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Quantification of the effect of river-damming and sand mining on riverbed incision in the Vietnamese Mekong Delta

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INTRODUCTION

The hydrodynamics of the Vietnamese Mekong Delta (VMD) is controlled by the inflow discharge from the Mekong River (MR) and the tide from the East and West Seas of Vietnam. The VMD has been formed by the abundant sediment supply from the MR of 166.7 Mt/yr (Binh et al., 2020), which supports the VMD to sustain from land subsidence, sea level rise, and saltwater intrusion.

Sand mounts in the estuaries resist tidal and saltwater influences. However, the VMD's riverbeds have been significantly incised (Binh et al., 2020; Eslami et al., 2019), leading to increasing saltwater intrusion (Eslami et al., 2019). Brunier et al. (2014) found large-scale morphological changes in the VMD's main rivers between 1998 and 2008, and they attributed such changes were caused by sand mining. Recently, Jordan et al. (2019) quantified the effect of sand mining on riverbed incision in a 20-km reach of the Tien river based on the data measured in 2018.

Although some studies were conducted, no study investigates large-scale riverbed incision in the VMD in recent years. Therefore, the aim of this study is to quantify riverbed incision in the VMD' main rivers, then to link the incision with upstream dams and sand mining.

DATA AND METHODS

Sixty-four large dams (>15 m) have been built in the MR basin by 2015. Existing dams trapped a significant volume of the incoming sediment from the MR (Binh et al., 2020). Inside the VMD (Fig. 1), sand mining is increasing. These two drivers have caused substantial increases of riverbed incision and saltwater intrusion in the VMD.

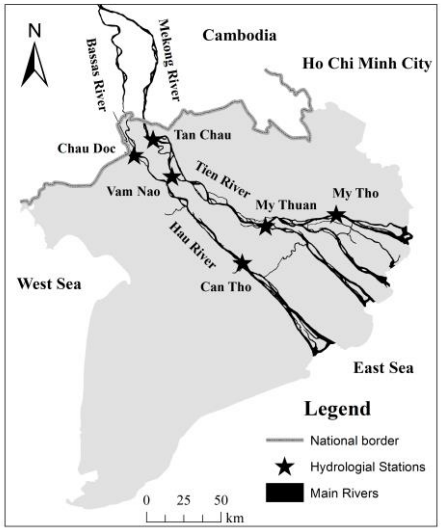

Fig. 1 Spatial map of the VMD, including hydrological stations

In quantification of recent riverbed incision, a boat-based bathymetric survey was conducted in the high flow season of 2017 by ADCP (acoustic Doppler current profiler) along the main rivers in the VMD. The distance between two adjacent cross sections was ranging from 1 to 5 km. The 2017 bathymetric data were compared with bathymetric data taken in 2014 and 1998 to quantify riverbed incision. The incision volume was then linked with long-term sediment discharge and sand mining volume in the VMD (obtained from Bravard et al., 2013 who estimated sand mining in the entire VMD in 2012 being 7.75 Mm^3). Moreover, to examine the effect of reduced sediment load on riverbed incision in the VMD, a coupled TELEMAC-2D and Sisyphe model was developed for the upper part of the VMD (Fig. 2).

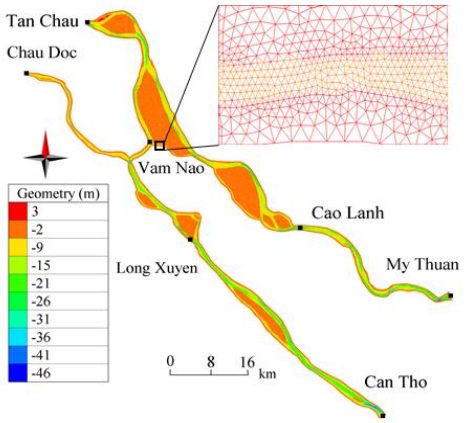

Fig. 2 Study domain and geometry mesh of the model

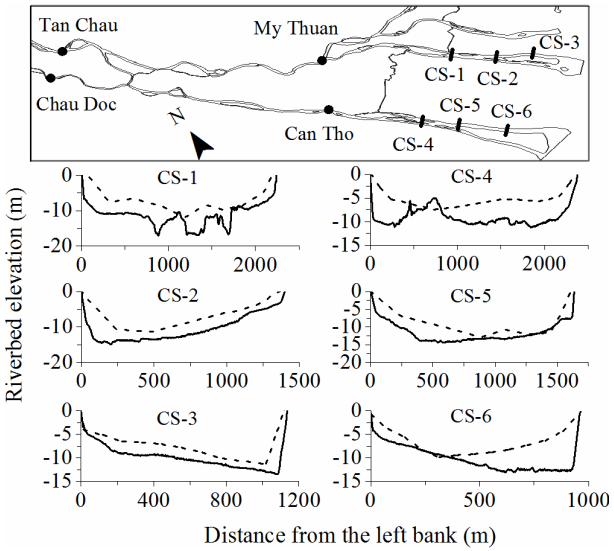

Fig. 3 Riverbed incision in the estuaries of the VMD

RESULTS AND DISCUSSIONS

The riverbeds of the Tien and Hau rivers near the estuaries were incised by a mean cross-sectional value of -3.7 m and -4.3 m, respectively, between 1998 and 2017 (Fig. 3), equivalent to the mean incision rates of -0.18 and -0.21 m/yr, respectively. In the upper VMD from Tan Chau to My Thuan (Fig. 1), the total net riverbed incision volume in 2014-2017 was approximately -157.5 Mm^3, which was in a similar order of the total incision volume of -200 Mm^3 of the entire Tien and Hau rivers in 1998-2008 reported by Brunier et al. (2014). It indicates that recent riverbed incision in the VMD was approximately threefold the past.

Such highly incised riverbeds in the VMD were caused mainly by upstream dams which reduced the sediment load of the VMD by 74% from 166.7 Mt/yr in the predam period (pre-1992) to 43 Mt/yr in the period of 2012-2015. Sand mining was also a main driver of riverbed incision (Eslami et al., 2019). Comparing the total sand mining volume in the entire Tien and Hau rivers in 2012 of 7.75 Mm^3 (Bravard et al., 2013) with the total incision volume of only the Tien river from Tan Chau to My Thuan and the Vam Nao channel of -157.5 Mm^3, sand mining was responsible for 14.8% of riverbed incision. Therefore, we concluded that upstream dams caused large-scale riverbed incision in the VMD whereas sand mining additionally caused riverbed incision at local scales.

The results of the coupled TELEMAC-2D and Sisyphe model show that the mean VMD's main rivers may be increased by -2 m in 2026 if the sediment load of 2017 decreased by 84.8% during 2017-2026. The most severe incision occurred in the Vam Nao channel, followed by the Tien river. We concluded that riverbed incision is one of the strongest drivers of increasing saltwater intrusion in the VMD in recent years. Therefore, the VMD is at a dangerous phase because of upstream dam development and uncontrolled sand mining.

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