THE HYDRO-ENVIRONMENT AND LIVELIHOODS IN COASTAL BANGLADESH

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EXTENDED ABSTRACT

Delta environments are one of the most densely populated areas in the world, where human livelihoods and wellbeing are closely tied to the highly modified bio-physical environment (Milliman *et al.*, 1989). This is especially true for the coastal zone of Bangladesh where more than a thousand people live in each square kilometre of land. While livelihoods, food security and poverty in Bangladesh are strongly dependent on natural resources, these are under threat from various factors including climate variability and change, upstream river flow modifications, unsustainable commercial fish catches in the Bay of Bengal, and engineering interventions such as polderisation (Roy, 2011). Scarcity of fresh water, saline water intrusion and natural disasters such as fluvial flooding, cyclones and storm surges negatively affect drinking water availability and crop irrigation potential, severely affecting land use and livelihood opportunities of the coastal population (Hossain *et al.*, under review).

Hydro-environmental changes can be particularly detrimental for the well-being of the poorest households that are highly dependent on natural resources. Bangladesh is not only vulnerable to the impacts of climate change, it also has a large proportion of its population (~43%) living below the poverty line. This population continues to grow and as such there are real barriers to food security in the context of negative environmental impacts and changes in international markets (Pender, 2008).

Rural livelihoods in Bangladesh are complex. High population densities (950 individual km^{-2}) combined with landownership concentrated into the hands of a small number of landlords means that approximately half of the rural population is landless. Therefore, to assess the wellbeing of rural populations, any model should investigate not only the impact on environmental change on the productivity and quality of environmental resources, but also the socially-differentiated dependence of the population on those resources.

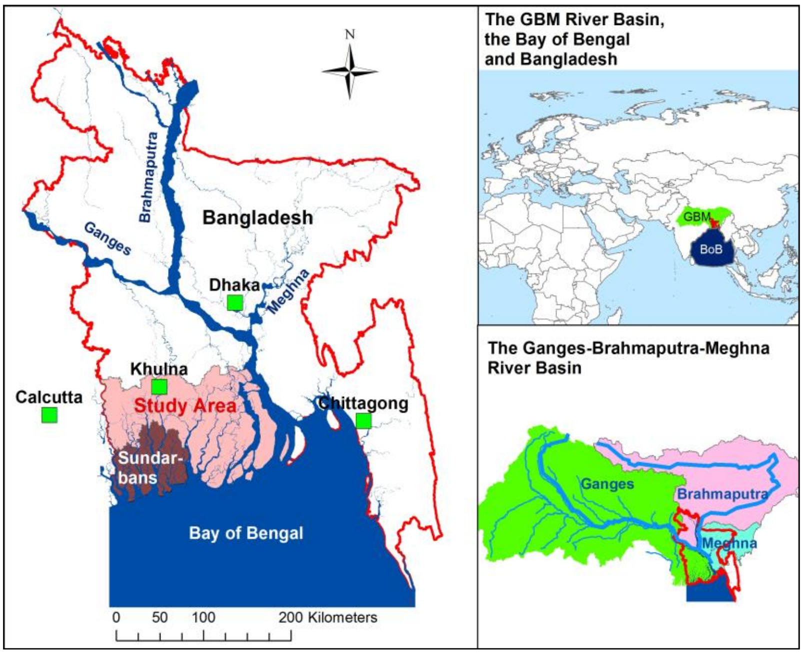

Figure 1: Study area

The ESPA Deltas project aims to examine holistically the interaction between the bio-physical environment and livelihoods of households in coastal Bangladesh (Figure 1). To achieve this ambitious goal, an innovative new integrated model is being developed with a large group of experts that allows the long-term analysis of the possible changes in wellbeing of the population in this system by combining plausible future scenarios of physical processes (e.g. river flows, nutrients), with productivity (e.g. fish, rice), social processes (e.g. access, property rights, migration) and governance/management (e.g. fisheries, agriculture, water and land use management). This integrated approach is designed to provide Bangladeshi policy makers with science-based evidence of possible development trajectories within the coastal delta plain over timescales up to 50 years, including the range of challenges and impacts from climate and human activity they will face and the range of effect mitigation and adaptation governance measures they could have.

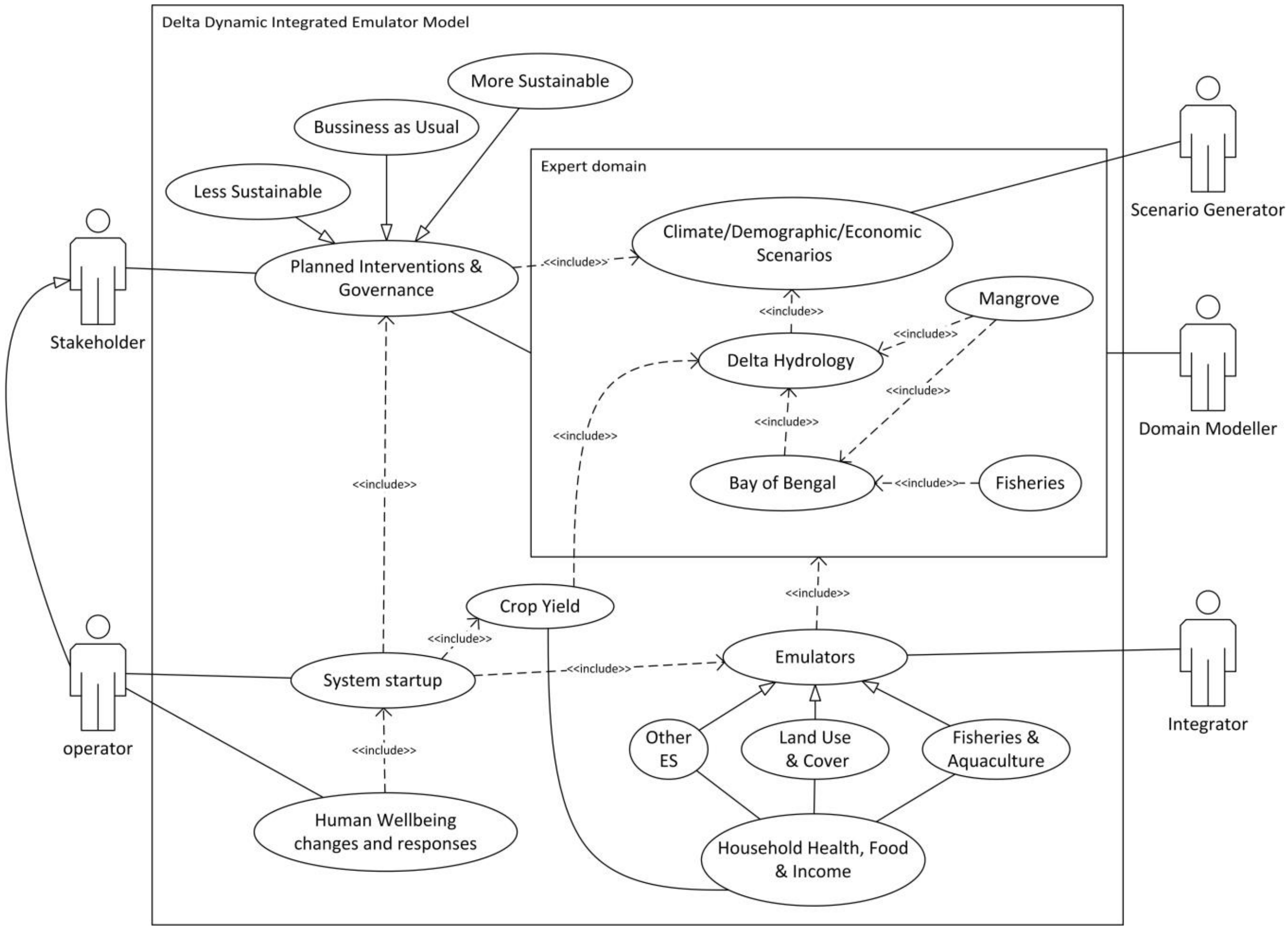

Figure 2: Conceptual model using UML conventions

Although process-based mathematical models are useful to study the internal processes and cause-effect relationships at high level of accuracy, many of these models are too computationally demanding to be integrated in a large integrated model (e.g. Delft-3D, GCOMS, etc.). Integrated system models not necessarily require the understanding of the internal process-details of each system element. Rather, integrated system models often require effective runtimes, quantification of errors and uncertainties to allow ensemble analysis. The ΔDIEM (Delta Dynamic Integrated Emulator Model) of the ESPA Deltas project fully couples several simple simulators and emulators of the CPU demanding simulators in an integrated socio-environmental framework (Figure 2). It has four major blocks describing the governance, the bio-physical environment, the socio-economic processes and the human well-being. Less computationally expensive models (e.g. CROPWAT agriculture model) are directly integrated into the framework; whereas the results of complex models (e.g. Delft-3D coastal hydrodynamic model, Haque *et al.*, under review) are either captured with a linear or non-linear statistical emulator or used as a time-series if dynamic interaction with other system elements is not required (e.g. GCOMS sea level results and fisheries projections, Fernandes *et al.*, under review; Kay *et al.*, under review). Using state-of-the-art model testing techniques (e.g. Vasquez and Whiting, 2005; Vermeulen et al., 2013), the uncertainties and error propagation within the model framework is being assessed. Input and parameter uncertainties are assessed for the bio-physical models and parameter uncertainties are also being assessed for the socio-economic models. Input uncertainties are difficult to evaluate for the household-level socio-economic models, because of data scarcity and ΔDIEM is largely builds on the primary data collection of the ESPA Deltas project. The integrated model is being validated on observed, historical data for each element separately, and as a whole.

The validated model is then used to test plausible future scenarios. Three scenario narratives (Less Sustainable, Business As Usual, More Sustainable) were developed together with the stakeholders following the Shared Socio-economic

Pathways approach (O'Neill et al., 2012), but tailored to the Bangladeshi conditions (Allan and Barbour, 2015). Both the narratives and their quantifications were discussed and agreed with national decision maker and expert stakeholder groups. The SSP scenarios and then combined with climate projections to explore a range of plausible futures for coastal Bangladesh.

Preliminary results are available for many system elements. For example, crop simulations with ΔDIEM shows that traditional farming is more predictable than many of the more progressive farming methods and thus generates more secure livelihoods for farmers under a changing climate (Figure 3a) if technological developments (e.g. more resilient crops) do not occur (Lázár *et al.*, under review-a), consistent with qualitative findings from the development anthropology literature. Emulation of river flood inundation results of Delft-3D (Figure 3b) is also promising and having relatively low errors (Lázár *et al.*, under review-b). This error, when propagates into a spatial Bayesian poverty model, is only translated into a minus -1.7% and +2.7% uncertainty in poverty likelihood on average.

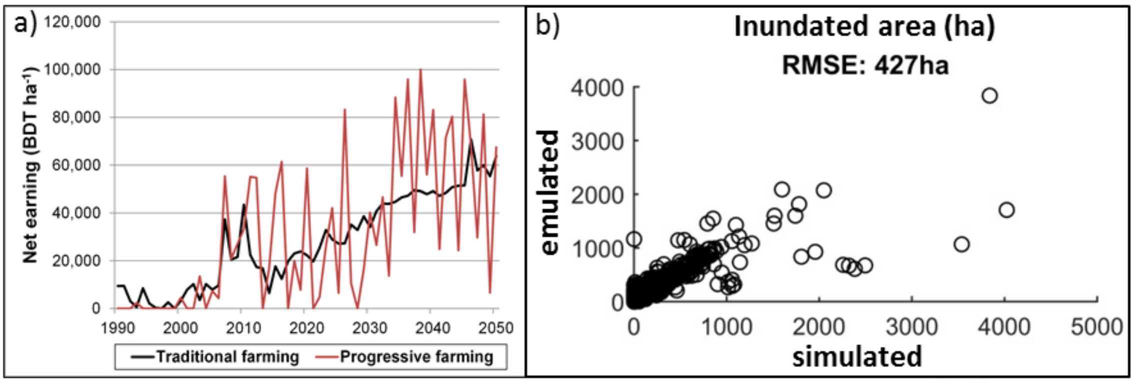

Figure 3: Net earnings from two farm management types (a), and goodness of river flood emulation (b)

This presentation describes the model framework, some initial results that illustrate the complex relationship between changes of the hydro-environment and the security of livelihoods of the coastal population of Bangladesh, and the ways in which different future scenarios modulate the wellbeing outcome for the poorest.

Keywords: Ganges-Brahmaputra-Meghna Delta, integrated system modelling, physical environment, livelihoods

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