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Climatic Impacts on the Fluvial and Tidal Inundation Patterns in the Ganges-Brahmaputra-Meghna Delta

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Abstract**:** *The Ganges-Brahmaputra-Meghna (GBM) delta is the largest and one of the most significant tide dominated deltas of the world that provides rich and diverse ecosystem with low-lying coastal plain. This delta is perceived to be at great risk of increased flooding due to climatic impacts and submergence from sea-level rise. In this study, fluvial and tidal inundation patterns resulting from temperature and sea level rise is evaluated by applying a numerical model (Delft3D Flow). Boundaries of temperature and sea level rise are provided by a hydrological (INCA) and an ocean model (GCOMS) respectively. To study the impacts, two time horizons, namely mid and end century are considered. This study has mainly focused on inundation area and mean flood depth. Results show that in this region, fluvio-tidal floodings are characteristically different in different climatic and sea level rise scenarios.*

Keywords: *GBM delta, Fluvial and tidal inundation, Sea-level rise, Numerical model*

1. Introduction

Deltas are important dynamic environments that are constantly reshaped and reformed. The Ganges-Brahmaputra-Meghna (GBM) delta is one of the most dynamic tide dominated deltas in the world, a dynamism forced in part by the huge flows and sediments generated in the catchments of the GBM basins [1]. This Delta is one of the main extreme threatened Deltas by IPCC [2], situated in Bangladesh and India (West Bengal), cover approximately 100,000 km^2 of lowland flood and delta plains [3]. The flow generated in the upper catchment of the GBM basins is drained through the estuarine systems of the delta [1]. Land elevation of 50% of the Bangladesh is within 7.6 m of Mean Sea Level (MSL) [4]. As a result 20-30% of the area becomes inundated during normal flooding [4]. Bangladesh will be among the most affected countries in South Asia by an expected 2°C rise in the world's average temperatures in the next decades, with rising sea levels and more extreme heat [5]. In Bangladesh, 40% of productive land is projected to be lost in the southern region of Bangladesh for a 65cm sea level rise (SLR) by the 2080s [6]. The future impact of sea-level rise and climate change on the coastal zone of Bangladesh will depend on the vulnerability and resilience of its physical, biological, social and economic systems [5]. Climate change threatens increased levels of fluvio-tidal flooding in the coastal and riverine flood plain, as well as the degradation of nationally and internationally important coastal ecosystems [7]. Understanding of such factors is necessary in order to fully assess the future effects of climate and sea-level change on the coast. It is important to mention that this study is focused only on the fluvio-tidal floods generated by the SLR and does not consider the floods due to coastal phenomena such as storm surges. Several scenarios are considered here for calculating future inundation due to fluvial and tidal flooding (henceforth will be termed as fluvio-tidal flooding).

2. Study Area

Bangladesh coastal region is divided into eastern, central and western region [9]. The study area selected comprises the south-western and south-central region of Bangladesh including the Sundarban (Figure 1). Western part is known as Ganges tidal plain and consists of semi-active delta and has a very low and flat topography. The area lies about 0.9 to 2.1m above the mean sea-level [10]. The combined flow of the mighty Ganges, Brahmaputra and Meghna rivers drains out to Bay of Bengal in this region through the very active Lower Meghna river estuary. Future inundation has been calculated for this coastal zone.

Fig. 1: Study area with polders and validation locations

3. Model Description

Delft3D flow model is applied to simulate the land inundation due to fluvio-tidal flooding. Time series of discharge is specified as the upstream boundary condition, with a time series of water level for the downstream boundary condition. Discharge boundaries are generated from the output of a hydrological (INCA) model [11] and for downstream water level boundaries, tides are generated by using GCOMS [12].

Cross sectional data for each of the estuarine systems of the GBM delta are measured under the ESPA delta project (http://www.espa.ac.uk). The domain of the measurements covers the entire study area. Open access General Bathymetric chart of the Oceans (GEBCO) data is used as the bathymetry of the Bay of Bengal. The inland ground elevation data is collected from Centre for Environmental and Geographic Information Services (CEGIS), Bangladesh. Several scenarios have been used to describe future fluvio-tidal flooding which are shown in table 1.

TABLE I: Scenario used to describe fluvio-tidal flooding

Scenario No.	Temperature Rise (°C)	Sea level Rise (m)	Time
Scenario 1	2.26	0.26	Mid Century
Scenario 2	4.05	0.54	End Century
Scenario 3	2.62	0.26	Mid Century
Scenario 4	4.09	0.54	End Century
Scenario 5	2.64	0.26	Mid Century
Scenario 6	4.63	0.54	End Century

4. Model Calibration and Validation

The flow model is calibrated and validated for three different locations which are shown in Figure 1. Performances of the model during the calibration exercises are evaluated by computing the model reliability as described by Haque et al. (unpublished) [13]. Using this indicator, model reliability for the flow model for the 'most acceptable model parameters' is obtained approximately 60%. The calibrated model is then validated where measured tidal water level was available. The calibration and validation performances of the model are shown in [Figure 2and 3].

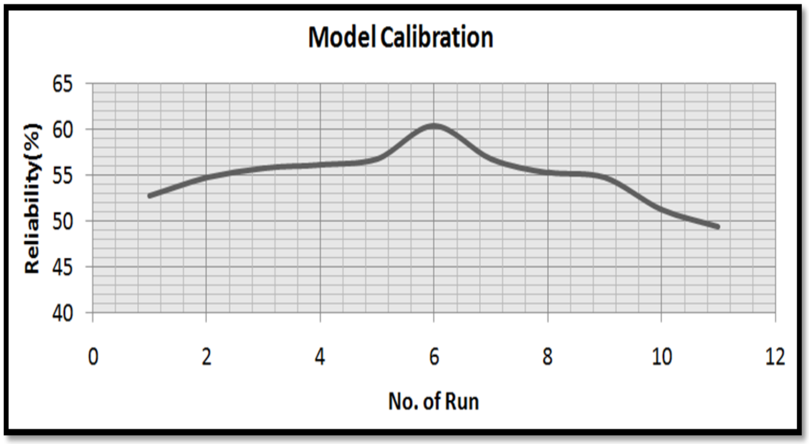

Fig. 2: Model calibration

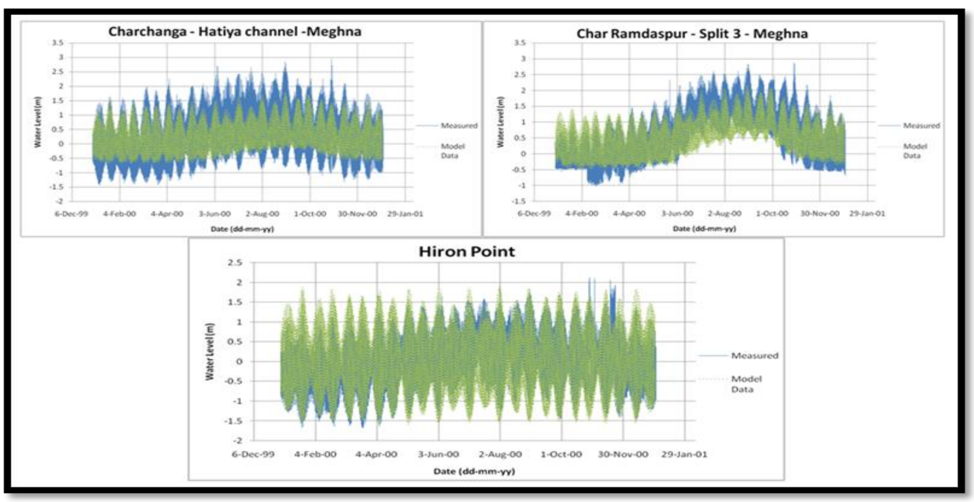

Fig. 3: Model validation

5. Result

5.1. Inundation Area and Depth

In this study, mid-century and end-century scenarios for the fluvio-tidal inundations are generated. For Scenario-02 and 06 (end century scenarios) when both the climatic and SLR scenarios will reach the extreme, the extent of inundation will be the maximum as well as inundation depth. But scenario-04 (an end century scenario) when both the climatic and SLR scenarios will reach the extreme, the extent of inundation will be the maximum, but not the inundation depth. For mid century scenarios (1, 5) areal extent of fluvio-tidal inundation is less than the end century. The same trend is found for inundation depth also. In scenario 3 (a mid century scenario), although the climatic and SLR scenarios are not the extreme as that of end century, inundation depth will be the maximum, but not the areal extent of inundation. This shows that increase of inundation area does not necessarily mean the increase of inundation depth. Inundation map, total inundation area and average depth of inundation for different scenarios are shown in Figure 4, 5, 6.

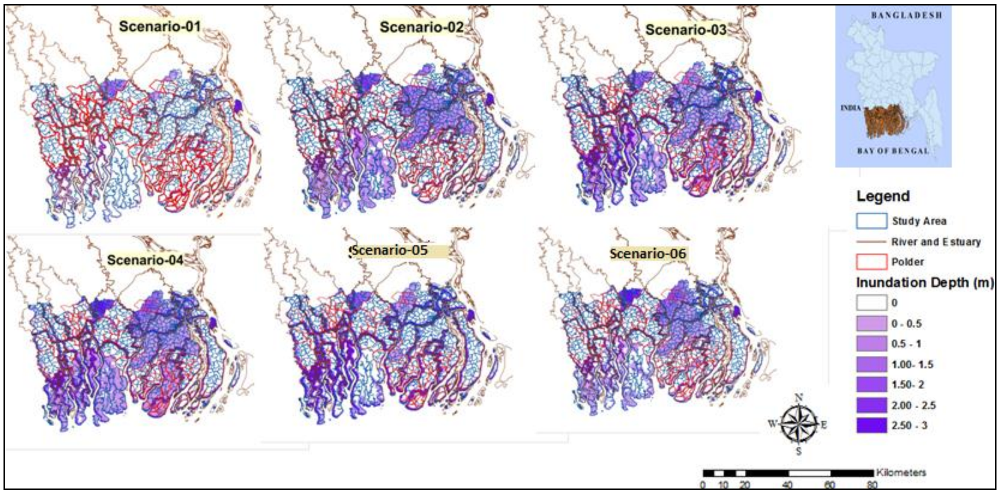

Fig. 4: Inundation Maps

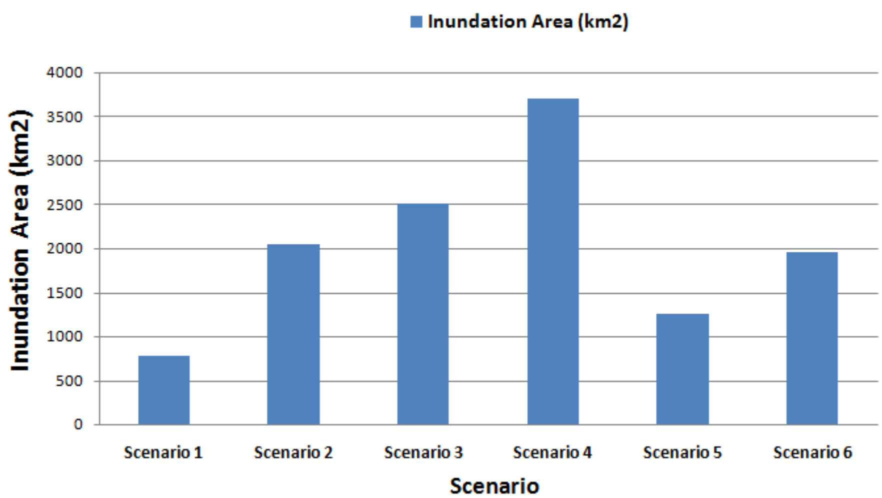

Fig. 5: Inundation Area

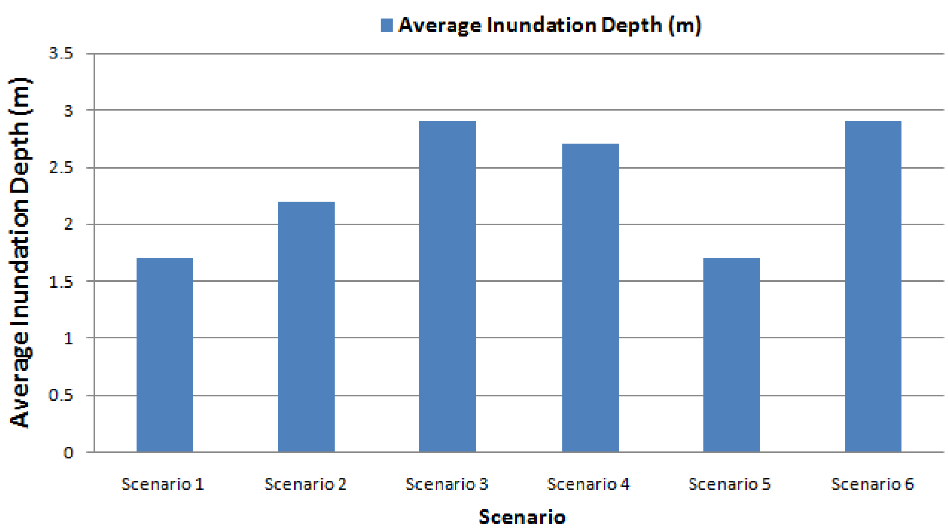

Fig. 6: Inundation Depth

5.2. Polder Overtopped Scenarios

Polders (a kind of encircled embankment) play an important role in the region while flooding, either fluvial or storm surge generated, is considered. The maximum, minimum and average polder heights in the study region are 5.75m, 4.5m and 4.79m respectively (Source: Bangladesh Water Development Board and Center for Environmental and Geographic Information Services data bases). The regions inside the polders are not flooded during fluvio-tidal flooding if the flood water elevation outside the polder is lower than the polder height. The polders are designed to protect the enclosed area from fluvio-tidal flooding up to certain limit. Several scenarios where polders are overtopped during fluvio-tidal flooding are shown in Figure 7.

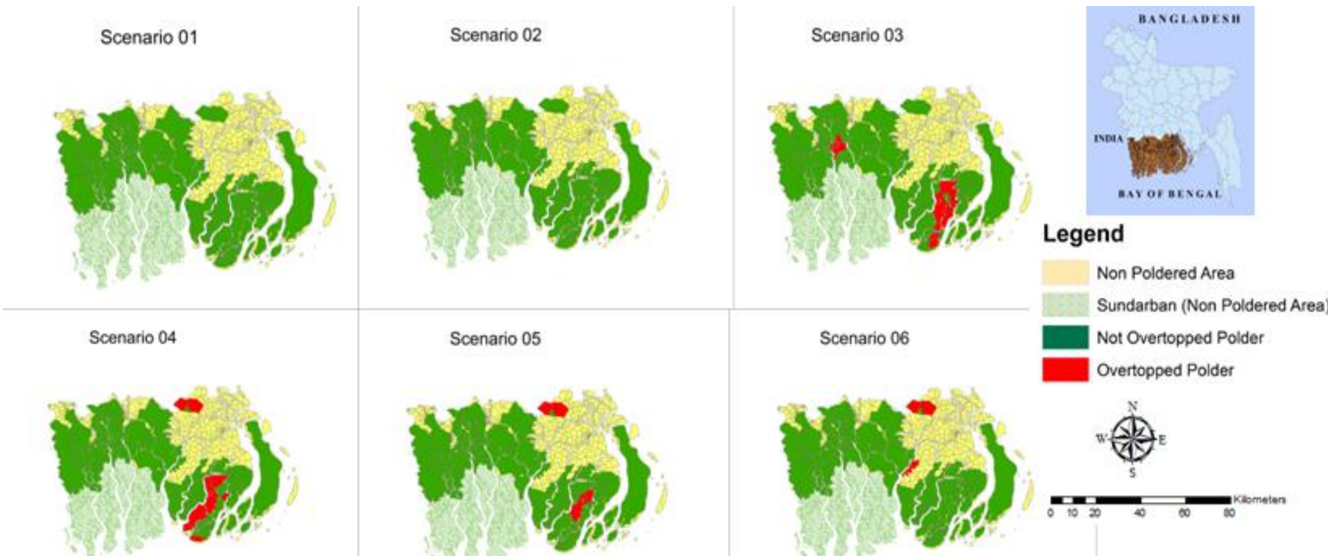

Fig. 7: Polder Overtopped maps

6. Conclusion

Results show that fluvio-tidal floodings are characteristically different for different climatic and SLR scenarios. Both climatic and SLR impacts are clearly visible on the inundation patterns. End century scenarios are found to be more vulnerable compared to mid-century scenarios.

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