Science of the Total Environment 643 (2018) 1054–1064

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Recent sediment flux to the Ganges-Brahmaputra-Meghna delta system

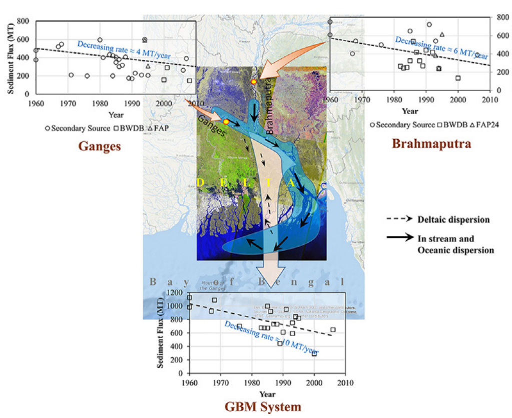
Munsur Rahman [a,*], Maruf Dustegir [a], Rezaul Karim [a], Anisul Haque [a], Robert J. Nicholls [b], Stephen E. Darby [c], Hajime Nakagawa [d], Motahar Hossain [e], Frances E. Dunn [f], Marin Akter [a]

[a] Institute of Water and flood Management (IWFM), Bangladesh University of Engineering & Technology (BUET), Dhaka, Bangladesh
[b] Geography and Environment, University of Southampton, Highfield, Southampton SO17 1BJ, UK
[c] Engineering and the Environment and Tyndall Centre for Climate Change Research, University of Southampton, Highfield, Southampton SO17 1BJ, UK
[d] Ujigawa Open Laboratory, Kyoto University, Japan
[e] Bangladesh Water Development Board (BWDB), Bangladesh
[f] GeoData, University of Southampton, Highfield, Southampton SO17 1BJ, UK

HIGHLIGHTS

- The temporal natural of the sediment flux in GBM delta has been explored.
- Sediment flux to the GBM delta is not constant which is being considered in planning documents.
- Sediment flux from the Ganges and Brahmaputra is decreasing due to multiple reasons.
- The combined decrease in sediment from the Ganges and Brahmaputra is 10 MT/year.
- Considering the sediment trend is vital for sustainable management of the GBM Delta.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 18 January 2018
Received in revised form 9 June 2018
Accepted 12 June 2018
Available online xxxx

Keywords:
Sediment flux
GBM system
GBM Delta
Ganges
Brahmaputra

ABSTRACT

The physical sustainability of deltaic environments is very much dependent on the volume of water and sediment coming from upstream and the way these fluxes recirculate within the delta system. Based on several past studies, the combined mean annual sediment load of the Ganges-Brahmaputra-Meghna (GBM) systems has previously been estimated to vary from 1.0 to 2.4 BT/year which can be separated into components flowing from the Ganges (260 to 680 MT/year) and Brahmaputra (390 to 1160 MT/year). Due to very limited data and small contribution of the Meghna system (6–12 MT/year) to the total sediment flux of the GBM system, the data of the Meghna is not considered in the analysis assuming the sediment flux from GB system as the sediment flux of GBM. However, in this paper our analysis of sediment concentration data (1960–2008) collected by Bangladesh Water Development Board shows that the sediment flux is much lower: 150 to 590 MT/year for the Ganges versus 135 to 615 MT/year for the Brahmaputra, with an average total flux around 500 MT/year. Moreover, the new analysis provides a clear indication that the combined sediment flux delivered through these two major river systems is following a declining trend. In most of the planning documents in Bangladesh, the total sediment flux is assumed as a constant value of around 1 billion tons, while the present study indicates that the true value may be around 50% lower than this (with an average decreasing trend of around 10 MT/year).

* Corresponding author.
E-mail address: munsurbuet1989@gmail.com (M. Rahman).

https://doi.org/10.1016/j.scitotenv.2018.06.147

1. Introduction

Deltas are home to over half a billion people, many of whom are poor and live with a high dependency on ecosystem services (Ericson et al., 2006; Nicholls et al., 2018). The ecosystem resources in these areas are experiencing multiple stresses from climate change, sea level rise, subsidence, changing catchment management and land use change (Nicholls et al., 2016). The flows of water and sediment into these deltaic environments from their feeder catchments upstream are one of the most important factors for shaping deltas. Recent evidence shows that many deltas are experiencing a severe shortage of sediment because of different types of anthropogenic interventions that intercept significant volumes of sediment flux (Gupta et al., 2012; Kondolf et al., 2014; Syvitski et al., 2009; Syvitski and Kettner, 2011; Syvitski and Saito, 2007). A continuous reduction of sediment flux means there is much less potential for the formation of new sedimentary layer (Syvitski et al., 2009) over the delta plain and the ability to counterbalance sea level rise and subsidence (Brown and Nicholls, 2015; Tessler et al., 2017) is diminished, resulting in the reality that many of the world's deltas are sinking.

On the contrary, the Ganges-Brahmaputra-Meghna (GBM) delta has been gaining new land by 17 km^2/year for the last five decades (Sarker et al., 2013). The above fact leads the policy makers, implementing agencies and even the local community to implicitly think that the system is receiving sufficient sediment that would lead to continued future delta building processes. The secondary literature revealed that estimates of the total sediment load reaching the GBM delta vary at the order of 1–2.4 billion metric tons per year (detailed references have been reviewed in Section 3.1). In reality, the rivers within the GBM basin are also being affected by anthropogenic activity including the development of water control structures (both at basin scale and local scale) such as dams, barrages, and embankments (Gain and Giupponi, 2014; Gupta et al., 2012; Rahaman, 2009). These structures might have some adverse impact on the downstream transmission of sediment. In addition, the coarse fraction of the incoming sediment load (which is the most significant in terms of the potential for delta-building process) may be more susceptible to being trapped than the fine fraction, leading to an increase in the ratio of the fine/coarse fraction of sediment (Okada et al., 2016). The change in the total sediment load and its calibre are critical for understanding the formation of the river planform and the opportunities and threats for sustainable river and delta management which are the two major hotspots (out of 6) identified in Bangladesh Delta Plan 2100 (BDP 2100, 2015). However, the information related to the amount of sediment load is available in the major rivers (e.g. impact of upstream developments) and the amount reaching to the deltaic system and its trend of changes are not clear in the long term delta planning documents. Therefore, it is important to have clear understanding on the incoming sediment flux and its trend of change to GBM system.

Due to future changes in climatic factors such as temperature and rainfall, future sediment generation is expected to increase based on the HydroTrend model for both the Ganges (34% to 37%) and the Brahmaputra (52% and 60%) system by the end of the 21st century (Darby et al., 2015) depending on the climate scenarios. While, Fischer et al. (2017) estimated (using HEC-RAS) around 40% increase of sediment load along the Brahmaputra/Jamuna by 21st century because of the future climate change. However, the estimated sediment load would not be realized under the different planned anthropogenic interventions. Following the above two studies, introducing the upstream planned dams in the global hydrological model WBMsed, it is found (Dunn et al., accepted) that, under 12 potential future scenarios of environmental change and socio-economic development pathways, the modelled fluvial sediment flux to the Ganges delta showed a large decrease over time from 566 MT/year in the 'recent' past, to 79–92 MT/year by the end of the 21st century (a total decline of 88% on average; while yearly decreasing rate is around 5 MT/year) which is consistent with other deltas in anthropocene. However, the above estimated changes of sediment flux have some inherent uncertainties with the uncertain nature of climatic factors as well socio-economical pathway factors. Moreover, the past trend of changes is also unknown. Under the above circumstances, it is important to understand the recent sediment flux and its trend of changes using the data available from secondary sources (summarized in Section 3.1) as well as data measured by the national agency, Bangladesh Water Development Board (BWDB). It is worth mentioning here that depending on the methodology followed during data collection and analysis, the results may vary significantly. Therefore, the aim of the present study is, to understand the past, recent past and projected trend of sediment flux in the GB system from two sources of information: (1) Chronological documentation of sediment flux in the published literature during 1958–2010; (2) Analysing the available long-term measured sediment transport rate in the two major distributaries (Ganges and Brahmaputra) of the Ganges-Brahmaputra rivers from BWDB.

The paper is structured as follows:

1. Demonstration of the historical sediment flux from different published papers and BWDB measured data;
2. Trend analysis of the historical sediment flux in the Ganges and Brahmaputra; and
3. Projection of the sediment influx to the GBM delta systems at different time scales and implications for the river and delta management.

2. Methodology

The methodology of this article is segmented in to three parts as follows:

Firstly, we have thoroughly reviewed the literature for the investigation of the sediment flux in the Ganges-Brahmaputra system. After the extraction of the sediment flux, all the datasets have been organized corresponding to their measurement period. It is important to note that the source of secondary data are diverse that includes several project base measurements and often mentioning the BWDB source as well. In many cases, only the value of the yearly sediment flux is quoted without mentioning the methodology of the data collection and calculation procedure. However, it can be assumed (after consultation with the BWDB senior officials) that all the data sources are following the similar basic approach practicing in BWDB for the collection of suspended sediment transport.

Secondly, BWDB datasets have been analysed to investigate the total suspended sediment flux. The datasets of sediment load collected from the BWDB are in sediment transport rate (kg/s) along the cross-section of the channel for a specific time. Generally, BWDB collects data at 15 day intervals, sometimes data for several months in a certain year are not available. To derive the total suspended load of a particular year, this available data set are summed up using trapezoidal method (see Section 3.2). For the calculation of yearly sediment flux, those years have been considered, when most of the datasets are available round the year. However, the variability of the sediment transport processes within the collected sediment samples have been tested in terms of Q vs Qs graphs.

Thirdly, the yearly sediment flux data, extracted from the secondary literature together with estimated values using BWDB data sources, have been assembled chronologically to understand the sediment dynamics in the GB systems. The rationale of using the data from secondary sources and BWDB data within a single platform is that both data sources are representing the total suspended sediment flux. Although the chances of double counting between the data from secondary sources and BWDB data cannot be ignored fully as some of the secondary sources are mentioning BWDB as data source. But as we assembled all the data chronologically, the impact of such unavoidable errors will be minimum while estimating the trend of change of sediment flux through linear regression.