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Effects of river training in Bangladesh

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Taming the Jamuna: effects of river training in Bangladesh

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Introduction

The 10 km wide Jamuna river in Bangladesh is one of the most morphologically active rivers in the world, with bank erosion rates of up to 500 m per year (Mutton and Haque 2004). Such extreme river migration in the center of Bangladesh, one of the most densely populated and impoverished regions in the world, displaces roughly 60,000 people per year (Mutton and Haque 2004). To alleviate this, the Government of Bangladesh has committed to stabilizing and narrowing it's major rivers with the Flood and Riverbank Erosion Risk Management Investment Program (FRERMIP) (ADB 2016).

FRERMIP is investigating numerous training scenarios and final stabilized widths (4-8 km). These scenarios are combinations of works (spur dikes, dredging) at different locations and activation rates (i.e. construction schedules) which FRERMIP seeks to optimize for cost, navigation, bank erosion prevention and flood mitigation. However, little is understood about how these proposals may affect the sediment balances in Bangladesh.

The Jamuna combines with the Ganges and Upper Meghna to form the world's second largest delta: the Bengal delta. Due to the high sediment load delivered from these Himalayan rivers, accretion rates in the delta have been in the order of 5 km^2/yr (Sarker et al. 2011). Changes in the supplied sediment to the delta may reduce this accretion, amplifying the consequences of sea level rise. A better understanding of how proposed trainings will affect the sediment supply to the delta can help decision makers weigh the pros and cons of implementation, and prepare for these impacts on the delta.

Objectives

This study aims to estimate the sediment balance impacts for the range of training scenarios and final stabilized widths currently under consideration by FRERMIP on the Jamuna River. This paper describes the methodology, motivation, and preliminary results of this study.

Considering the limited understanding of the current sediment balance, uncertainties in training scenarios and boundary conditions, and the time scales involved, an exact account of sediment balances is impracticable. Instead, we compare relative impacts of various scenarios against historical baselines. If these changes are significant and unavoidable, the direct impacts to the delta (e.g. accretion rates) should be assessed through further study.

Additionally, we assess model sensitivity to understand which parameters have the greatest affect on the sediment balance.

Methods

To assess these impacts, we develop a simplified sediment mass balance model for the Jamuna (Fig. 1). This model uses a semi-2D discretization to apply an Exner type equation to each activated node:

$$(1-e)\frac{\mathrm{d}z}{\mathrm{d}t} = -\frac{\mathrm{d}q}{\mathrm{d}L}$$

where e is the porosity, z the bed level (m), q the sediment volume load (m^2/s), and L the longitudinal dimension (m). This is not a true 2D approach as lateral nodes (x axis) in

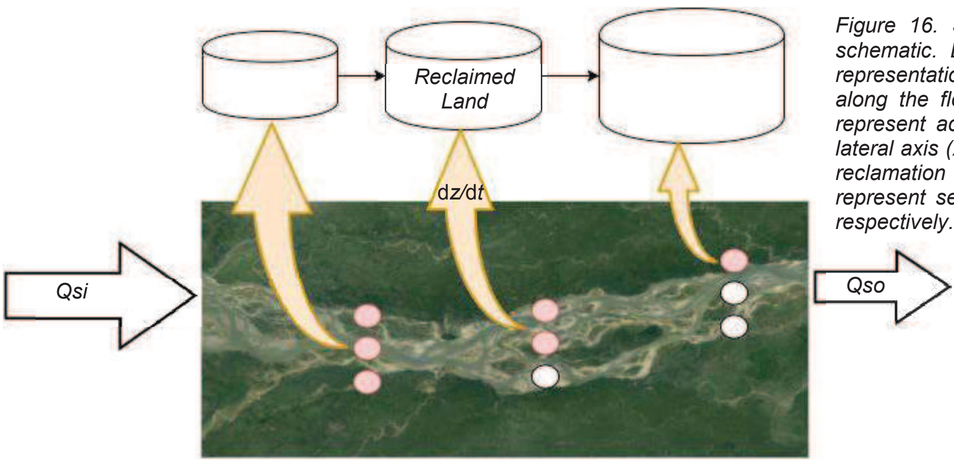

Figure 16. Sediment mass balance schematic. Left to right objects are representations of 1D spatial nodes along the flow axis (L). Red circles represent activated nodes along the lateral axis (x). 'dz/dt' represents land reclamation rates. Qsi and Qso represent sediment input and output respectively.

parallel interact with hydraulic and sediment transport phenomon as a 1D cross section.

Training scenarios are simplified and categorized for inclusion into the model by activation domain (L_o,L_e), activation rates (along the flow dimension (dL_a/dt) and lateral dimension (dx_a/dt)), and land reclamation rate (dz/dt). This allows land reclamation rates specific to the work type, and for the implementation of those activities, to better reflect proposed construction staging.

Table 1 provides an example of the simplest training scenario where dredging (from the main channel to reclaimed areas) will be implemented for land reclamation in 10 km segments along the reach each year until the entire reach (220 km) is within a dredging program (i.e. activated). These dredging programs will narrow the river 200 m/yr until the final stabilized width is achieved.

Table 1. Training scenario 'A' with activation parameters.

Works dz/dt	Location L_o,L_e km	Activation dL_a/dt km/yr	Activation dx_a/dt km/yr
Dredging	0-220	10	0.2

To establish land reclamation rates (dz/dt) for dike spur type works, we use the hyperbolic elevation functions of Hassan et al. (1999). In their study, aerial imagery and bed topography of the Jamuna from 1973-1996 were compared to estimate changes in relative land height.

This approach provides an order of magnitude approximation for land reclamation rates that may be achievable by different training works (excluding dredging). We approximate dredging rates from historical values and current project budget estimates.

SOBEK 3, a 1D physics based morphology model developed by Deltares, is used to model the progression of the sediment deficit wave, update bed levels, and calculate water depths -- as inputs for land reclamation rates. Hydraulic and sediment characteristics are taken from Delft Hydraulics and DHI (1996). Finally, we conduct a model sensitivity analysis.

Preliminary Results and Discussion

The scenario shown in Table 1, for a final width of 4 km, was analysed using a disconnected (from SOBEK 3) version of the sediment mass balance model. Results are shown in Fig. 2.

Fig. 2 shows the initial expected drop in sediment output from the 'filling in' or narrowing of the cross section as a result of land reclamation.

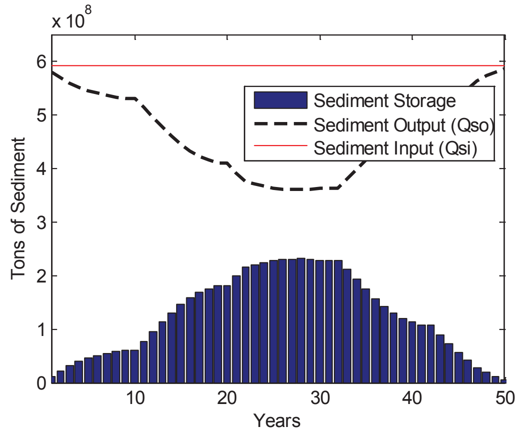

Figure 17. Sediment balance for Jamuna River under training scenario 'A' to a final stabilized width of 4 km.

Sediment output then reaches a minimum around year 22, when the entire reach is activated (i.e. being dredged) and land reclamation rates remain high. Finally, sediment output rises back to equilibrium as nodes 'fill in' and withdraw less sediment from the river.

While these results do not account for the lag in sediment output as a result of the sediment deficit wave travel time, they do demonstrate that the proposed river narrowings have the potential to impact the sediment supplied to the delta beyond annual variations (in this case on the order of 30% for 10 years).

Ultimately, the final width and trainings implemented in Bangladesh are political decisions. The approach discussed here, along with further refinements (the discussed SOBEK connection), the analysis of more scenarios, and a sensitivity analysis, combined with the broad considerations of FRERMIP, can provide a robust foundation from which to make these decisions in an informed way.

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