Responses of the Meghna estuary of Bangladesh to the climate change

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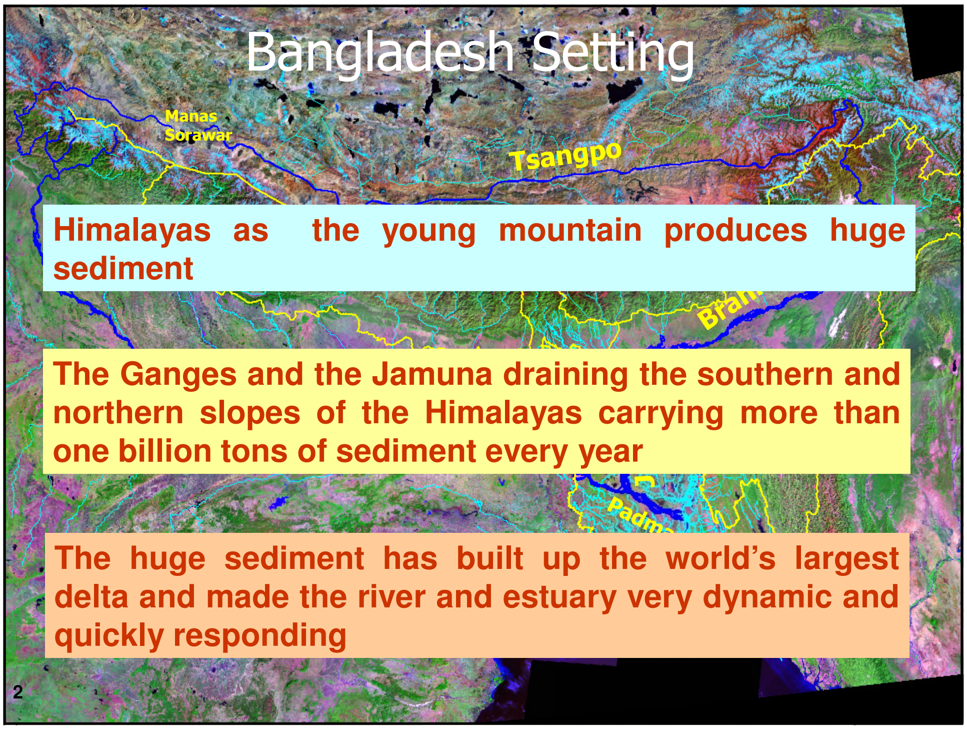
Bangladesh Setting



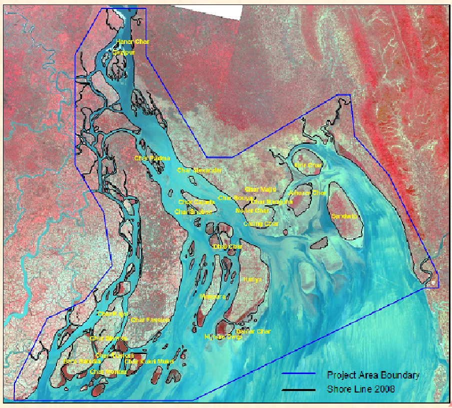
Himalayas as the young mountain produces huge sediment

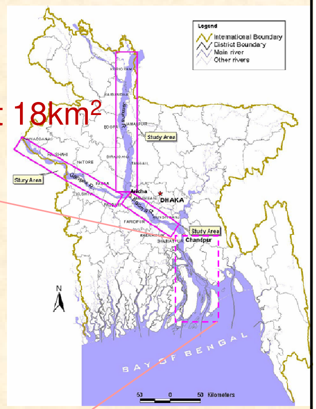
The Ganges and the Jamuna draining the southern and northern slopes of the Himalayas carrying more than one billion tons of sediment every year

The huge sediment has built up the world's largest delta and made the river and estuary very dynamic and quickly responding

Meghna Estuary

- Total area is 15,000 km^2
- Land is 45% of the total area
- Mud flat is 6 % and rest is water
- Annual av. rate of net accretion is about 18km^2





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Rationale

As the Meghna estuary is the main delta building estuary and more than 10 million people are living in this area, it is important to know the morphological response to the sea level rise

This would provide a better understanding on the responses of the other estuaries and rivers to the climate change

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Methodology

Effects of climate change on the river and estuary morphology are not yet well understood

Studying the fluvial responses during high rate of sea level rise in the Holocene (last 10,000 years) can be useful to understand the processes (Parker et al., 2004)

de Vries (1975) and Parker (2006) models were used for assessing Morphological time scale

Long-term sediment balance was used to validate the model result

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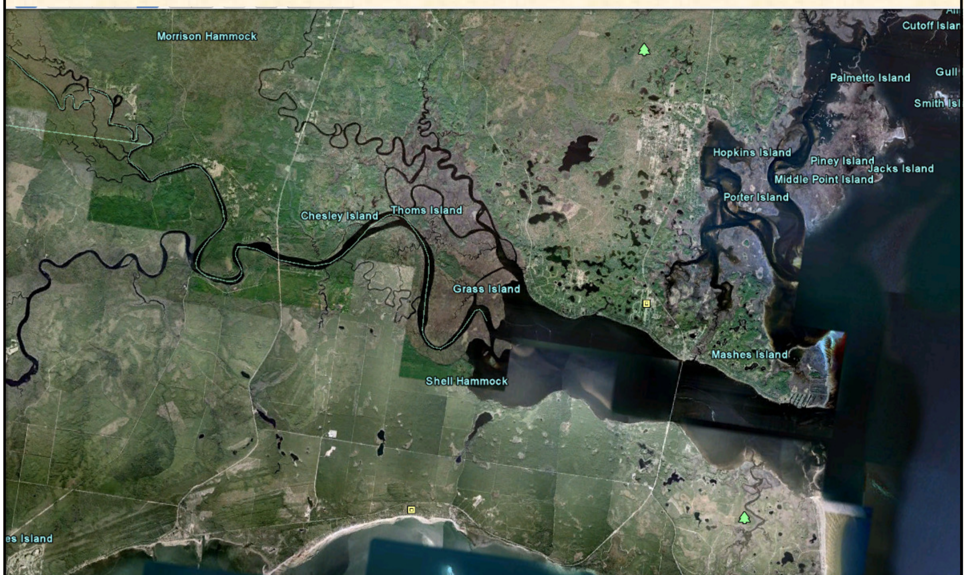
Transgression



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Progradation

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Transgression/progradation depends on

Rate on sediment input

Rate of sea level rise

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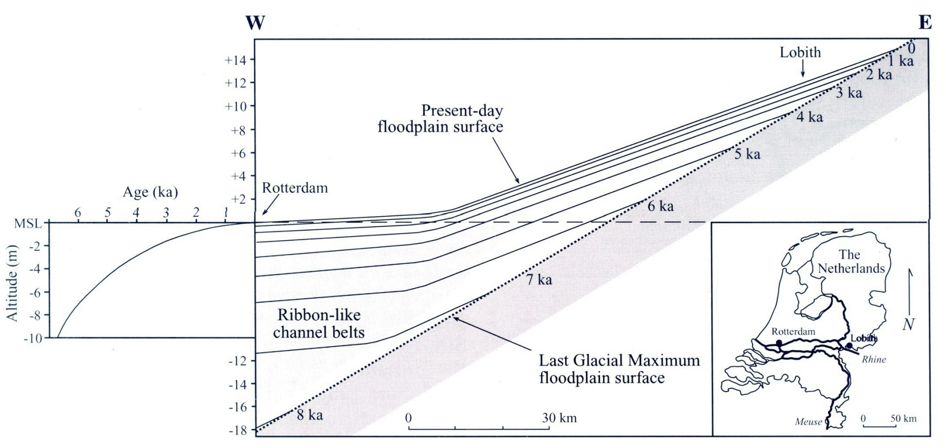
Holocene rise of the floodplain surface of the Rhine-Meuse Delta (Blum and Törnqvist, 2000)



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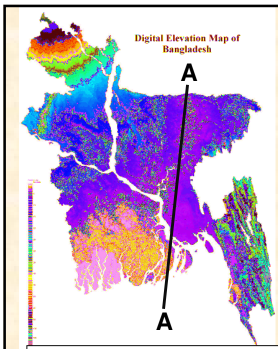

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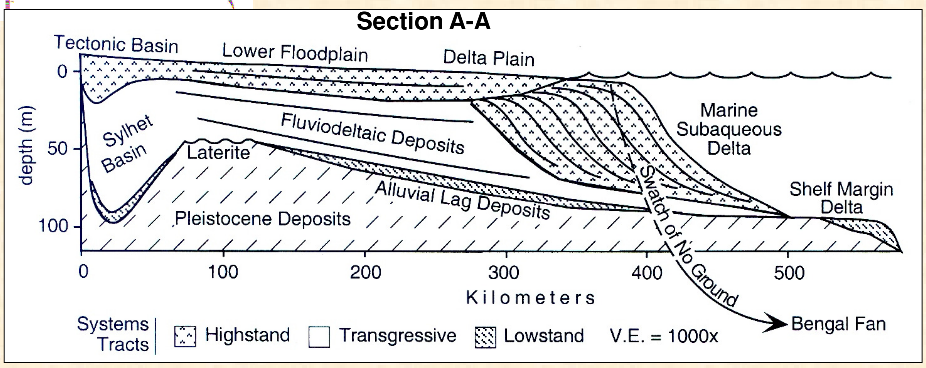
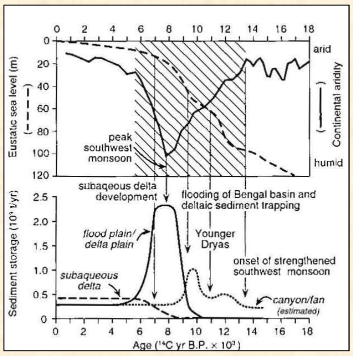
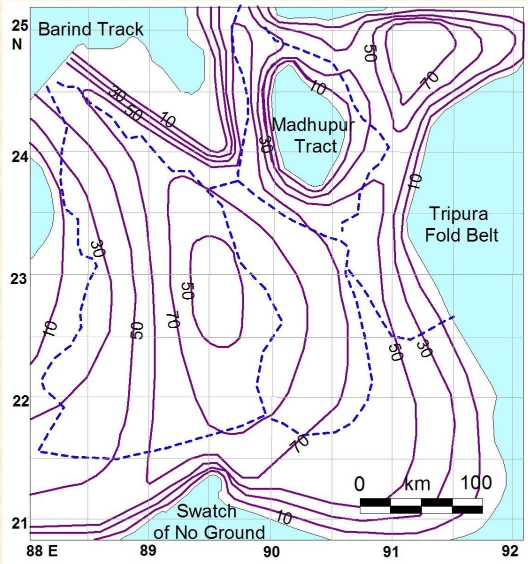
A generalized sequence stratigraphy of the Ganges-Brahmaputra Delta (Goodbred and Kuehl, 2000)



Deposit of sediment during the last 11,000 years





Sea level rise was 60 m and Sediment thickness varies from 50 to 55 m

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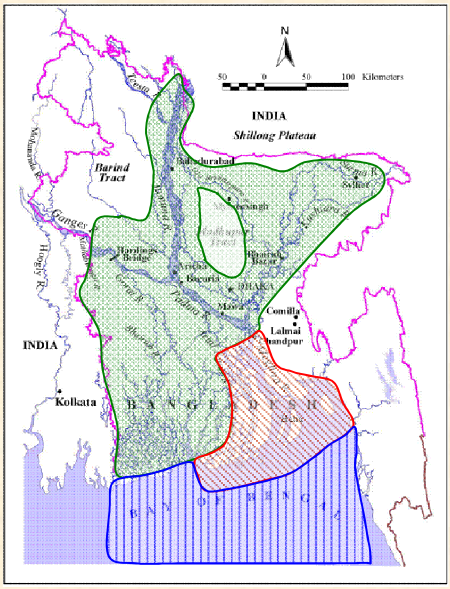
Holocene Sediment Budget

Sediment brought by the major rivers

- 1/3 → **Floodplain and Tidal plain sedimentation**
- 1/3 → **Horizontal and vertical accretion of the sub-aqueous delta**
- 1/3 → **Lost in the ocean**



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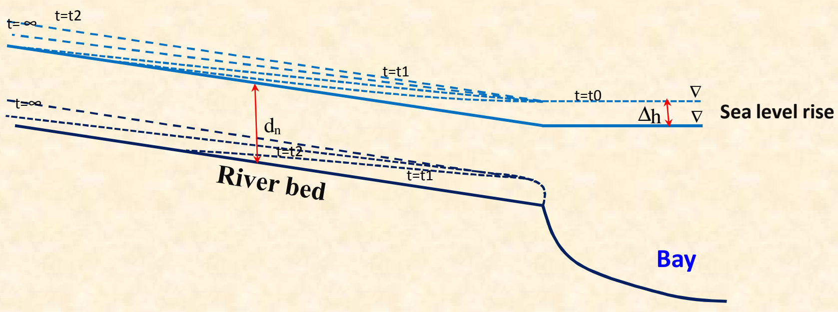
All models and evidences demonstrate that in the scale of thousand years the responses of the delta is in the same pace as the sea level rise

Simplified model showing the fluvial responses to the sea level rise



Main challenge is to find out the time-scale

Morphological Time-scale (de Vries, 1975)

$$T = \frac{L_m^2}{K}$$

$$K = \frac{1}{3}\frac{n}{wi}\int_0^{1\,year} S(t)dt$$

L_m = Distance from sea or lake
T = Adjustment time
n = Exponent of velocity
w = River width,
i = Slope,
S = Sediment transport

Sediment load in 1990s

Type of sediment	Jamuna	Ganges	Padma
$S_{wash\ load}$ (m ton/yr)	277	558	721
$S_{susp.\ bed}$ (m ton/yr)	125	76	227
Total suspended load	402	634	948

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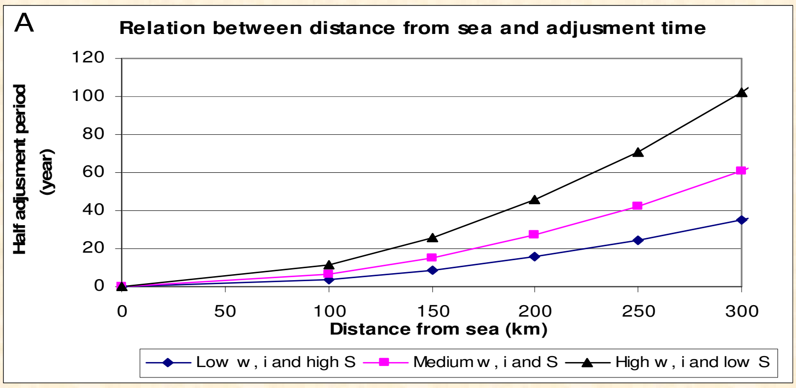
Parameters used for calculating T

Width (m)	Slope (cm/km)	Sediment (10^6 ton/y)	Distance of Mawa from sea (km)	Period of half adjustment (T) (year)	*Bed/bank level rise (cm)
4,000	2.5	350	200	15	52
5,000	3.0	300	200	27	43
6,000	3.5	250	200	45	34



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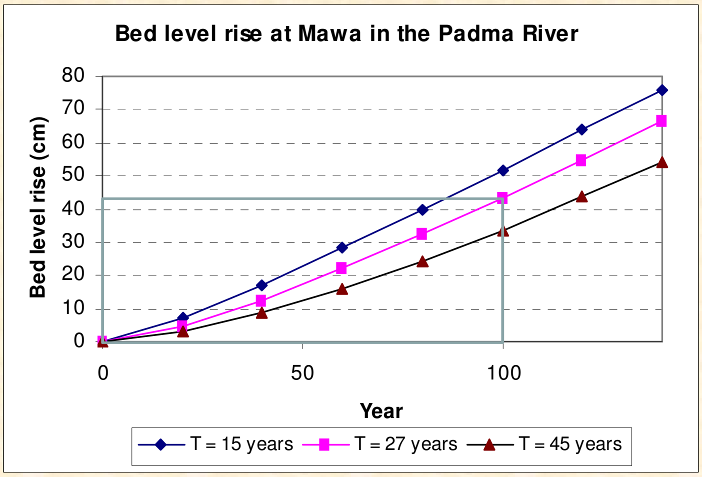
Using the values of T and radio-active decay function, bed level rise was calculated

$$\Delta ht = h_0 - h_0 2^{-\frac{t}{T}}$$

Δ h = bed level rise at a particular time (t),

T = period of half adjustment of bed level.



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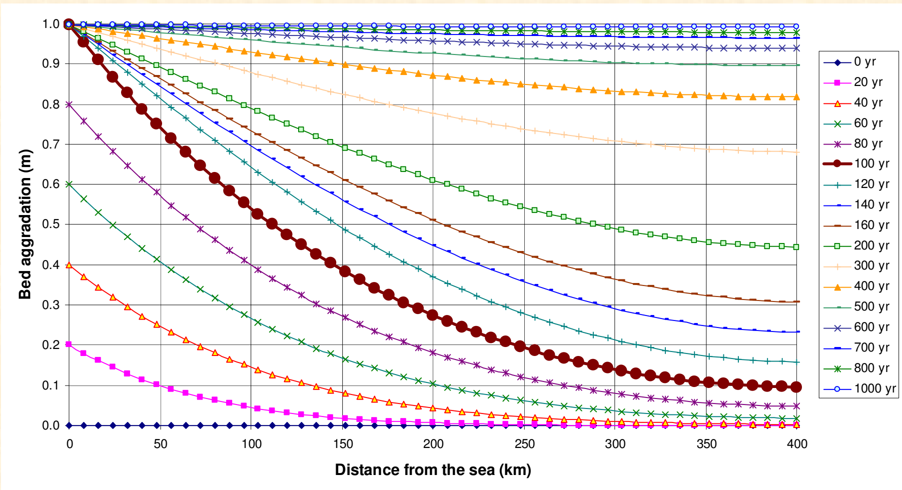
Riverbed adjustment with distance upstream based on Parker (2006) model



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Subsidence and sediment balance

Locations of sedimentation		Dimensions of sedimentation	Fine sand (billion m^3)	Silt+clay (billion m^3)	Part of input sediment (%)
		Sediment input in the coming 100 years			
			14.00	47.00	100 ($61x10^9$ m^3)
		Sediment expenditure			
Jamuna River	Riverbed, char and levee	L=150km, W=12km, T=0.1m, S=0.1m	0.36	-	0.59
	Floodplain	L=150km, W=60km, T=0.05m, S=0.1m	0.19	1.16	2.21
Ganges River	Riverbed, char and levee	L=185km, W=5km, T=0.08m, S=0.1m	0.17	-	0.27
	Floodplain	L=185km, W=60km, T=0.04m, S=0.1m	0.22	1.34	2.55
Padma & Lower Meghna River	Riverbed, char and levee	L=265km, W=10km, T=0.5m, S=0.1m	1.59	-	2.61
	Floodplain and tidal plain	L=265km, W=80km, T=0.25m, S=0.1m	1.03	6.39	12.16
Estuary and self		L=150km, W=120km, T=0.6m, S=0.1m	5.00	7.60	21.00
Total expenditure			**8.56**	**16.49**	**41.39**
Balance			**5.44**	**30.51**	**58.61**

For 60 cm sea level rise,
after adjusting river, estuary and floodplain,
there would be enough sediment for the delta to prograde

But other estuaries of Bangladesh would suffer from sediment starvation

Due to lack of sediment, adustment of the southwest region would be slower

Findings and its implication

Results of the research should be considered as indicative

Result derived from Vries (1975) model matches well with the long-term sediment distribution process

No transgression along the Meghna Estuary is expected if the sea level rise is within 100 cm in the coming 100 years

Adjustment of bed and tidal plain in the Meghna estuary to the rising of sea level would be very quick

The flooding and inundation pattern and salinity intrusion due to climate change would be different than what is predicted using the model considering fixed bed and bank

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Future Research

Research to find an effective process to inject sediment in the coastal polders

Research in assessing the morphological time-scale for Bangladesh river and coastal system

Research on the possibility of diverting rivers to the low laying back swamp areas

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Thank You All

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