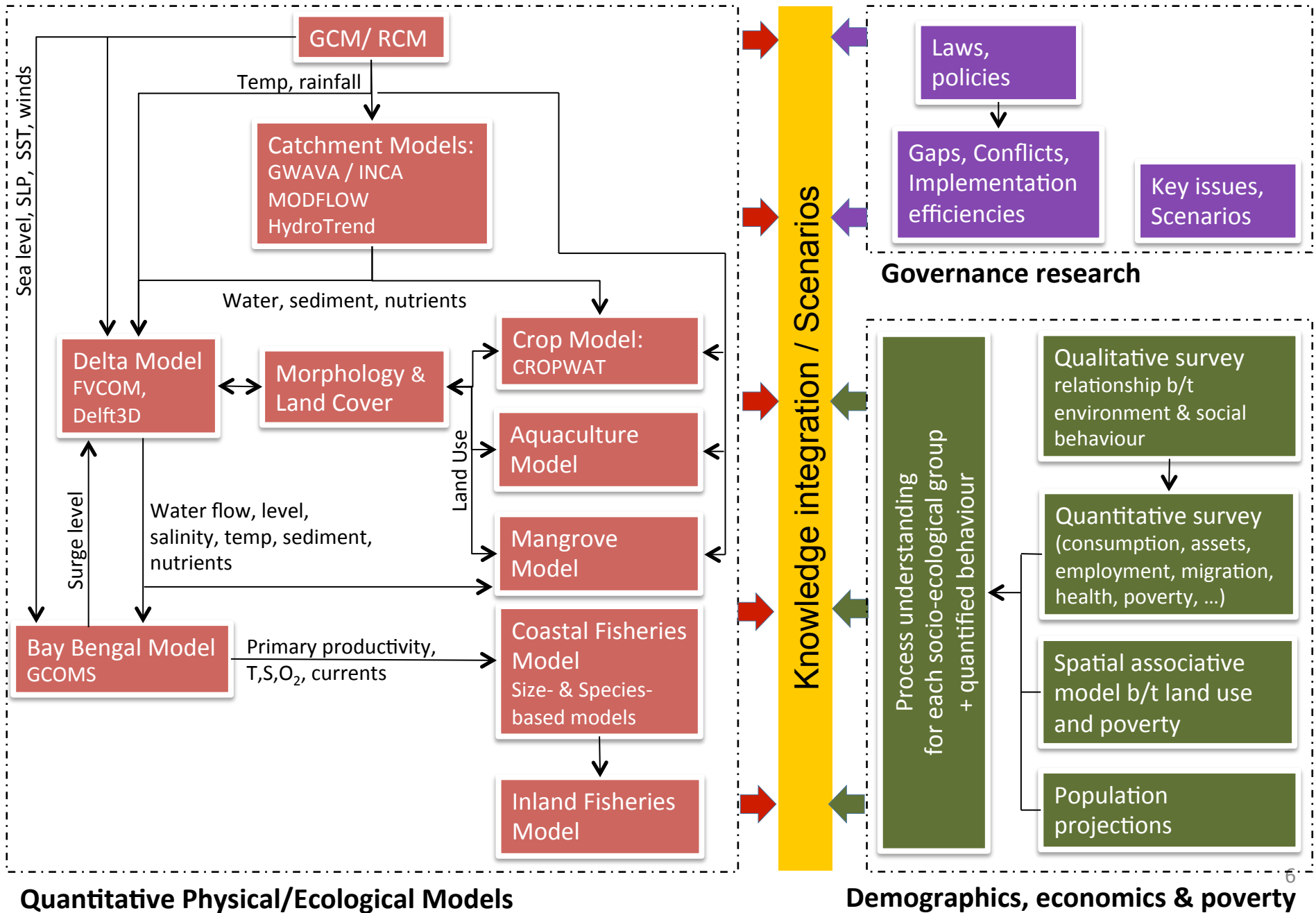
Scales and project elements



Iterative learning with stakeholders



Project elements

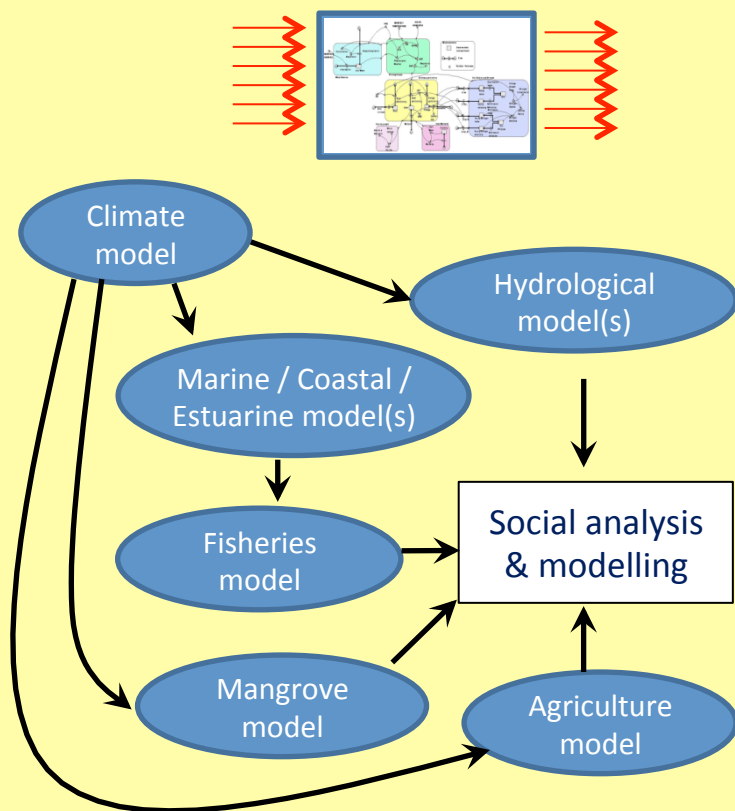


Aim of integration work

- Special focus:
support & dependence of the rural poor on ecosystems
- The Aim of this work is to **quantify ecosystem provisions** with an integrated model (**ADIEM**)
- The model will be used to **explore the impacts of changes** in
 - climate and sea level rise
 - environmental change (e.g. salinization)
 - land use changes (e.g. rice to shrimp farming)
 - external influences (e.g. water and nutrient changes in rivers)
 - etc.
- The outputs will enable decision makers to identify the likely **key drivers** of change and the **impacts of policy decisions**

Project (integration) approaches

1. Chain of existing models



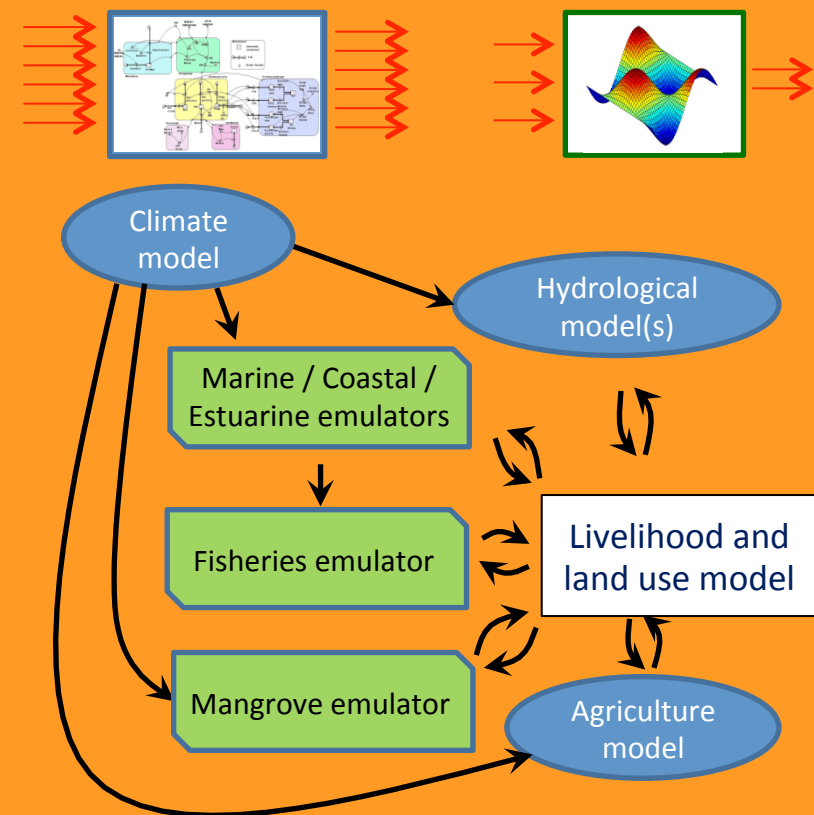
Pros:

- existing models / methods
- process understanding

Cons:

- slow running time
- limited no of scenarios
- no feedback

2. Chain of simple models & Bayesian emulators



Pros:

- builds on calibrated models
- quick running time
- forward stepping feedback
- estimated uncertainty

Cons:

- simplification
- boundary condition changes

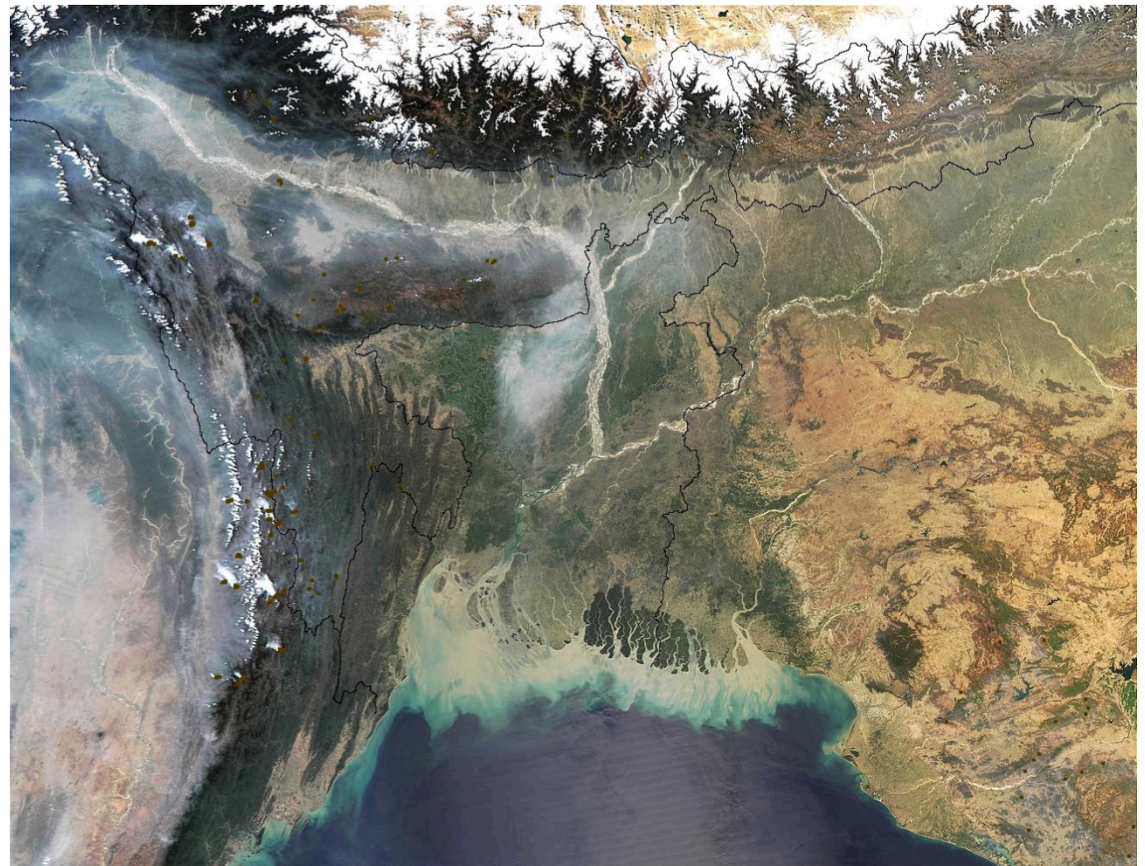
The Δ DIEM model

Delta Dynamic Integrated Emulator Model - Δ DIEM

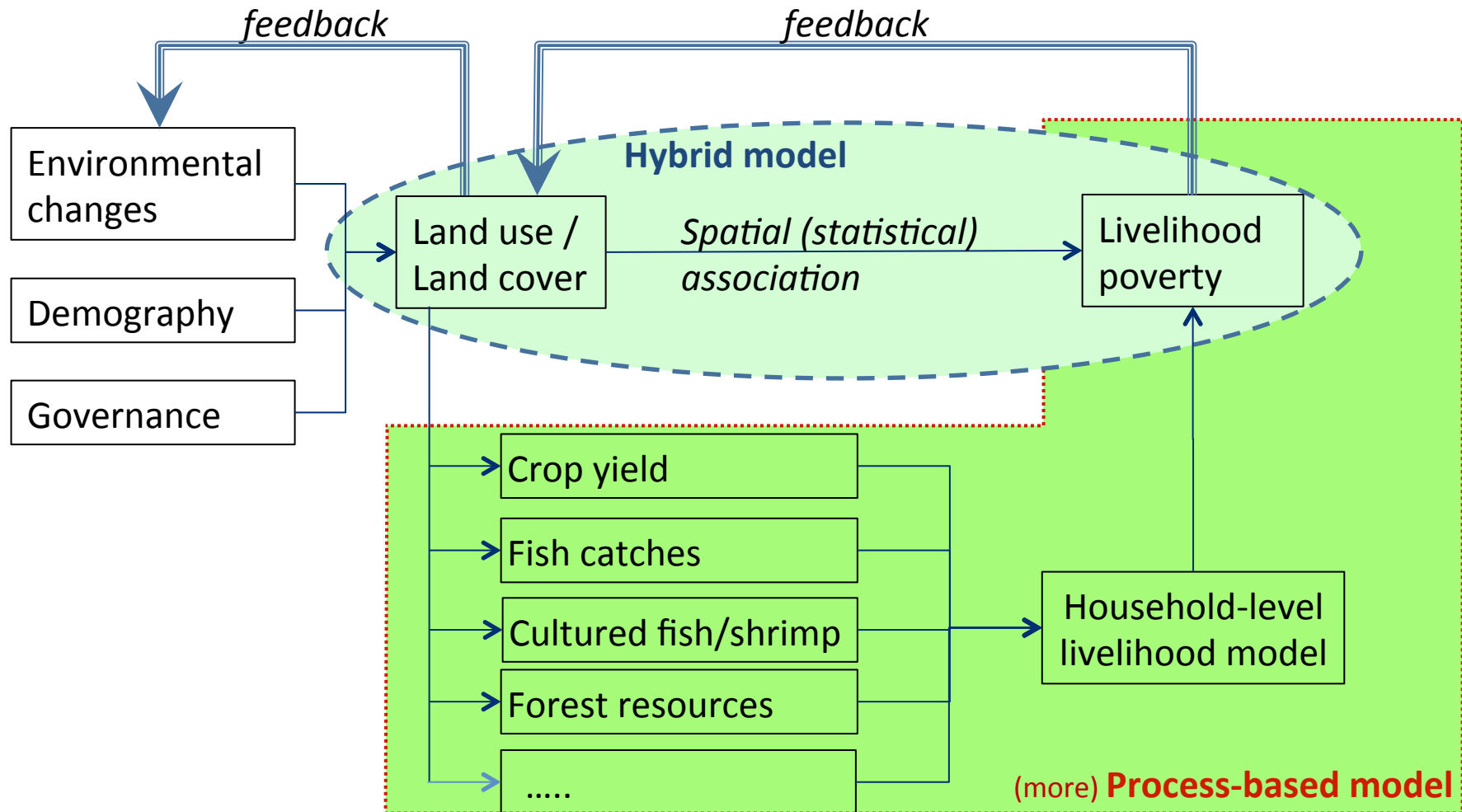
- a **holistic tool** to capture the trends and emergent properties of a system:
 - bio-physical environment (upstream, coastal/marine and local environments),
 - social behaviour and livelihood
 - governance

- a **metamodel** that enables the efficient run of different models in a harmonised and systematic way

- **model elements** working on different spatial and temporal scales:
 - statistical relationships,
 - deterministic models,
 - probabilistic emulators,
 - agent-based type model

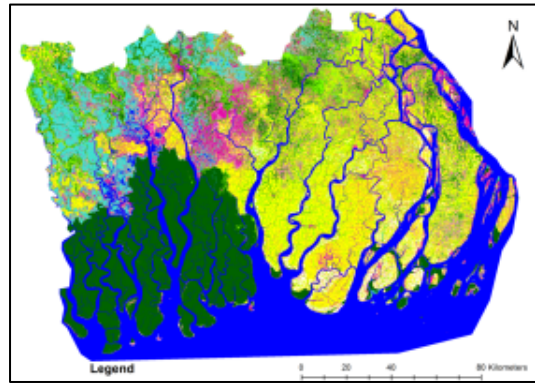


The Δ DIEM models

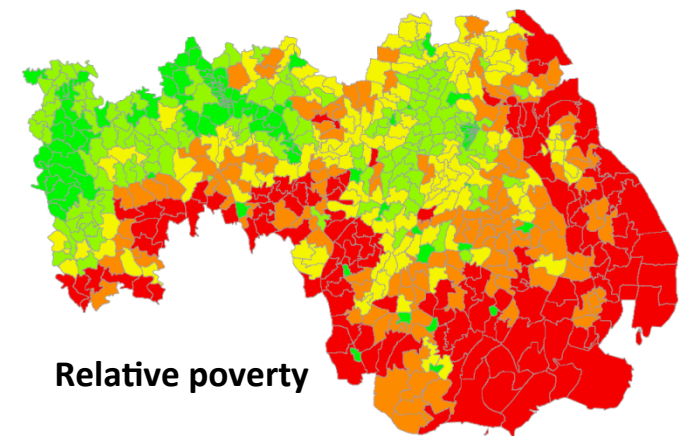
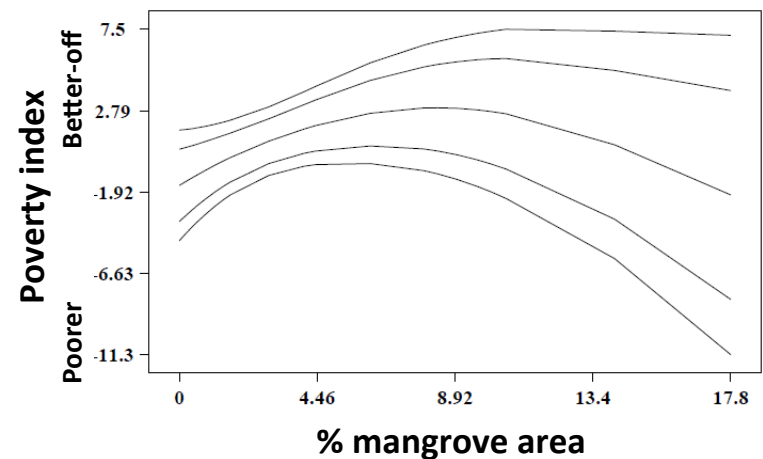
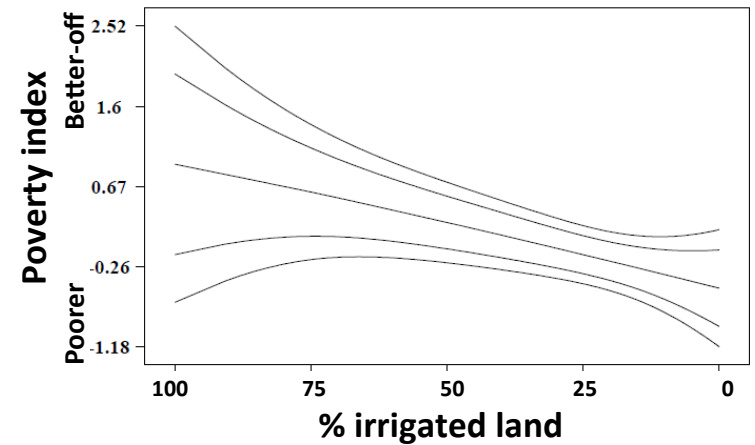


Not all model elements and relationships are shown!

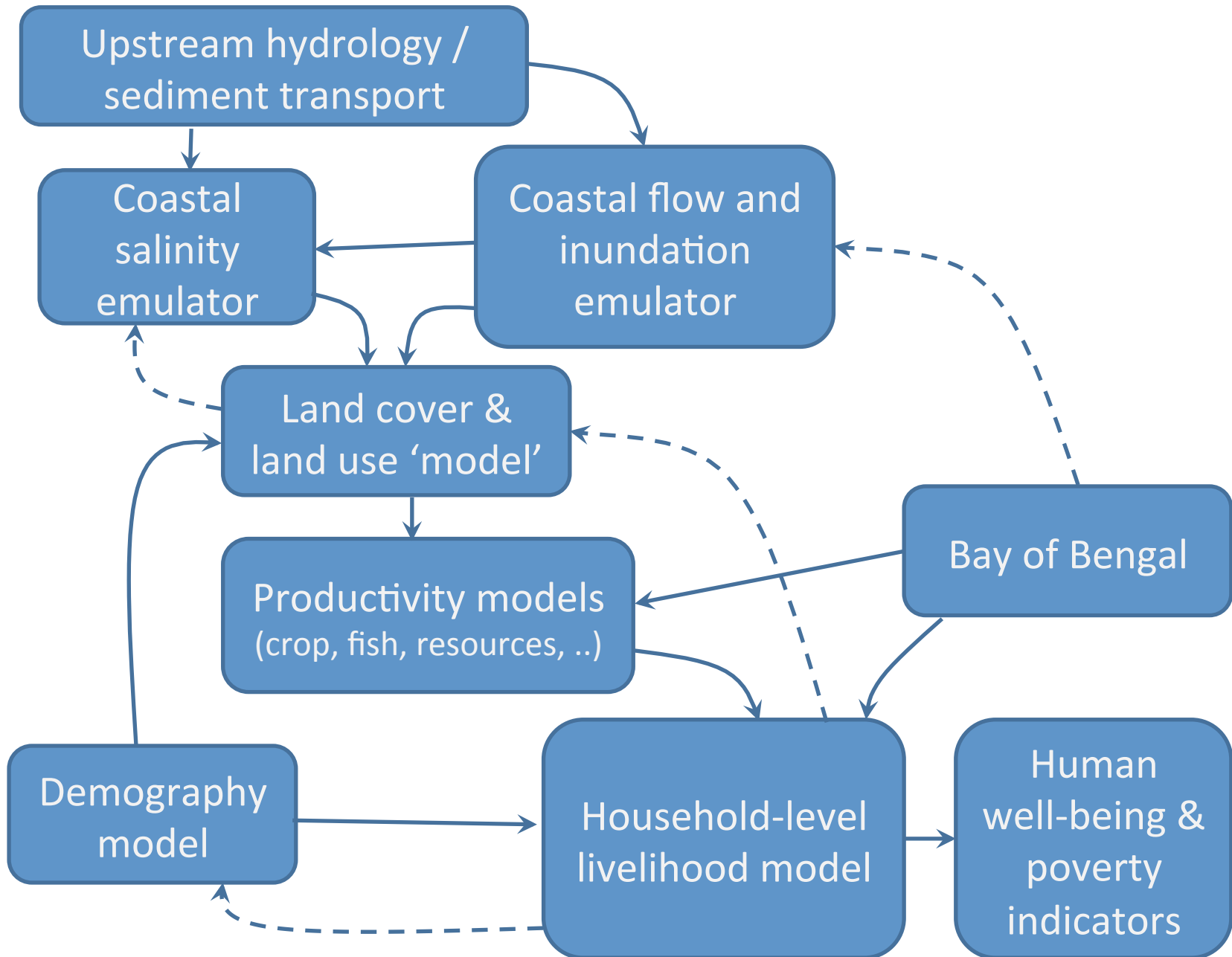
The Hybrid Δ DIEM



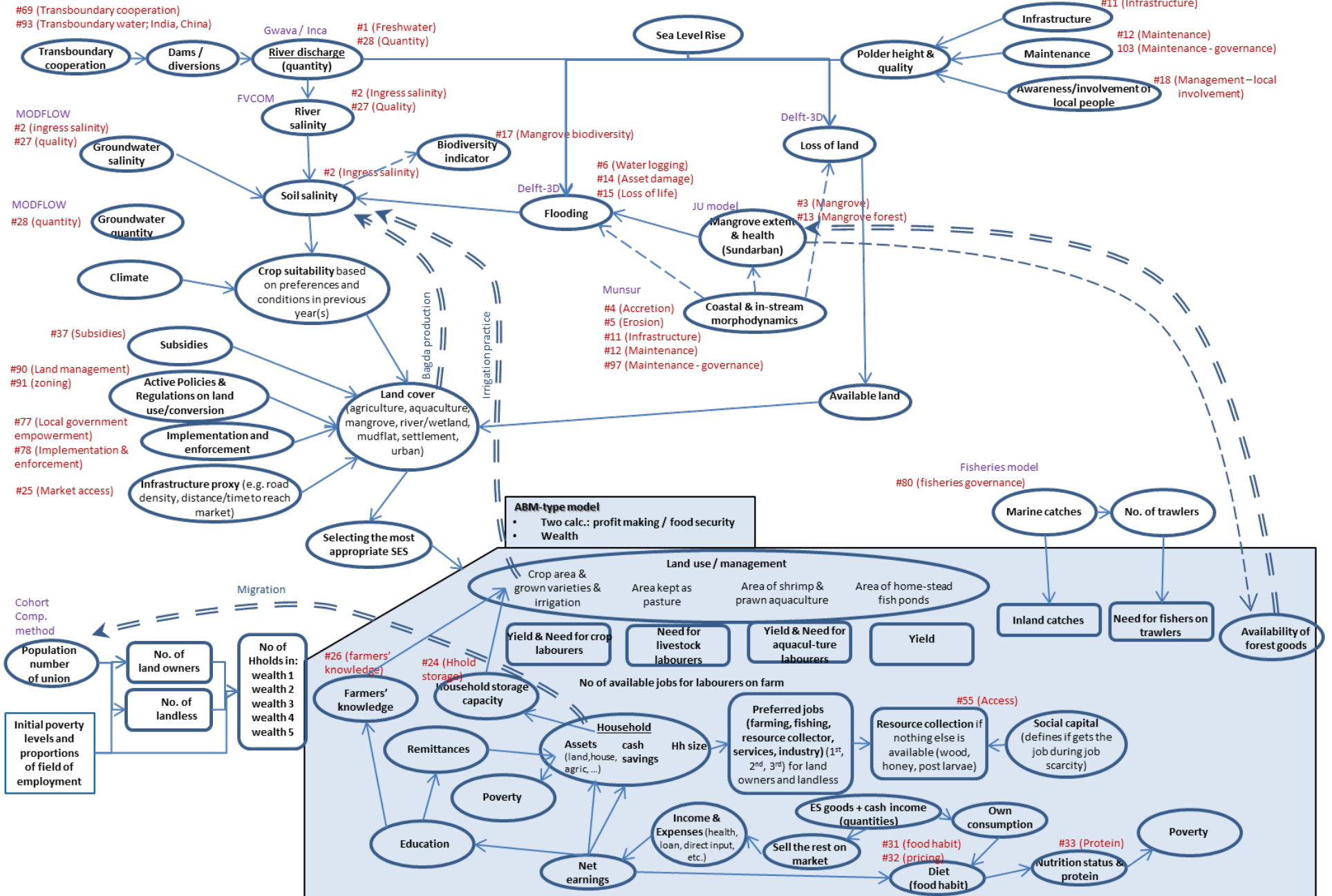
- Searching for **associative relationships** amongst:
 - land use/land cover,
 - environmental quality and
 - Poverty (based on Census data)
- considers spatial dependence and spatial heterogeneity
- uses a variety of techniques:
 - Spatial autocorrelation techniques
 - Multivariate logistic regression models
 - Bayesian Geosadditive Semiparametric (BGS) logistic regression model



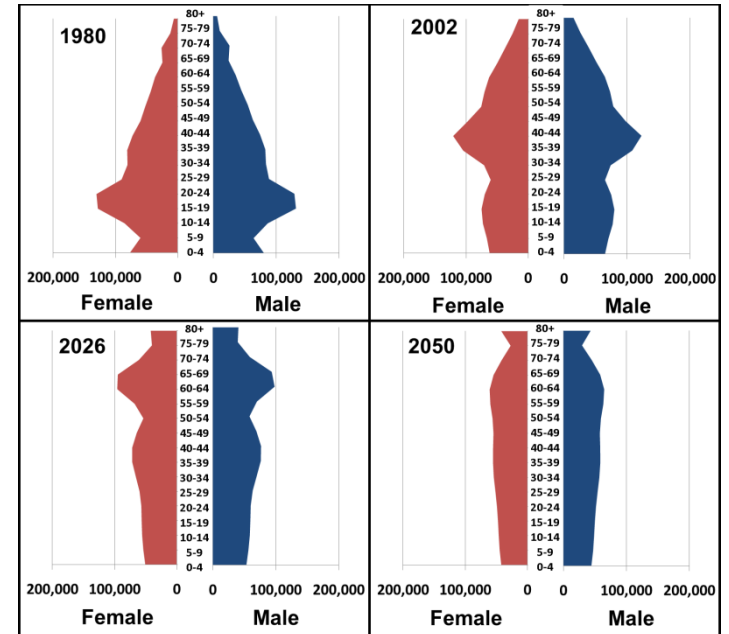
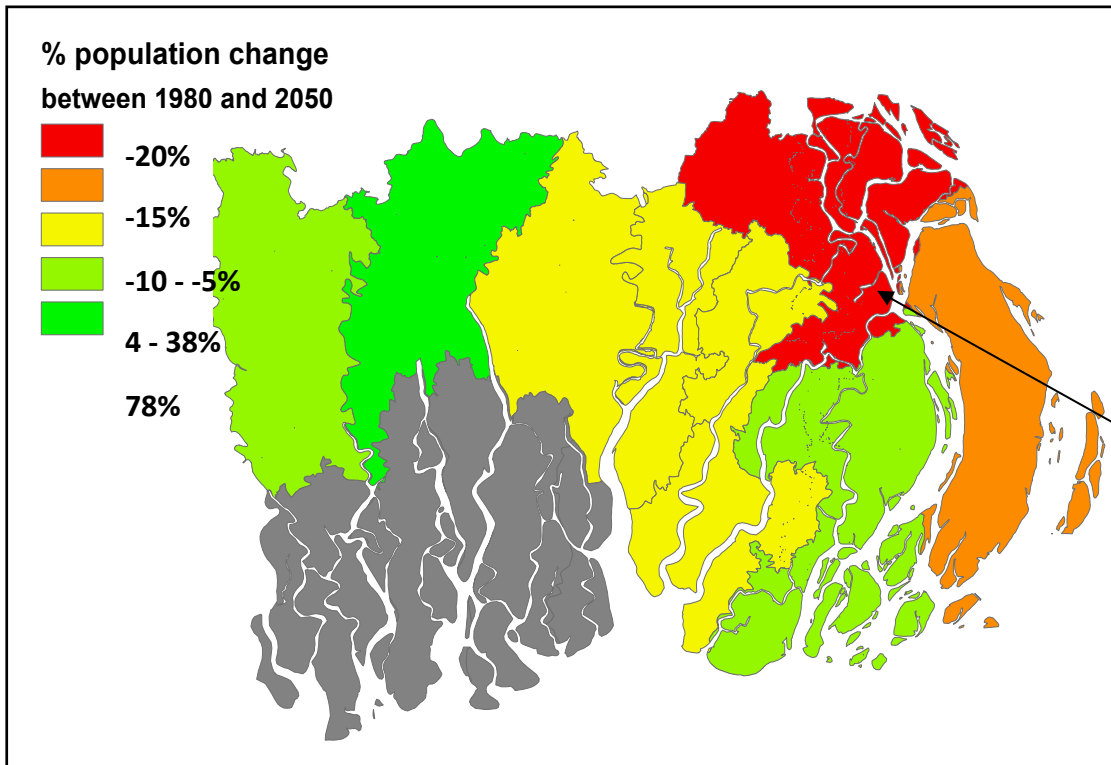
The process-based Δ DIEM



The process-based Δ DIEM



Some early results - demographic changes



Barisal (decrease)



The model suggests **decreasing population** over time in many districts (land fragmentation, salinization, migration)

These are not final results!

Some early results – crop suitability - yield (t/ha)

scenario: no irrigation & Salinity increases by 5dS/m from 2010 to 2050

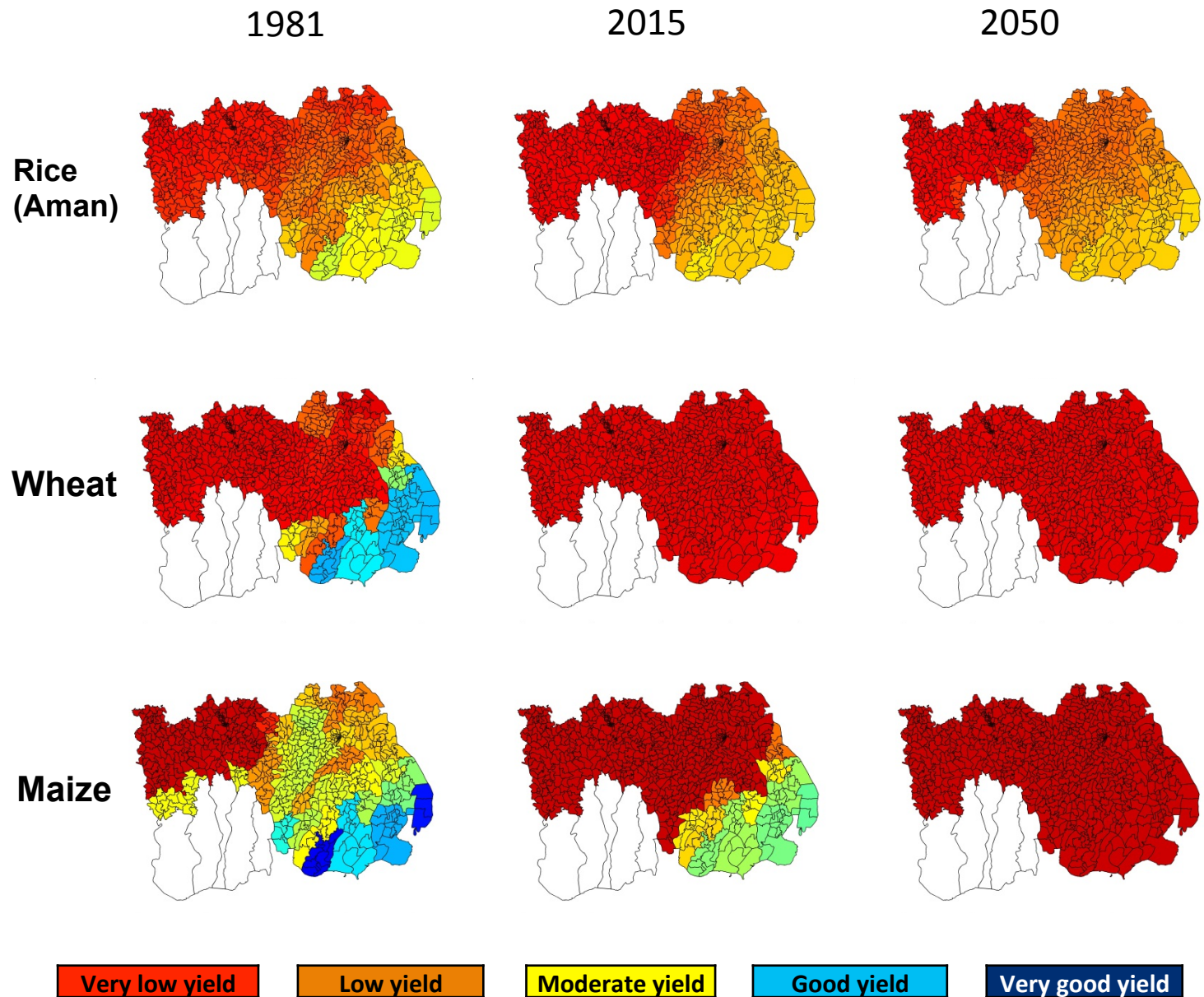
Changes are necessary:

- Crop diversification
+ value addition

- Better management

- multiple jobs

These are not final results!

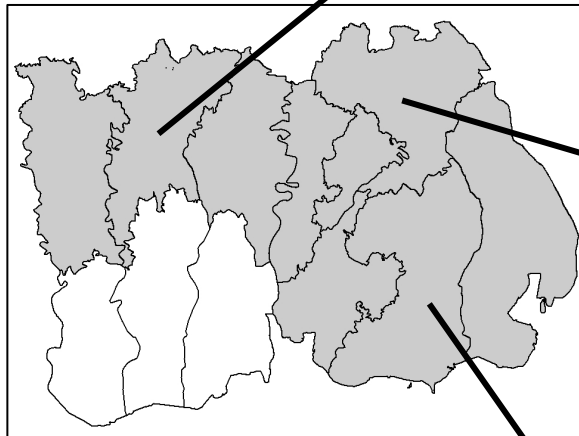


Some early results - Profit Margin (fraction)

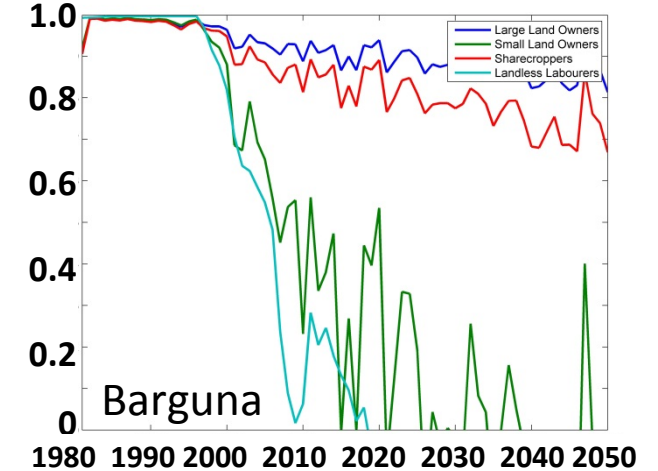
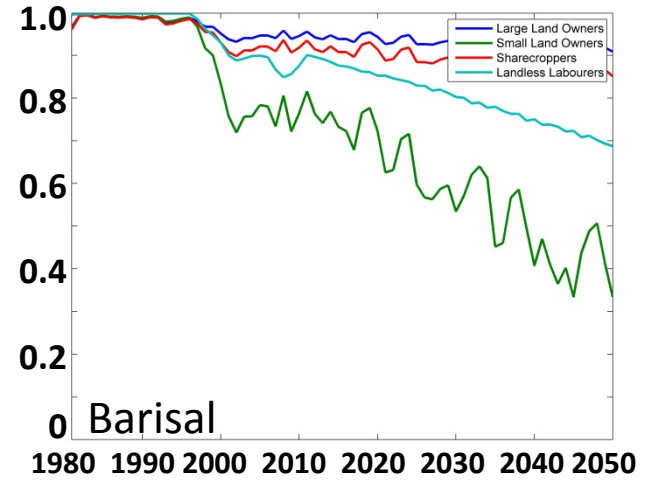
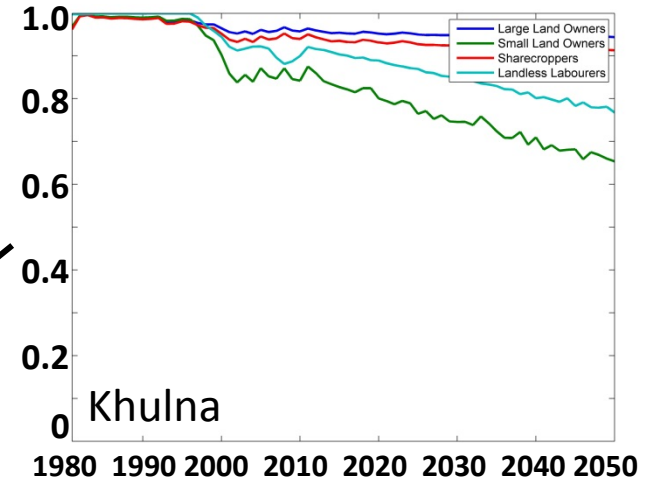
the fraction of revenue that remains in the pocket of the households after all the costs paid

When fraction is around zero, loan is necessary or multiple jobs

- Farming is increasingly difficult over time
- These are not final results!



- Large Land Owners
- Small Land Owners
- Sharecroppers
- Landless Labourers



Livelihood, poverty and health

Livelihoods:

- Income using different Ecosystem Services
- Income/expenditure ratio

Health:

- Nutritional status: Calorie/protein intake
- Blood pressure and hypertension
- BMI nutrition

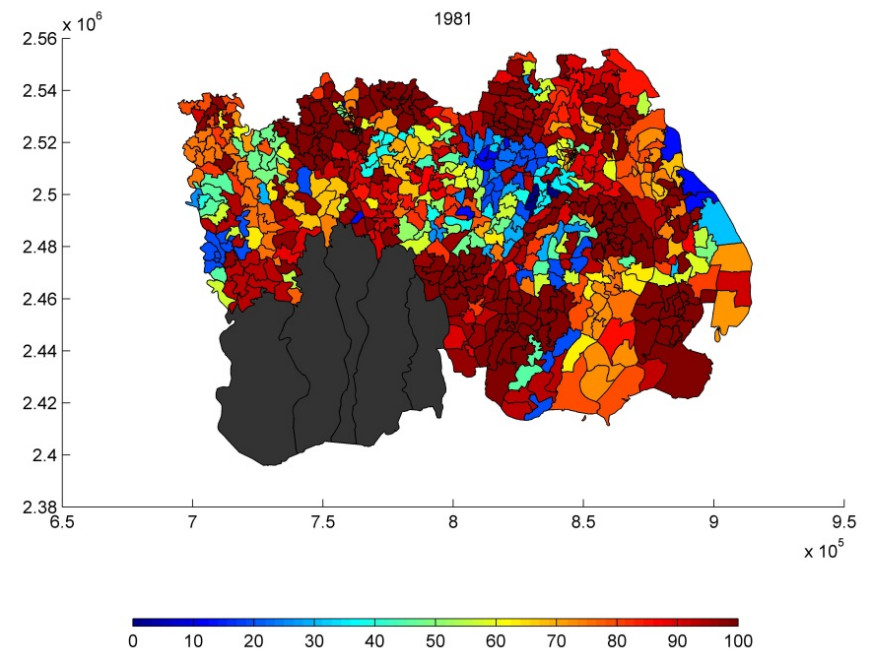
Poverty:

- \$1.25 Headcount (monetary poverty)
- Food insecurity / Hunger periods
- Multi-dimensional poverty index

- Indicators are being developed.
- Poverty levels are high.
- These are not final results!

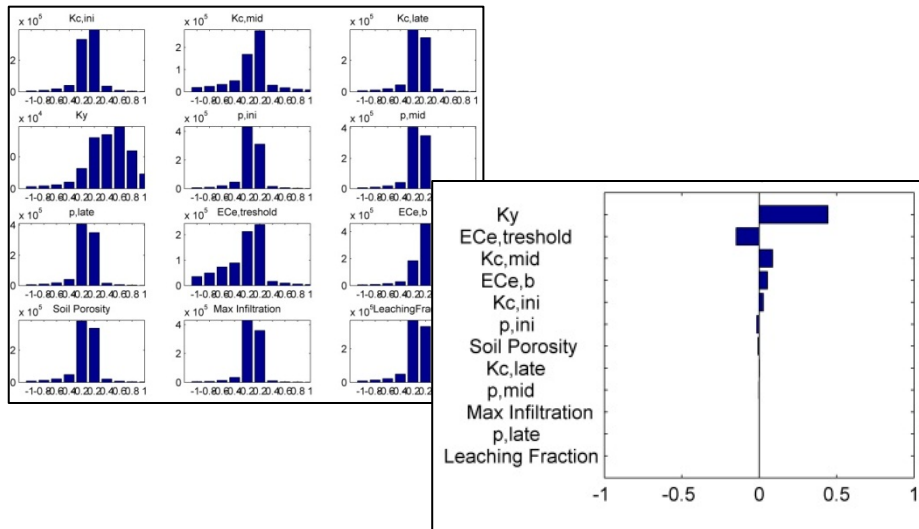


% of farmers living under the \$1.25 Poverty line

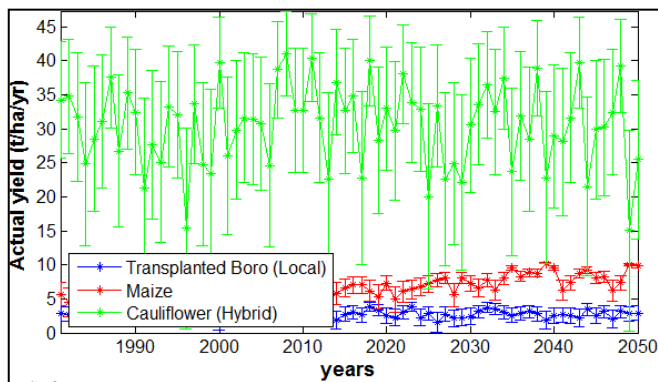


Uncertainty estimation in Δ DIEM (accuracy & precision)

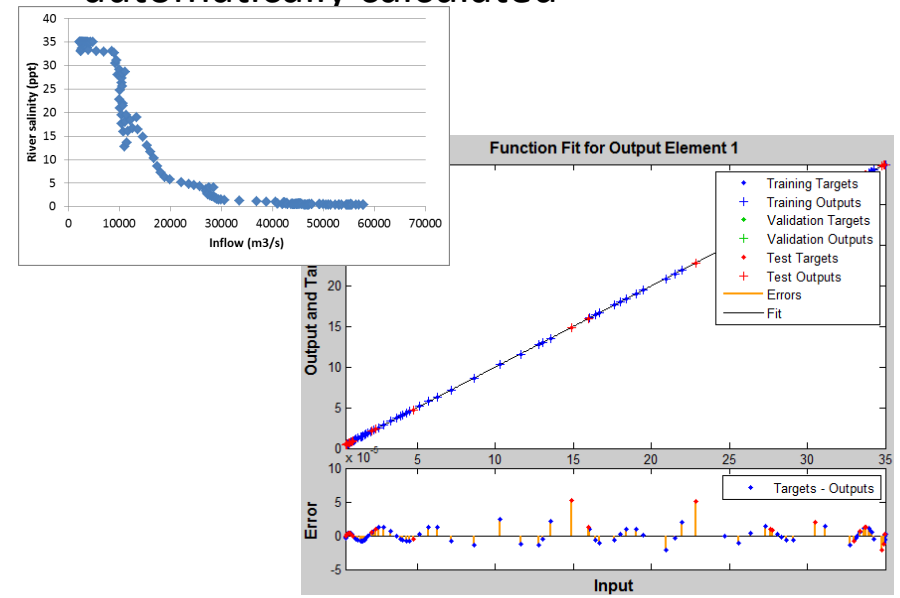
1. Formal sensitivity analysis of process-based models



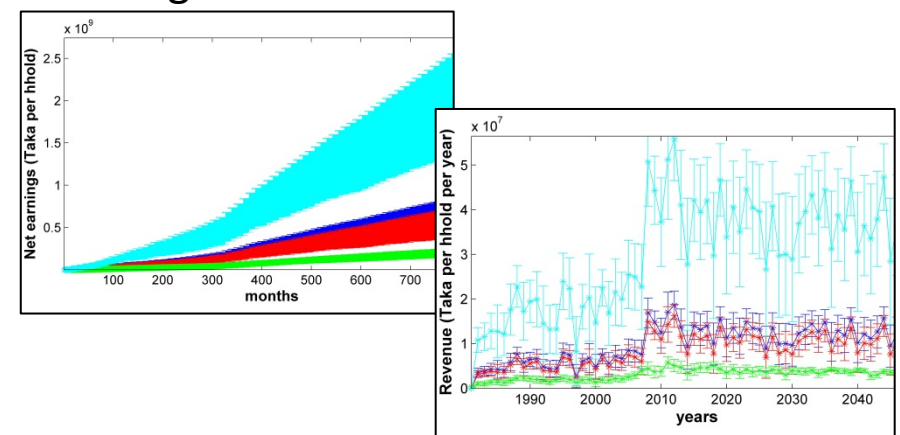
2. Process-based models – built-in Monte Carlo sequence (mean, ± 1 std dev)



3. Bayesian emulators – uncertainty automatically calculated



4. Accounting uncertainties all the way along the model chain.



Model testing & validation

Oreskes, Shrader-Frechette, Belitz
**Verification, Validation, and Confirmation of
Numerical Models in the Earth Sciences**

Science 4 February 1994:
Vol. 263 no. 5147 pp. 641-646
DOI: 10.1126/science.263.5147.641



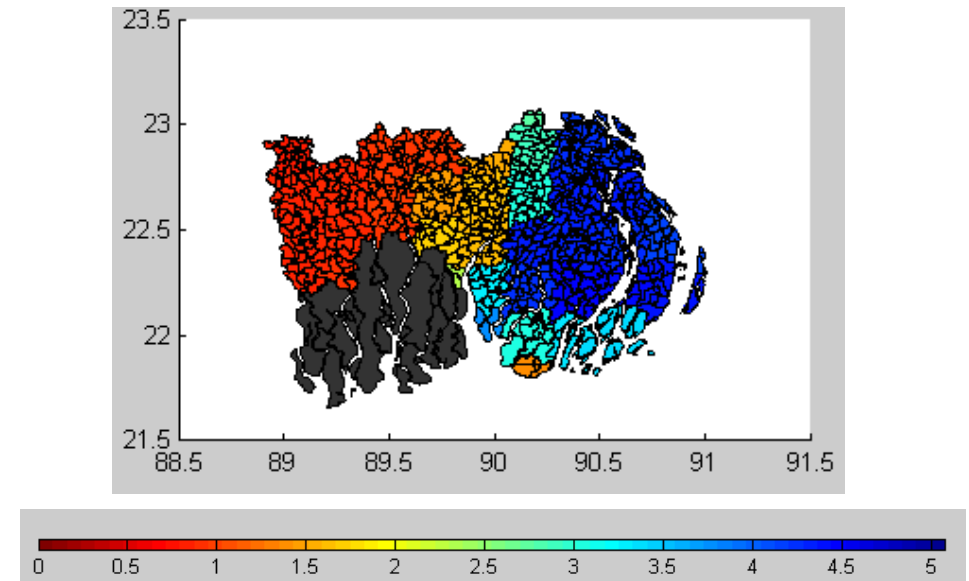
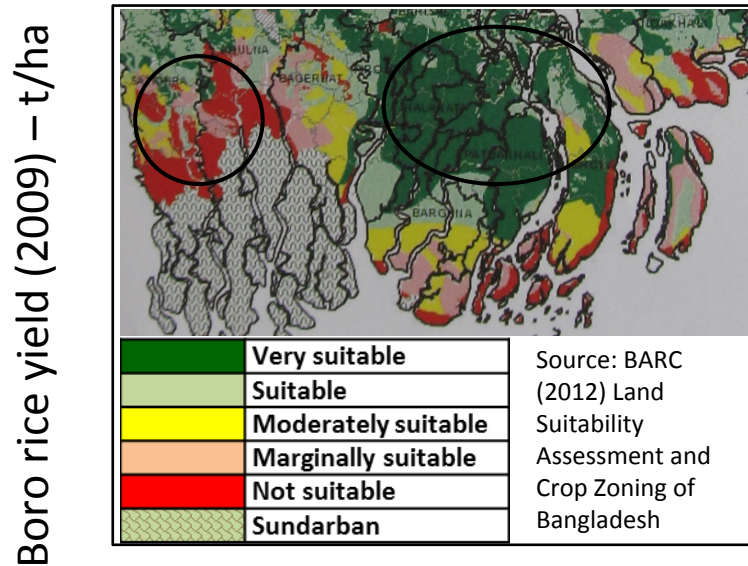
Naomi Oreskes

Model testing & validation

1. **Debugging the code** by comparing model results with outputs of the real model(s)

2. **Testing of individual elements** (with observed data from 1981-2013)

E.g. population numbers, water depths / discharges , farmers' yield, fish catches, etc.



3. **Testing of entire model** (with observed from 1981-2013)

E.g. land cover, poverty levels, extent of flooding after an event, migration patterns, etc.

4. **Compare Hybrid and (more) process-based results and discuss with stakeholders**

So what can we capture? – a few examples

We will not give accurate 'weather' forecasts - only trends, likelihoods, robustness

- What will be the **extent of inland flooding** following a hypothetical cyclone event?
- Where will the **isoline for threshold** (wheat, rice) salinity lie?
- What will be the effect of changing climate, river regime and salinity on **agricultural, fisheries and aquaculture and thus poverty**?
- What happens if there is a **massive decline in GBM river flow** and sediment transport?



- Where will the ability to derive any livelihood drop below an acceptable level thus driving **migration**?
- To what extent would **subsidies or remittances** offset the poverty increases or losses of livelihood in rural areas?
- What would be the effect on farmers and ecosystem services of a rapidly increasing trend in **global commodity prices** (eg rice)?

Summary

- A generic, holistic approach
- To understand the importance of the environment on livelihood, poverty and health
- Ongoing in-depth research & integrative model development/testing
- First comprehensive simulation results are expected in November 2014





Thank you for your attention!

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 <http://www.espadeltas.net>

Scenario development & policy testing

